ISSN: 2186-2311

acsee2011

The Asian Conference on Sustainability, Energy & the Environment
Official Conference Proceedings

The 1st Asian Conference on Sustainability, Energy and the Environment

Osaka, Japan, 2011

The Asian Conference on Sustainability, Energy and the Environment

Conference Proceedings 2011

The International Academic Forum (IAFOR)
Aza Katahira 23-4 801, Ouaza Nagakute
Aichi-gun, Aichi-ken, Nagakute-cho
480-1131 Japan

ISSN: 2186-2311

http://www.iafor.org/acsee_proceedings.html

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The Asian Conference on Sustainability, Energy and the Environment

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Contents

LabVIEW-Based Real-Time Evaluation System for Validation and Reliability Tests of Fuel Cell Scooters
Jenn-Jiang Hwang
Jia-Sheng Hu
Yu-Jie Chen
Lai-Ho Huang
Wei-Ru Chang pp. 1-6

Valuation of Urban Green Space in Bangkok, Thailand
Somskaow Bejranonda
Valaiporn Attanandana pp. 7-19

Heat Trap and Light Concentration Mechanism to Enhanced Temperature Gradient Thermoelectric Energy Harvesting System
Airul Azha Abd Rahman
Wan Adil Wan Jamil
Amilia Ahmed Khozim
Aymen M. Karim
Dr. Gunawan Witjaksono pp. 20-28

Property Assessed Clean Energy Financing in Italy
Nadia Ameli
Daniel M. Kammen pp. 29-42

Renewable Energ: The Indian Perspective
Himadri Roy Ghatak pp. 43-52

Sustainable Spatial Development in the Danube Delta Biosphere Reserve: Planning, Architecture, Seismic, Construction and Energy Related Criteria
Vasile Meita
Emil-Sever Georgescu
Alexandru-Ionuț Petrisor pp. 53-70

Evaluation of Air Pollution Baseline from Bituminous Power Plant in Thailand
Wasin Pinprateep pp. 71-81

The Effect of Sea Level Rise on Freshwater Flooding, the Human Population, and Natural Forest Communities of Miami-Dade County
Stephanie Long
Camilo Arias
Kristie Wendelberger
Sylvia Lee
Ivan Blanco Rubio pp. 82-106

An analysis of the landscape ecological effects of land-use changes in Dongshan River basin, Taiwan
Shu-Chun L. Huang
Wen-Pin Lin pp. 107-117

The Impacts of Thai Household Smoking Spending on Expenditure Patterns and Health Care Costs
Aunkung Lim
Valaiporn Attanandana pp. 118-129

Awareness toward environmental problem solving of students at Sirindhorn college of public health, Yala, Thailand
Anchalee Pongkaset
Kannika Ruangdej pp. 130-136

Applied γ-ray preirradiated fabrics grafting with acrylic acid to heavy metal removal
Bor-Tsung Hsieh
Yi-Kuo Chang
Chia-Chieh Chen
Juu-En Chang pp. 137-142

Problem Solving of Mountain Waterworks System during a Decade in Bankangsuan, Tambon Koh Saba, Amphoe Thepha, Changwat Songkhla, Thailand
Paiboon Chaosuansreecharoen pp. 143-155

Establishing the Holistic Sustainability Evaluation Framework for Asia-Pacific Regions by Exploring Local Practices in China
Wenli Dong
Jamie Mackee
Michael Mak pp. 156-169

Energy Access to Rural Areas: Exploring Decentralized Renewable Energy Systems for the Indian State of Bihar
Anjula Gurtoo pp. 170-180

Yield stability of rice under high temperature
Jitlada Chok-amnuay
Phaweesuda Ramnud
Vilai Saothongnoi
Suphachi Amkha
Kruamas Smakgahn pp. 181-186

Study of Dynamic Characteristic of PM10 Concentration During Street Sweeping
Chih-Mei Chou pp. 187-194

Optimum air change rate for night ventilation in order to achieve energy saving in Yemeni office building
Aymen Aklan
Volker Hukemann
M.Norbert Fisch pp. 195-204

Lauric Oils Synthesis in a Semi-Batch Reactor using Tungstated Zirconia as a Solid Acid Catalyst
Kanokwan Ngaosuwan pp. 205-212

Single-walled Carbon Nanohorns Supported Sulfonated Catalyst for Biodiesel Production
Chantamanee Poonjarernsilp
Kanokwan Ngasuwan pp. 213-218

Accuracy Discharge Measurement for irrigation water distribution and conservation
Hsun-Chuan Chan
Wei-Che Huang
Yu-Min Wang
Jan-Mou Leu
Ping-Jen Mo pp. 219-227

Effects of Carbon-based Materials on the Hydrogen Desorption of LiAlH4
P. Purasaka
T. Chaisuwan
P. Rangsunvigit
B. Kitiyanan
S. Kulprathipanja pp. 228-240

Are Italian firms proactive in Sustainability practices?
Marco Minciullo pp. 241-277

Applying Warping for Improving Land Subsidence and On Farm Water Supply- A Case Study for Choshui
Chien Ming-Song
Chun-E. Kan
Jin-Hwua Chen pp. 278-295

Using Geographical Information System to Evaluate Evapotranspiration Models Accuracies in Belize
Lennox A. Gladden
Yu – Min Wang pp. 296-309

Trends of Biofuels Derived from Renewable Biomass as Sustainable Energy and Environmental Solution
M. Rofiqul Islam
M. Parveen and H. Haniu pp. 310-323

Desalination Powered By Entropy
S. Kazadi
Y. Hong
C. Chau
A. Chaudhary
J. Park
J. Liu
M. Kim
D. Kim
S. Kim pp. 324-336

Developing a Green Metric Mechanism Versus Leed for Tall Buildings in Qatar: Evaluation-based Case Study
Hatem Galal A Ibrahim pp. 337-353

The Importance of Ecological and Spiritual Approach in Chemical Engineering towards Practical Conception of Sustainable Development
Azizan Ramli
Mohd Shaiful Zaidi Mat Desa
Tuan Sidek Tuan Muda
Abdul Kamil Jamaludin pp. 354-368

Renovating the Industry through Energy Efficiency Projects: A case study of Iranian Brick Industry
Ali Abolghasemi pp. 369-377

Explaining the Adoption of Sustainable Agricultural Practices: An Improved Integrative Agent-Based Framework
Yeong Sheng Tey
Elton Li
Johan Bruwer
Amin Mahir Abdullah
Jay Cummins
Alias Radam
Mohd Mansor Ismail
Suryani Darham pp. 378-395

Chemical Reaction Method to Utilize Geothermal Energy
Rakesh Kumar Soni
Jitender Agarwal
Manuj Gupta pp. 396-403

Design and Analysis of Small Scale Straight-Bladed Vertical Axis Wind Turbine
Ji Xiao Na
Goh Seach Chyr
Jörg Schlü ter pp. 404-417

Income, Energy Consumption and Carbon Dioxide (CO2) Emissions in India: Modeling of Causal Relationships
Mohammad Jahangir Alam
Ismat Ara Begum
Jeroen Buysse
Sanzidur Rahman
Guido Van Huylenbroeck pp. 418-428

The significance of competent photoexciton diffusion process in order to accelerate the power conversion efficiency of organic solar cell
Ariful Haque
M. Abdul Awal
Mashiur Rahman
Fauzia Sultana pp. 429-438

The Implementation of an Open Space Policy by the States in Peninsular Malaysia: The Need for a Uniform Policy?
Putri Haryati binti Ibrahim
Melasutra binti Md Dali
Safiah Yusmah binti
Muhammad Yusoff pp. 439-451

Biohydrogen Production from Alcohol Distillery Wastewater in an Anaerobic Sequencing Batch Reactor under Thermophilic Temperature
A. Thungmanee
P. Rangsunvigit
S. Chavadej
T. Sreethawong pp. 452-470

Energy Consumption – Income Nexus in China: Heterogeneous Panel Causality Analysis
K. Ali Akkemik
Koray GÖKSAL
Jia Li pp. 471-497

Research on Precipitation and Soil Erodibility Factor in Western Mountainous Area of Taiwan
Chin-Ping Lin
Jih-Jang Huang pp. 498-518

A Study on Potential Use of Pulverized Oyster Shell as A Cementing Material in Civil Engineering
Hung-Yu. Wang
Chou-Fu. Liang
Wen-Guey Chung
Guey-Ying. Wu pp. 519-530

Mutual Dependence of Social and Environmental Sustainability in Offices
Robert H. Knapp, Jr.
Hiroto Takaguchi pp. 531-543

Decentralization and Environmental Governance: Insights from the Experiences of Selected Lakeshore Communities in the Philippines
Eliseo F. Huesca, Jr. pp. 544-554

Consumer Willingness to Pay for Energy Conservation: The Case of Taiwan
Jin-Long Liu
Pe-I Chang pp. 555-567

Spatial Drought- Distribution in the Northwestern Part of Bangladesh
Mohammad Adnan Rajib
Md.Rubayet Mortuza
Saranah Selmi
Asif Khan Ankur
Md. Mujibur Rahman pp. 568-575

Redefining economic efficiency in a post-fossil fuel world: Relation between food and energy scarcity
Patrik Gotz pp. 576-585

Effect of soil solarization in greenhouse agro-ecosystem of organic vegetable production
Bahram Tafaghodinia
Mmohammad Kamalpour
Abbasali Nasrollahi pp. 586-589

Public Participation towards environmental issues in Kota Bharu, Kelantan, Malaysia
Haliza Abdul Rahman pp. 590-595

Working Towards Enhancing the Quality of Urban Life Through a Greener City: Aspects of Policy and Law in Malaysia Relevant to Urban Green Spaces Development and Environmental Quality Protection
Maizatun Mustafa pp. 596-609

Thermal Modeling of Parabolic Solar Water Heaters by Adapting the Fully Mixed Model of the Storage Tank
Zahirnia Sasan
Ghaffari Ali
Arebi Soleyman
pp. 610-615

LabVIEW-Based Real-Time Evaluation System for Validation and Reliability Tests of Fuel Cell Scooters

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Abstract — This paper offers design and evaluation methodologies for the validity and reliability tests of fuel cell (FC) scooters. The fuel cell scooters were tested along a 12.6Km closed circuit per day for experimentation in Tainan, Taiwan, all of which are powered by proton exchange membrane fuel cells (PEMFC) and driven by electric motors. The real-time status of testing FC scooters is crucial for reliability, fault, and malfunction detection. This information facilitates the design and development of FC scooters. Hence, the real-time monitoring interface is important in the evaluation stages. This study presents an integrated drive recorder, which can transfer all driving data to remote web server wirelessly. A web-based, real-time elevation system, which utilized software LabVIEW as the interface is proposed to carry out the monitoring tasks. All testing data is stored in the Access database. The real-time experimental results are published on a website for end users to examine worldwide. Illustrated schemes and demonstration video are given for comprehensive understanding.

Keywords: Fuel cell scooter; web-based real-time information exposing; drive recorder.

I. Introduction

Technologies for hydrogen fuel cells have been maturing in recent decades. Fuel cells based on hydrogen energy shares some of the same benefits as electric vehicles, such as pollution-free operation. Unlike internal combustion engine vehicles, fully electric vehicles powered by batteries can achieve quieter and pollution-free operation. In addition, electric vehicles powered by renewable energy can overcome the overuse of petrochemical energy and its greenhouse gas problems. Future urban electric vehicles can be powered by battery, super capacitor, or wireless power grid [1]. However, for the sake of seeking long distance travelling, battery cells should cascade a fuel cell module as a range extender [2]. Alternatively, these issues accelerate the fusion between fuel cells and electric vehicles. For urban transportation, scooter is always a popular solution. Consequently, the demand for fuel cell scooters is tremendously on the roadmap of future vehicles. It is known that the most popular fuel cell concept vehicles such as Honda's FCX Clarity [3] and Toyota's FCHV [4] are planed to face the commercial market around 2018. Nowadays, these potential vehicles are all on the phase of validation test. Crucial and practical tests validate the possibility of using fuel cell vehicles in the near future. In order to realize this schedule, the social demonstration for reliability is going on recently. The Japan Electric Vehicle Association announced the Japan Hydrogen and Fuel Cell Demonstration Project (JHFC) [5] in 2002 and the National Renewable Energy Laboratory [6] of US Department of Energy announced the Hydrogen, Fuel Cell and Infrastructure Technologies Program (HFCIT) in 2003, respectively. The goals of these projects are to facilitate large scale testing of vehicles powered by fuel cells. It examines the performance of fuel cell vehicles and the required supporting hydrogen infrastructure. In this phase, the testing data can hasten engineering standards, infrastructure, and power grid to an integrated and unified system. Hence, the end user may be able to purchase a fuel cell car with an acceptable prize in the near future.

The situation of fuel cell scooter is as well. Nowadays, many prototypes of fuel cell scooters are proposed. This phenomenon raises the importance and significance of practical validation tests. In case of fault and/or malfunction, the fuel cell scooter has to be evaluated in different operating conditions to examine its reliability. Publishing and updating the testing information to the public, the web-based interface shows its convenience. The National Instruments' software LabVIEW [7] can be embedded in the website program is an alternative for revealing the real-time testing results in a visualization way. Due to its user-friendly function and graphical interface, LabVIEW is gradually accepted as a flexible toolkit adopted under the framework of World Wide Web (WWW). Additionally, under the admission of security check, the end user can even control the LabVIEW program remotely via the web platform. For example, Gong and He [8] construct a LabVIEW interface for automatic speed control of stepper motor. Nikitin and Rao [9] built a LabVIEW-based UHF RFID tag for measurement system. Pecen *et al.* [10] presented a LabVIEW-based instrumentation system for a wind-solar hybrid power station. In [11], Ertugrul showed LabVIEW's powerful function on teaching and engineering education. From the reviewed studies, one can find that using LabVIEW as a real-time data processing platform is highly recommended. Due to this reason, this study employed LabVIEW to constructing a website with rich, real-time, and interactive information revealing functions.

This paper aims to make use of the advantages of WWW and internet to develop a real-time information spreading platform for the FC scooter validation test is structured as follows. Section 2 describes the system constructions and its corresponding algorithm. Details of the proposed hardware setting are presented in Section 3. Section 4 gives discussions and practical examples for evaluating the proposed strategy. Finally, Section 5 offers some concluding remarks.

II. System Construction

In this study, as shown in Fig. 1, a scooter manufactured by Asia Pacific Fuel Cell Technologies, Ltd. [12] is utilized to test the feasibility of the proposed design and evaluation methodologies. This FC scooter is powered by a proton exchange membrane fuel cell (PEMFC) and driven by electric motors. Real-time status of the FC scooter is important for fault and malfunction detection. All of the aforementioned points validate the development of a FC scooter market. Therefore, the real-time monitoring interface is important in the evaluation stages. In order to carry out the validation test, the testing scooter are evaluated along a 12.6 Km closed circuit per day in Tainan, Taiwan. Figure 2 illustrates the concept of the proposed objectives on wireless data transfer. Each FC scooter is equipped with a drive recorder that contains a microcontroller to execute the controlled program. As can be seen in this figure, in order to receive stabilized information for publishing in the internet, this study sets 2 sec as a data-transferring waiting time. This standby buffering time is curial for data storing in the remote server. Without receiving a stable data, the presented website cannot reveal a complete driving condition simultaneously. Figure 3 shows the entire monitoring system. The FC scooter is positioned by Global Positioning System (GPS) and its real time status is reveled by website through the General Packet Radio Service (GPRS) wireless data transfer.

Fig. 1. Experimental fuel cell scooter.

Figure 4 reveals the interface and platform employed in the information publishing. The in-vehicle drive recorder reports all monitoring parameters including the current position via the telecom protocol of GPRS. Subsequently, a computer server remotely collects this data and stores it via a program developed by Microsoft Visual Basic [13]. This program plays a role as a file manager, which stores the received data into an Access database [14]. All useful information is copied with a graphic interface for comprehensive understanding. Thus, alternative program developed by LabVIEW establishes the graphical interface for showing the real time status of the remote driving FC scooters. This program can be embedded into a website program. Consequently, all end users can check the firsthand validation testing data of FC scooters on an interactive, graphical, and user-friendly platform. It is very convenient for all end users to browse the testing data via the website worldwide. Nowadays, the WWW is prospering under the development of internet. Hence, this study takes advantage of this property to spread the validation testing results on FC scooters.

Fig. 2. Flowchart of the wireless data transfer to the proposed drive recorder.

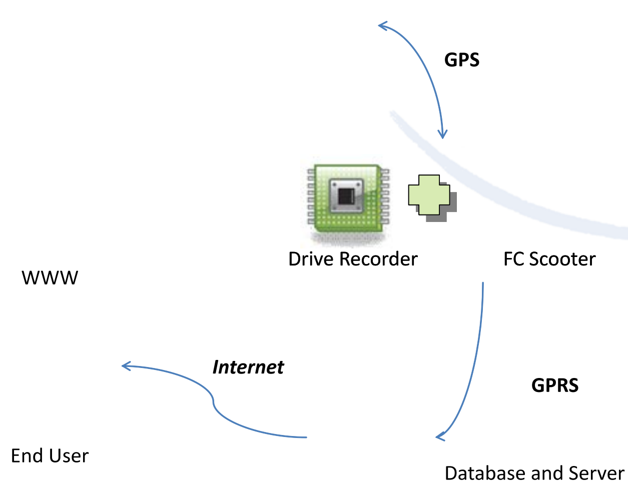

Fig. 3. Proposed real-time monitoring system.

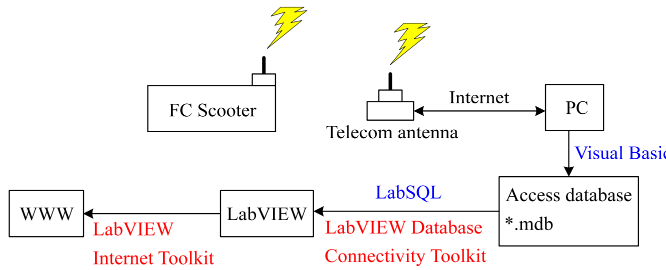

Fig. 4. Interface and platform employed for information publishing.

The in-vehicle drive recorder collects more than twenty parameters in each transferring. To reveal all information in a compact website needs scroll, Fig. 5 shows the website data accessing and renewing process. The index frame of web is a map that shows the address where the FC scooter is. In this urban area, all driving condition can be expected, e.g., uphill, downhill, bumpy road, heavy traffic, and so forth. After acquiring data from database, the web renews the position of FC scooter on map automatically. Then the end user can click the scooter icon to check its present address on map or choose the scooter No. to switch to another running scooter. Due to the in-vehicle drive recorder set a 2 sec buffering period, the server side renews the web information in this period as well. Figure 6 illustrates the flowchart of database constructing and accessing. As aforementioned statements, a Visual Basic program carries out this process. This program can update and store real time testing data to Access database continuously.

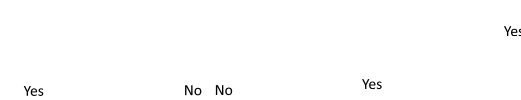

Fig. 5. Flowchart of website data accessing and renewing.

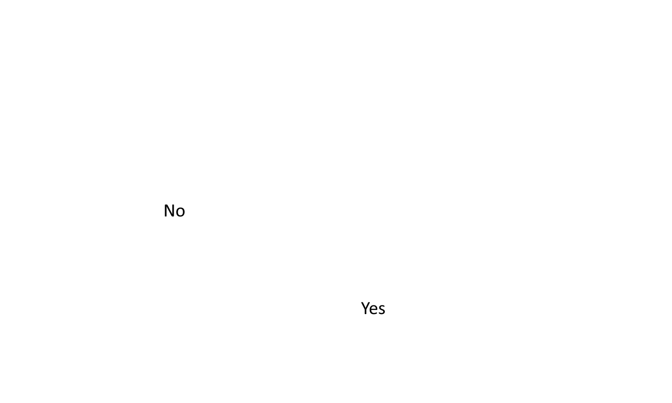

Fig. 6. Flowchart of database constructing and accessing.

This paper aims to make use of the advantages of the Internet to develop a use-friendly real-time evaluation system for FC scooters. A LabVIEW-based, real-time elevation system, as shown in Fig. 7, is proposed to take part in the monitoring tasks. All the illustrated data is acquired from the Access database. The real-time evaluation interface is embedded in the web program, and hence the end users can examine the newest results worldwide. Additionally, all end users can inspect up to twelve scooter parameters on the website. The engineers, hence, can upgrade the system according to each performance index before commercializing.

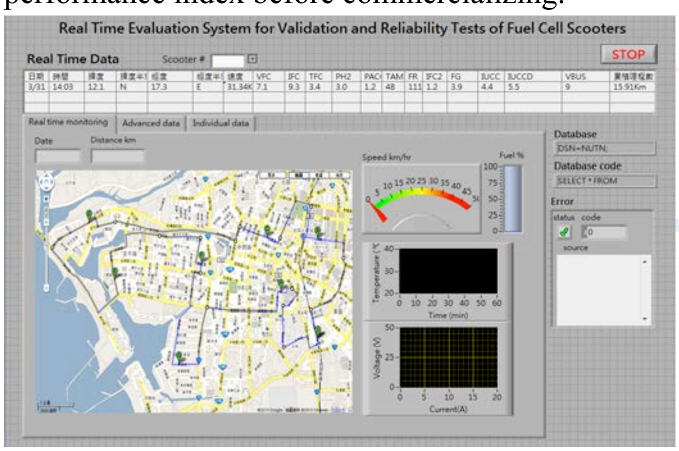

Fig. 7. User interface for the testing FC scooter.

III. Integrated Drive Recorder

As presented in Section 2, the in-vehicle drive recorder is crucial to the validation test of FC scooter. In this section, the proposed design will be exposed. Figure 8 shows the proposed design and construction of integrated drive recorder. As can be seen in this figure, a microcontroller is utilized to control all the information exchanging process. A GPS model is used for positioning the real time position of FC scooter in the map. A GPRS module is used for transferring all driving data to the remote server via the cellular network of telecom company. Consequently, a SIM card and an activated telecom account is needed. This board is power supplied by a DC 12V battery. During the driving condition, the battery can be charged by fuel cell for sustained driving. Figure 9 shows the photograph of the proposed drive recorder. Note that, the receiver of GPS cannot be shielded. Otherwise the positioning function will be failed and the end user may loose control of the FC scooters. Validation test can not be continued if the drive recorder only pass partial driving data during the test. Circuit sheet of this drive recorder can be downloaded via link of [15]. The interested reader can download this circuit and rebuild a similar experiment. This circuit is also available to the remote management of alternative vehicle applications. For instance, this system is capable to link with the traffic control unit. The end user in the traffic control center can utilize this system to build a real time traffic model. Hence, the traffic control center can employ this information to control the traffic sign and guide the traffic loads.

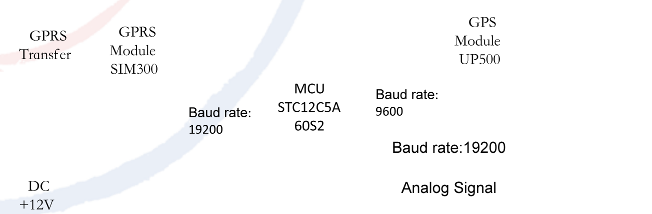

Fig. 8. The design and construction of presented drive recorder.

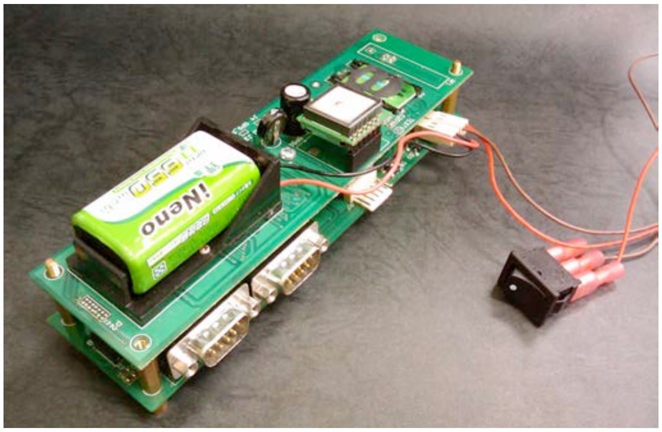

Fig. 9. Photograph of the integrated drive recorder.

IV. Example and Discussion

In this section, the proposed web-based real-time evaluation system for validation and Reliability tests of FC Scooters is illustrated in the following examples. Figure 10 illustrates the web-based end user interface. The web link of this site can be found in [16]. As can be seen in Fig. 10(a), the end user can check all information of the testing FC scooter on the map in real time. The domestic information such as temperature and weather is also available on the website for reference. The end user can select a specified FC scooter to monitor the individual status. Figure 10(b) reveals the real time graphical status of specified FC scooter. The parameters of individual FC scooter are presented in a graphical style for easier comprehension and user-friendly purpose. Practical demonstration video of user interface can be referred on the website [17], which further verifies our experimentation. As can be seen in our experiment, the proposed system is reliable and stable. The end user can be worldwide for sharing evaluation comments to the FC scooter design team. With the express information exchange on the web-based platform, technical consultant can quickly advise their suggestions for next prototype FC scooter system. Finally, these feedbacks facilitate the technology development in a very efficient way.

(a) Real time driving path.

(b) Real time graphical status of specified FC scooter.

Fig. 10. Web-based end user interface.

Actually, to facilitate FC scoter as a product to public, the infrastructure of Hydrogen Filling Station (HFS) is also an issue. Due to the raise of fuel cell vehicles, the demands of HFS catalyze the development. It is no doubt that the number of HFS will increase gradually and push the hydrogen life coming. Another issue does not discuss in this study and can be treated as an extended investigation is the lifetime of fuel cell stack. For further investigation, the impact of fuel cell efficiency decay should be considered in the validation test. Usually, a scooter should run at least five years without large repair. In the meantime, it is still cruel for fuel cell stack to work in such a long time. However, it is also believed that the fabrication technology can overcome this problem when the market growth.

V. CONCLUSIONS

Validation and reliability tests are essential to all vehicles before commercializing to the public. FC scooters are in no exception. For future urban transportation, the FC scooter plays an important role due to its convenient and pollution free feather. In order to validate the feasibility of FC scooters, the validation tests are crucial before commercializing. This paper has offered the design and evaluation methodologies for the validity and reliability tests on FC scooters. The presented system were tested in a real urban traffic for evaluation in Tainan, Taiwan. This study has proposed an integrated drive recorder, which can transfer all driving data to remote web server wirelessly. Fault and malfunction to the FC scooter then can be detected in a short time for avoiding disaster. The circuit deign of proposed control board has been opened to the public as a reference. This design can help engineers construct a similar system according to this circuit sheet. This study has proposed a web-based, real-time elevation system, which embedded software LabVIEW as the end user interface. The real-time experimental results have shown that the proposed validation strategy is stable and reliable. Furthermore, it also has the ability to assist improving the traffic jam of the around area. All testing results have pointed out that the proposed web-based evaluation system has the cost effective and quick response properties on evaluating a new generation urban vehicles.

ACKNOWLEDGEMENTS

This work was supported by National Science Council (NSC) of Taiwan under project of NSC 99-2218-E-024-001.

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Valuation of Urban Green Space in Bangkok, Thailand

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Abstract

Green space encourages interaction between community residents and the natural environment. Such areas also provide social and environmental services that contribute to the quality of life in cities. This study explored Bangkokians' behavior in using green space and the monetary value of green space uses in Bangkok. The monetary value of the non-priced benefits of green space investigated via the willingness to pay for the green space management by using a contingent valuation method with a closed-ended, double-bounded payment approach. The study involved interviews in 2009 with 676 households in Bangkok.

The results indicated that Bangkok residents actively use urban green space. Public parks were the most popular venue. People tended to use the parks accompanied by their family members during weekends for exercise and for recreational activities. They also used roadside parks and green space in public buildings, especially in shopping complexes. Based on the study, green space in Bangkok equates to approximately 3.52 m^2 per person, which is below the international standard. The lack of green space has been the main problem. People, therefore, are willing to contribute an average of THB 750.48 (USD 23.45) per household per year for the establishment and management of green space. From the study, green space in Bangkok is worth THB 1.69 billion (USD 52.8 million). The factors affecting respondents' willingness to pay for green space development were the starting bid, income, gender, and age.

Therefore, policymakers should provide and effectively manage the budget for green space development, and apply economic mechanisms to encourage people to take action in increasing the available green space to promote sustainable green space development in Bangkok.

Keywords: urban green space, valuation

Valuation of Urban Green Space in Bangkok, Thailand

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1. Introduction

The dramatic increases in urban population and urban growth are important factors contributing to environmental and urban problems such as air pollution, noise pollution, aesthetics loss, and health risk among others. These problems have emerged in many cities all over the world including Bangkok, the capital of Thailand, which is a mega city with a population of more than ten million in 2010. Since the Earth Summit in 1992, development policies in Thailand have focused on economics and social aspects based on sustainable environmental and natural resource management. Based on Agenda 21, the Bangkok Metropolitan Administrator (BMA) has proposed sustainable development policies that include increasing the green space in Bangkok. The benefits of increasing urban green space include: provision of opportunities for leisure and recreational activities, reduction of air and noise pollution, improvement in people's physical and psychological health and well-being, provision of shade and alleviation of urban temperatures, and stabilization of the soil surface (Marcus and Barnes,1999; Tyrväinen, 1999; Baines, 2002; MacArthur, 2002; Chiesura, 2004). Moreover, green space also makes urban conditions livable and sustainable, contributes to a more beautiful landscape, and increases the productivity of the residents, among other factors (Parker, 1992; Randall *et al*., 1992; Barreiro *et al.*, 2005, Jim and Chen, 2006).

Therefore, the BMA has allocated a substantial budget every year to many sustainable policies to increase green space by encouraging the local government and private sectors amongst other actions to: increase green space in their workplaces, develop vacant or open space under expressways as green areas, and rectify the law and regulations to promote green space. In 2010, Bangkok had more than 3,500 public parks, representing an area of approximately 20 million m^2. However, the ratio of public parks per person in Bangkok is about 3.52 m^2, which is below the BMA target at 4 m^2.

The sustainable management and development of green space in Bangkok requires the participation of the people. Therefore, to make Bangkok residents aware of the importance of green space, the tangible and intangible benefits of green space should be measured in monetary terms as non-marketed commodities and services. Among many methods used to evaluate the non-market benefits of aesthetics and recreation values (Garrod and Willis, 1999), the contingent valuation method is one approach that can assess the value of green space. The economic concept defines the economic value of urban green space as the amount that consumers are willing to pay for the services that satisfy their needs.

This paper explored the behavior of Bangkok residents towards green space and calculated the monetary value of green space (both the direct and indirect use values) using the contingent valuation method. Some applications of the findings were also proposed.

2. Theoretical Foundation

The contingent valuation method (CVM) is a technique of using a questionnaire approach to quantify the economic value of non-marketed goods and services (Hanemann *et al.*, 1991). It was first suggested in theory by Ciriacy-Wantrup (1947) and first applied by Davis (1963) to evaluate recreation value. CVM is widely applied to evaluate the use and non-use of public goods and services, of natural resources, and for environmental impact assessment.

The main concept of CVM is that individuals reveal their preferences for consuming various goods including natural resources and the environment in terms of money via a hypothetical market. It is straightforward to ask individuals how much they would be willing to pay for obtaining particular goods (specifically green space in this study) given the information provided.

Based on Mitchell and Carson (1989) and Johansson (1993), the individual will reasonably maximize his or her utility (Equation 1) subject to their budget constraint (Equation 2).

$$\text{Max} \quad U = U(X, Z; S) \qquad (1)$$
$$\text{s.t.} \quad I = PX \qquad (2)$$

where X is a vector of private goods, Z is a vector of environment goods, I is income, P is a vector of prices, and S is socio-economic characteristics. Therefore, the quantity demanded of private goods (X) as shown in Equation 3 is a function of prices (P) and income (I), given the socio-economic characteristics affecting an individual preference (S).

$$X = X(P, I; S) \qquad (3)$$

When Equation 3 is substituted into Equation 1, the indirect utility function of an individual (V) is a function of price (P), income (I), and the quantity or quality of the environment (Z), given the socio-economic characteristics affecting an individual preference (S) and can be shown by Equation 4:

$$V = U[X(P, I), Z; S] = V(P, I, Z; S) \qquad (4)$$

When there is a change in the environment (in either quantity or quality or both), then the change in utility in Equation 4 can be written as Equation 5:

$$\Delta V = V(P, I, Z_1; S) - V(P, I, Z_0; S) \qquad (5)$$

The subscripts 0 and 1 denote the initial and final levels for environmental goods, respectively. Where the utility function is not observable, the money measure to evaluate the change in utility is provided by the compensating variation (CV) and can be shown by Equation 6:

$$V(P, I - CV, Z_1; S) = V(P, I, Z_0; S) \qquad (6)$$

CV denotes the maximum amount of money that can be taken away from the individual while still leaving that individual as well off as prior to the change. Therefore, CV represents the willingness to pay (WTP) for environmental change. In this study, an individual who resides and uses green space in Bangkok experiences an increase in utility or well-being because of the benefits derived from green space enhancement (as a hypothetical market). Hence, an individual is willing to pay an amount of money for these benefits to assure his or her utility gain.

3. Data and methodology

3.1 Study area and questionnaire design

The research was conducted in Bangkok, Thailand and data was collected via a survey in 2009 at which time there were 2,263,680 households in Bangkok. Before implementing the full-scale survey, a pilot test was launched to reduce the problems of CVM (Mitchell and Carson, 1989; Whitehead *et al.*, 1993). In the pilot test process, the respondents were required to express their preferences on the monetary values of green space as starting bids by applying an open-ended question. However, most of the respondents were not familiar with stating their preferences to value non-priced or non-marketed services such as green space. Therefore, a closed-ended double-bounded question was used in the full scale survey because it is easy for the respondent to answer. The top-four ranking frequencies of respondents in monetary value in the pilot test were THB 100, 200, 500, and 1,000, respectively and were chosen as the starting bids in the survey.

The questionnaire comprised five sections. The first section aimed to identify the respondent's awareness on environmental problems in Bangkok. The respondent's opinions were sought on the importance ranking of general problems (for example, economic, environmental, educational, quality of life, safety concerns), natural resource degradation, and environmental problems (such as water, air, and visual pollution, sewage, and land utilization), and benefits gained from green space. The perceived problems of green space were also classified. The second section described a definition of green space and description of green space circumstances in Bangkok. The CVM research was also undertaken in this section. The valuation scenario presented a hypothetical program to manage, develop, and increase green space in Bangkok due to the limited budget of the BMA. The payment vehicle was a contribution to a fund for this program. Under these circumstances, respondents were reminded that there was a budget constraint to participate in this program. The dichotomous choice question on a vector of the four prices derived from the pilot test (THB 100, 200, 500, and 1,000 as the first starting bids), was used for implementation. Each individual was assigned to one of these prices at random. If the answer to the first question was positive, then the following second bid vector was increased two times to THB 200, 400, 1,000, and 2,000, respectively. If the answer to the first question was negative, then the following second bid vector was decreased to one half (THB 50, 100, 250, and 500, respectively). The reasons for willingness to support or not support the program were raised in this section. The third section dealt with a respondent's behavior regarding the use of green space. The questions covered the objective, frequency, time, and type of use of green space. The fourth section explored the respondent's knowledge on green space as a public service. The last section aimed to identify the socioeconomic characteristics of the respondent.

3.2 Sampling and survey method

Full-scale survey data were collected from face-to-face interviewing in many parks and green areas in Bangkok of 676 respondents as representative of households in Bangkok during April to June 2009. The study area in Bangkok was divided into five zones according to the density of green space per household: i) less than 3 m^2 per household, ii) 3-6 m^2 per household, iii) more than 6 and up to 10 m^2 per household, iv) more than 10 and up to 20 m^2 per household, and v) more than 20 m^2 per household, respectively. In each zone, the sample was collected as a proportion of households. The questionnaires with four starting bids were divided equally among the zones. Each respondent was randomly presented with a different questionnaire with only one starting bid to express his or her willingness to pay for services of green space that he or she would be satisfied with.

3.3 Empirical Model

In this study, the empirical model in Equation 7 was used to estimate WTP or CV based on Cameron (1988). Maximum Likelihood Estimation based on a lognormal distribution function was applied. $LOWERN_i$ and $UPPERN_i$ are the lower and upper bounds, respectively, of an individual's willingness to pay to enhance green space. The definitions of the independent variables are shown in Table 1. The means of designing the questionnaire and collecting the data are presented in the next section.

$$
\begin{aligned}
(LOWERN_i, UPPERN_i) = \; & \alpha + \beta_1 BID + \beta_2 GENDER + \beta_3 AGE + \beta_4 INCOME \\
& + \beta_5 MEMBER + \beta_6 HEAD + \beta_7 OFFICE + \beta_8 BUSINESS \\
& + \beta_9 PRIVATE + \beta_{10} STUDENT + \beta_{11} HWORK \\
& + \beta_{12} LABOR + \beta_{13} RETIRE + \beta_{14} STUDY + \beta_{15} TIME \\
& + \beta_{16} ZONE + \beta_{17} ENVORG + \beta_{18} CONCERN \\
& + \beta_{19} PATLEVEL + \beta_{20} KNOW \qquad (7)
\end{aligned}
$$

3.4 Variables

3.4.1 Dependent variables

As mentioned, a closed-ended double-bounded approach based on Cameron (1988) was applied to investigate the green space values. The real values of different green space options cannot be observed; they are continuous random variables with values between the upper bound and lower bound of each respondent's willingness to pay.

The respondents were given different starting values (bids) to represent their expressions of green space values. Their answers had two forms. First, if the starting value was accepted, the interviewer would double the value as a second bid and then ask the same question. If the respondent said yes or accepted the second bid, then the respondent's valuation of the green space value would be between the second bid and infinity (∞). If the respondent said no or did not accept the second bid, then their valuation of the green space would be between the second bid and first bid. Second, if a respondent did not accept the starting bid, the interviewer would halve the value, as a second bid and then ask the same question. If the respondent said yes or accepted the second bid, then the respondent's valuation of the green space value would be between the second bid and first bid. If the respondent said no or did not accept the second bid, then their valuation of the green space would be between the second bid and zero. These values were then used as CV estimates in the research.

3.4.2 Independent variables

The independent variables used were divided into three parts as shown in Table 1. The first part comprised the starting bid. The second part consisted of the socioeconomic characteristics of the respondent including gender, age, income, number of household members, being the head of a household, occupation (official, businessman, employed by private company, student, housewife, blue collar, and retired person), education level, period of dwelling in Bangkok, and the density of green space in the living areas of the respondent. The last part of the survey involved perception factors consisting of membership of environmental organizations, environmental concern level, participation level in using green space areas, and knowledge of public spaces. In order to measure environmental concern, variables comprising the respondent's opinions on the importance ranking of natural resource degradation and environmental problems and benefits gained from green space created from the survey were summarized.

Table 1: Definition of variables

Variable	Description
$LOWERN_i$	Lower bound of individual's willingness to pay to enhance green spaces
$UPPER_i$	Upper bound of individual's willingness to pay to enhance green spaces
BID	Starting bid for each respondent being THB 100, 200, 500, and 1,000, respectively
GENDER	Respondent's gender; 1 if male, 0 if female
AGE	Respondent's age (year)
INCOME	Respondent's income (baht/year)
MEMBER	Number of members in respondent's household who earn income (person)
HEAD	Head of a household; 1 if yes, 0 if no
OFFICE	Working as an official; 1 if yes, 0 if no
BUSINESS	Working as a businessman; 1 if yes, 0 if no
PRIVATE	Working in a private company; 1 if yes, 0 if no
STUDENT	Occupation as a student; 1 if yes, 0 if no
HWORK	Occupation as a housewife; 1 if yes, 0 if no
LABOR	Working in a labor intensive occupation; 1 if yes, 0 if no
RETIRE	Retired person; 1 if yes, 0 if no
STUDY	Number of years in study by respondent (year)
TIME	Respondent's period of dwelling in Bangkok (year)
ZONE	Density of green space in living areas of respondent
ENVORG	Respondent's current or past membership of an environmental organization; 1 if yes, 0 if no
CONCERN	Respondent's environmental concern level (score)
PATLEVEL	Respondent's participation level in using green space (score)
KNOW	Respondent's knowledge of public spaces (score)

4. Results and implication

4.1 Background of respondents

The results showed that most respondents were female, married, aged 25-34 year, and working in a private company for a monthly salary of less than THB 10,000 (USD 313). They had approximately three members in their households who earned total income of THB 55,000 (USD 1,718) per month. They have been living in Bangkok for nearly 16 years. Among the problems in Bangkok, the respondents indicated in descending order of importance that traffic congestion, economic factors, safety, and environmental issues are the main problems, respectively. Environmental problems indicating in descending order of importance included air and water pollution, waste management, noise pollution, and land utilization as the main issues, respectively. Most of the respondents had not participated in natural resource and environmental activities. Of the respondents, 49.50 percent indicated that they had gained considerable advantage from green space provided by the BMA, whereas 33.90 percent had gained to a moderate level and 16.60 percent to a lesser level. Figure 1 shows that most of respondents knew the benefits of green space such as reducing city heat and CO_2 as a cause of global warming, and providing shade, among other benefits. They believed that green space areas are worthwhile to society whereas 27.40 percent also considered that green space on private land that the public cannot access is of no value to them. However, most believed that only the BMA has the responsibility to manage green space in Bangkok and that the BMA should allowed people to use green space areas without charge.

4.2 Respondents' behavior to using green space

The findings indicated that Bangkok residents actively used urban green space. Public parks were the most popular venue (53.80%). People tended to use the parks with their family members in the afternoon during weekends for recreational activities and exercise (Figure 2). They also used roadside parks and green space inside buildings especially in shopping complexes. Most green space used outside buildings was in government offices. Of the respondents, 42.90 percent considered that green space areas were not adequate in each zone, there was a lack of maintenance and safety, there was unsuitable utilization, and construction in the areas contrasted with the aesthetics of green space areas.

Figure 1: Respondent's opinion on green space

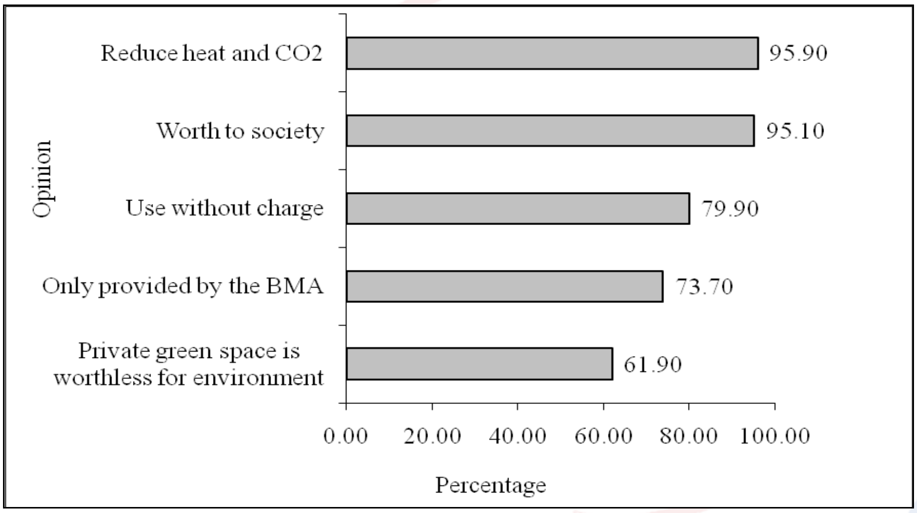
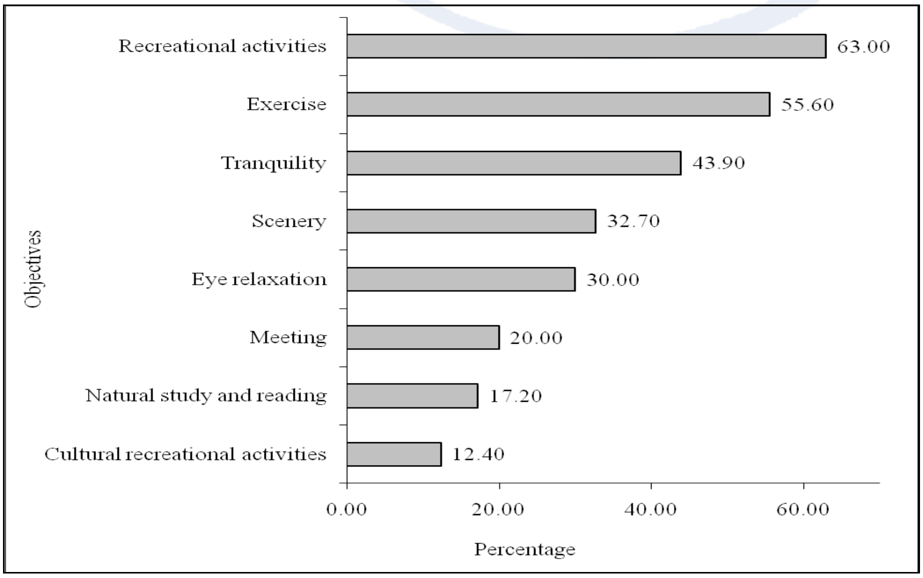


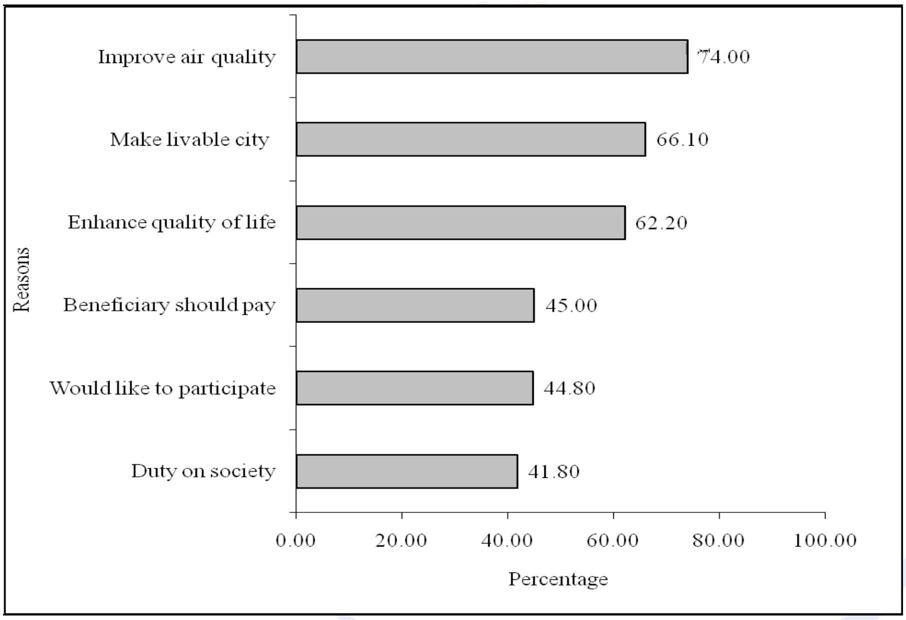
Figure 2: Respondent's objective of using green space



4.3 Willingness-to-pay to use green space

In Bangkok, there is no charge for entrance to public parks or other green space areas. Therefore, the respondents were asked to pay money to use green space via programs to develop and increase green space in Bangkok. Respondents indicated they would like to pay the money via donation (63.80%) in the forms of cash (52.20%) and an entrance fee and environmental tax (28.80%). Figure 3 shows that the reasons for donation were green space improves air quality, makes the city livable, and enhances the quality of life and well-being of residents. Furthermore, it was considered the beneficiaries' responsibility to pay for green space utilization, and some of respondents would like to participate in green space development by themselves. They would like to have more public parks, active and passive recreational areas, greenways, street parks, and natural green space areas.

Figure 3: Respondent's reasons for paying



However, 36.20 percent of the respondents did not want to pay for using green space areas with the reason given being that they already paid income tax and it was the responsibility of the BMA to provide green space areas, so therefore, the BMA on its own should allocate sufficient budget to develop green space effectively. However, some respondents with low income were still concerned about the importance of green space, and indicated that, if they had a greater income, they would like to contribute (Figure 4).

Nevertheless, the rate at which the percentage of respondents willing to pay declined as the bid amount increased as shown in Table 2.

The results of log-normal regression analysis are presented in Table 3. At a significance level of 10 percent, the factors that positively influence the probability of willingness to pay for using green space included the starting bid, income, and gender. The results showed that the likelihood of males being willing to pay was greater than for females. This was consistent with the finding that males used green areas for more activities than female, so therefore, the more often males used green space areas, the greater the probability that they would pay compared to females. As the results show, income had a positive influence on the probability of willingness to pay for using green space; therefore, the greater the income, the higher the probability of willingness to pay by respondents. Hence, green space could be considered as a normal good/service for the people residing in Bangkok. However, only age had a negative influence on willingness to pay; the elderly were less likely to be willing to pay for using green space than younger respondents. This has been a common finding in CV studies (for example, León, 1996; Amirnejad, *et al*., 2006)

Figure 4: Respondent's reasons for not paying

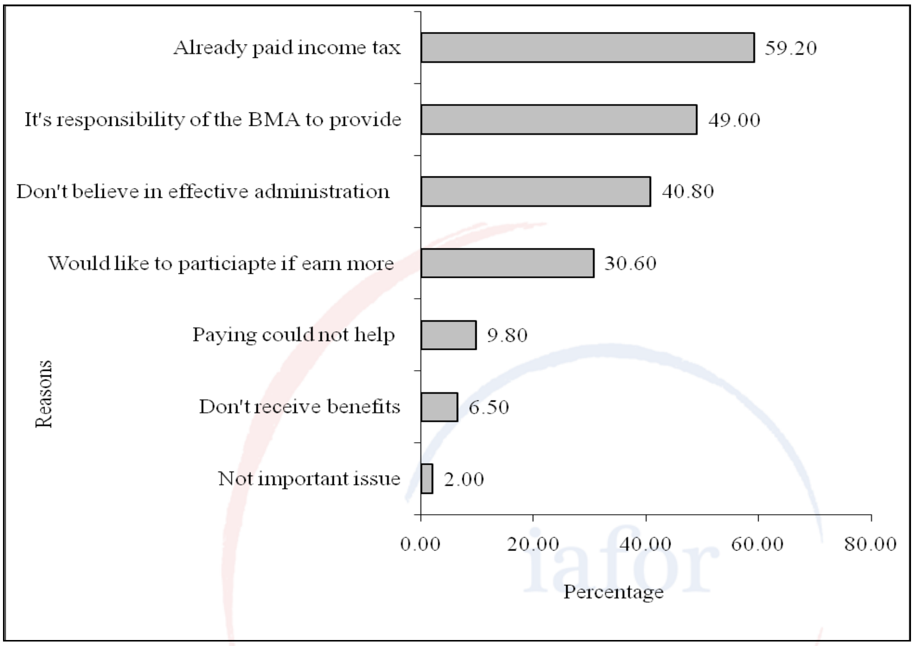


Table 2: Proportion of "yes" and "no" responses

Starting bid (THB)	Number of samples (person)	Percent of responses	
		Yes	No
100	169	71.60	28.40
200	176	65.90	34.10
500	163	63.20	36.80
1,000	168	54.20	45.80

The variable, ZONE, which explains the density of green space in the living areas of respondents, was not statistically significant at the 90 percent level; however, the sign on this parameter was as expected. This result indicated that people who live in areas with a lower density of green space were more likely to pay more for using green space. In addition, the variable, KNOW, which is the score of respondent's knowledge on public space, was not statistically significant, but also had positive influenced on the probability of willingness to pay for using green space. This result indicated that people who had more knowledge were more likely to pay more for using green space.

Table 4 shows that households were willing to contribute an average of THB 750.48 (USD 23.45) per year for using green space via the green space establishment and management program in Bangkok. Consequently, the green space in Bangkok was worth THB 1.69 billion (USD 52.8 million) in 2009.

Table 3: Log-normal regression results on willingness to pay for using green spaces

Variable	Coefficient	*P*-value
constant	3.958	< 0.0001***
BID	0.001	< 0.0001***
GENDER	0.131	0.0528*
AGE	-0.008	0.0896*
INCOME	0.175	0.0375**
MEMBER	0.008	0.7989
HEAD	0.109	0.2318
OFFICE	-0.079	0.5985
BUSINESS	-0.175	0.2865
PRIVATE	-0.182	0.2156
STUDENT	-0.005	0.9705
HWORK	0.024	0.9019
LABOR	-0.044	0.7981
RETIRE	0.001	0.5770
STUDY	-0.007	0.5681
TIME	0.001	0.8685
ZONE	-0.030	0.2783
ENVORG	0.006	0.9483
CONCERN	-0.003	0.3274
PATLEVEL	-0.001	0.9869
KNOW	0.015	0.3943
log-likelihood = -355.38	n = 676	Pseudo R^2 = 0.2177

*** indicates significance at the 1 percent level
** indicates significance at the 5 percent level
* indicates significance at the 10 percent level

Table 4: Estimate mean and aggregate value of green space

	THB per year	USD per year
Mean of willingness to pay (WTP)	750.48	23.45
Confidence interval (CI) of mean of WTP	647.10-853.85	20.22-26.68
Aggregate willingness to pay (WTP)	1.69 billion	52.8 million
Confidence interval (CI) of aggregate of WTP	1.47-1.93 billion	45.77-60.40 million

Mean of WTP = exp ($\alpha + 0.5\ \sigma^2$)
CI of mean of WTP = Mean of WTP ± 1.96 (SD of Mean of WTP)
α and σ denote the intercept and the scale value estimated, respectively. SD denotes standard deviation.

5. Conclusion

This study attempted to demonstrate the usefulness of a contingent valuation method in measuring the value of green space in Bangkok as a tool helping the creation of a funding program to enhance green space. This approach is applicable for researchers and others, such as policy makers, planners, and stakeholders, who are interested in urban development planning as they attempt to assess public opinion on green space policies in their communities.

The results also indicated that Bangkok residents with their family members actively use urban green space, especially public parks, during weekends for recreational activities and exercise. They also use roadside parks and green areas inside buildings especially in shopping complexes. Green space areas outside buildings were most commonly used as part of areas associated with government offices. The main problems of green space areas in Bangkok were: insufficient area, a lack of maintenance and safety, unsuitable utilization, and construction in areas that contrasted with the aesthetics of green spaces.

The findings revealed that a high percentage of people in Bangkok considered green space important, with 63.80 percent of respondents supporting the program to enhance green space. Mean household willingness to pay to support the program was THB 750.48 (USD 23.45) per year. Therefore, the economic use value of green space in Bangkok was about THB 1.69 billion (USD 52.8 million) per year. The factors that statistically influenced the probability of willingness to pay for enhancing green space areas were starting bid, income, gender, and age.

In 2009, the BMA proposed almost THB 874 million (USD 27 million) for green space development programs in Bangkok. However, only 38 percent of the budget was used directly for development programs in green space areas. Therefore, the BMA should manage its budget on green space efficiently by providing more green space in the forms of public parks, recreational areas, and natural green areas. In addition, the BMA and educational institutions should educate people and promote the benefits of green space to create public awareness, and encourage people to participate in using green space. Furthermore, to encourage interaction between community residents and the natural environment, other communities or cities that have initiated programs to provide more green space will find that the contingent valuation method is useful in assessing public opinion on urban development policies that provide social and environmental services and contribute to the quality of life in communities or cities.

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Heat Trap and Light Concentration Mechanism to Enhanced Temperature Gradient Thermoelectric Energy Harvesting System

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Asian Conference on Sustainability, Energy & the Environment 2011

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Abstract

Thermoelectric energy harvesting has increasingly gained acceptance as a potential power source that can be used for numerous wireless sensing networks and monitoring systems. Electronic designers have struggled to incorporate energy harvesting methods into their designs due to the relatively small voltage levels available from many micro-energy harvesting thermal collector. This paper addresses a technique for temperature gradient amplification mechanism on the thermal element that can be used and utilizes for low input voltage power conversion method i.e. to convert small amounts of scavenged ambient heat energy into a usable form of electricity. Our solution utilizes a technique to trap heat and focused light mechanism to amplify the temperature gradient on the thermoelectric and power management circuits used to control startup conditions. Experimental measurement show that the output voltage that has been generated by the improved thermal gradient electric module is 350mV and induced 1.5mA current with estimated conversion efficiency range is 40% to 50%. The power management system works as function to regulate and stabilize the voltage and stored into a storage element such as a super-capacitor or lithium-ion battery for use during brown-out or unfavorable harvesting conditions. Applications requiring modular, low power, extended maintenance cycles, such as wireless instrumentation would significantly benefit from the novel power conversion and harvesting techniques outlined by the proposed method.

Keywords

DC-DC converter, Power management, Thermoelectric, Energy conversion, Output voltage, Heat Energy Recovery, Thermal energy harvester, Power conditioning

Introduction

Today, sustaining the power requirement for autonomous wireless and portable devices is a paramount issue. In the recent past, energy storage has improved significantly. However, this progress has not been able to keep up with the development of microprocessors, memory storage, and wireless technology applications. For example, in wireless sensor networks, battery powered sensors and modules are expected to last for a long period of time. However, conducting battery maintenance for a large-scale network consisting of hundreds or even thousands of sensor nodes may be difficult, if not impossible. Ambient power sources, as a substitute for batteries, come into consideration to minimize the maintenance and the cost of operation. Power scavenging may enable wireless and portable electronic devices to be completely self-sustaining, so that battery maintenance can be eventually removed. Researchers have performed many studies in alternative energy sources that could provide small amounts of electricity to electronic devices. Energy harvesting methods are envisaged in variety energy sources, such as mechanical vibrations, electromagnetic sources, light, acoustic, and airflow, heat, and temperature variations. Energy harvesting, in general, is the conversion of ambient energy into usable electrical energy. When compared with energy stored in common storage elements, such as batteries, capacitors, and the like, the environment represents a relatively infinite source of available energy. Systems continue to become smaller, yet less energy is available on board, leading to a short run-time for a device or battery life. Researchers continue to build high-energy density batteries, but the amount of energy available in the batteries is not only finite but also low, which limits the life time of the systems.

Extended life of the electronic devices is very important; it also has more advantages in systems with limited accessibility, such as those used in monitoring a machine or an instrument in a manufacturing plant used to organize a chemical process in a hazardous environment. The critical long-term solution should therefore be independent of the limited energy available during the functioning or operating of such devices. Table 1 compares the estimated power and challenges of various ambient energy sources. The source of information for each technique is given in the third column of the table. Though this comparison is not comprehensive, it does provide a broad range of potential methods to scavenge and store energy from a variety of ambient energy sources. Light, for instance, can be a significant source of energy, but it is highly dependent on the application and the experience to which the device is subjected. Thermal energy, in contrast, is limited because temperature differences across a chip are typically low. Vibration energy is a moderate source, but again, it is dependent on the particular application.

Energy Source	Power Density & Performance	Source of Information
Acoustic Noise	0.003 μW/cm3 @ 75Db 0.96 μW/cm3 @ 100Db	(Rabaey, Ammer, Da Silva Jr, Patel, & Roundy, 2000)
Temperature Variation	10 μW/cm3	(Roundy, Steingart, Fréchette, Wright, Rabaey, 2004)
Ambient Radio Frequency	1 μW/cm2	(Yeatman, 2004)
Ambient Light	100 mW/cm2 (direct sun) 100 _W/cm2 (illuminated office)	Available
Thermoelectric	60 _W/cm2	(Stevens, 1999)
Vibration (micro generator)	4 _W/cm3 (human motion—Hz) 800 _W/cm3 (machines—kHz)	(Mitcheson, Green, Yeatman, & Holmes, 2004)
Vibrations (Piezoelectric)	200 μW/cm3	(Roundy, Wright, & Pister, 2002)
Airflow	1 μW/cm2	(Holmes, 2004)
Push buttons	50 _J/N	(Paradiso & Feldmeier, 2001)
Shoe Inserts	330 μW/cm2	(Shenck & Paradiso, 2001)
Hand generators	30 W/kg	(Starner & Paradiso, 2004)
Heel strike	7 W/cm2	(Yaglioglu, 2002) (Shenck & Paradiso, 2001)

Table 1: List of Energy Source and Power Density of Energy Harvesting Methods

Temperature Gradient (ΔT) Amplification Module Design

As shows in Figure 1, the work unit for thermal harvesting mechanism consists of optical lens, light reflector, thermoelectric element and heat rejecter. The incident lights are focused at the thermal element and temperature at the hot junction of thermal element increased up to 100°C. This enhancement increases the voltage potential developed between the two junctions (hot and cold). Typical thermoelectric device coefficient is 3mV/C and in total approximately 350mV is generated when temperature gradient reaches to 40°C. Potential voltage developed can be harvested; decent charging circuit and boosting circuit utilization is essential to adequately run wireless sensor network efficiently.

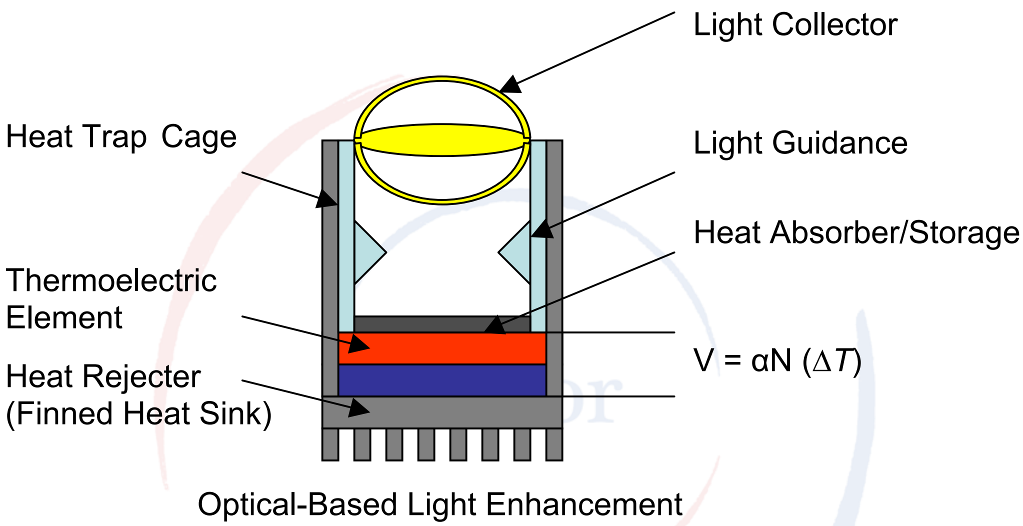

Figure 1: Method to enhance temperature gradient onto thermal element

Energy Harvesting System Overview

The typical generic blocks diagram model for any micro-energy harvesting power conversion is shown in Figure 2. The four main blocks are important functional blocks of any self-powered system design and consists of energy transducer, power conditioning system (i.e. DC-DC converter including power management controller), energy storage element (i.e. secondary battery or super-capacitor), data processing (e.g. MCU) and the data communication module.

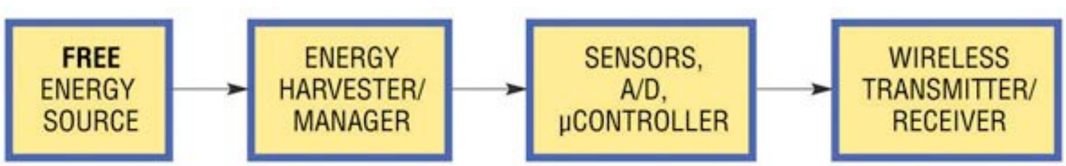

Figure 2: Typical energy harvesting power conversion system

Coupled Inductive Resonant Voltage Step-Up DC-DC Conversion

Based on the model of typical energy harvesting system, we developed and enhancing existing on-board low-voltage conditioning and DC-DC converter design with power control managing features in order to improve energy conversion process. Figure 3 shows the architectural block diagram and topology of the “Inductive Low Voltage Step-Up DC-DC Conversion” based on the LTC3108. The system consists of Resonant Voltage Step-Up Oscillator, DC-DC Converter and Power Manager Controller blocks which is function as to convert small amounts of scavenged ambient heat energy introduced by the thermal amplification module into a usable form of output electricity voltages. The system developed is ideal for harvesting and managing surplus energy from low input voltage sources such as TEG (thermoelectric), thermopiles or small PV cells. It is designed to accumulate and manage energy over a long period of time to enable short power bursts for acquiring and transmitting data. With the chosen ratio small step-up coupled inductor, experimental shows the voltage step-up topology operates from minimum input voltage as 300mV and delivered measured output voltage of 5V as a voltage source to charge energy storage element. In this case we have chosen super-capacitor with working voltage rating condition is 5.5V with temperature is 70°C. The storage element/capacitor can be sized using the following equation:

$$C_{STORE} \geq \frac{\left[6\mu A + I_Q + I_{LDO} + (I_{BURST} \bullet t \bullet f)\right] \bullet TSTORE}{5.25 - V_{OUT}}$$

Where 6µA is the quiescent current of the LTC3108, I_Q is the load on V_{OUT} in between bursts, I_{LDO} is the load on the LDO between bursts, I_{BURST} is the total load during the burst, t is the duration of the burst, f is the frequency of the bursts, T_{STORE} is the storage time required and V_{OUT} is the output voltage required.

By adding a suitable ratio small step-up coupled inductor at C_1 and C_2 pin, the LTC3108 can be used to gather energy from low input voltage sources and provides a complete power management solution for wireless sensing and data acquisition. The 2.2Volt, LDO powers an external microprocessor, while the main output is programmed to one of four fixed voltages to power a wireless transmitter or sensors. The power good indicator signals that the main output voltage is within regulation. A second output can be enabled by the host. A storage capacitor provides power when the input voltage source is unavailable. Extremely low quiescent current and high efficiency design ensure the fastest possible charge times of the output reservoir capacitor. Analog front-end directly interfaces with the external sensor to perform filtering and amplification so as to convert the analog signal into digital. Digital data is then processed in the Digital Processing unit and sent to the RF transceiver for transmission.

Design Description

To describe the system regarding to Figure 3, the thermal based energy harvesting system consists of the small step-up coupled inductor and the LTC3108 which received low input electricity through solar heat radiation energy conversion from the thermal energy collector that has been described. The step-up coupled inductor works as a resonant voltage step-up oscillator doing function to multiply and boost (controlled by no: of turns ratio) low-level voltage source to desire high output level. The boosted voltage then transfers to dc-dc converter, regulates and stores into storage element (e.g. super-capacitor) as a power provider for powering other electronics system. As example as shown in the Figure 3, the stored power is further supplied to power the wireless portable electronics device via interconnect power bus architecture to ensure they keep work continuously for a long period time without needs batteries replacement and minimizing maintenance and cost of wireless sensing networks operation.

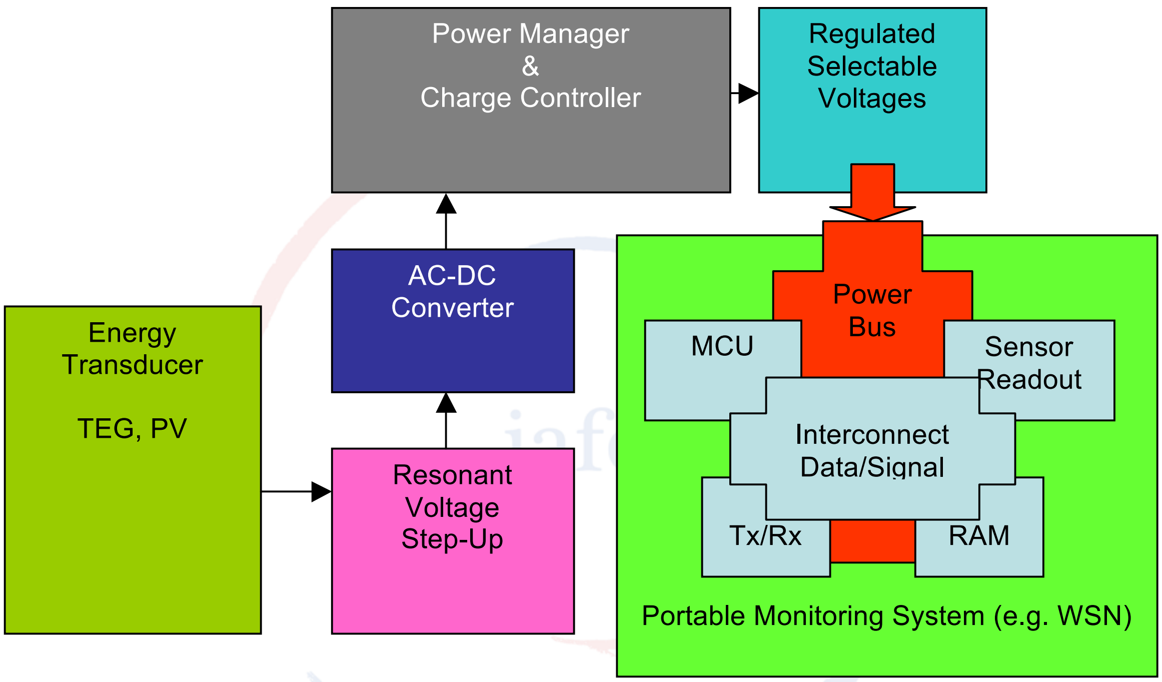

Figure 3: Low Voltage Step-Up Converter & Power Control Manager for Micro-Energy Harvesting

Experimental Results

Final simulation was intended to verify the proposed design of temperature gradient enhancement technique for the low-voltage DC-DC converter power conversion efficiency. As referred to Figure 4, the voltage increases because of the temperature increases, from the gradient approximately 3mV/°C of voltage developed reciprocally. Additional boosting circuitry as shown in the Figure 3 is required to increase the generated voltage to a substantial level to run power-demand for WSN electronic devices. As additional feature, a 5V voltage multiplier and charging circuit has been developed to enhance the constant and stable power supply unit. This is vital for reliable communication link.

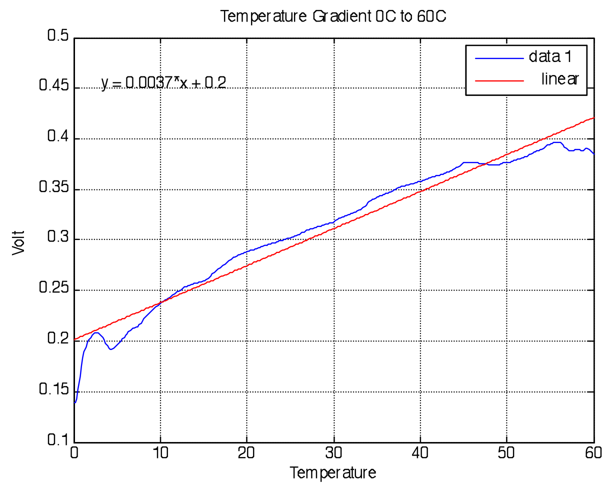

Figure 4: Measured output voltage available from the thermoelectric based-on the temperature gradient amplification method

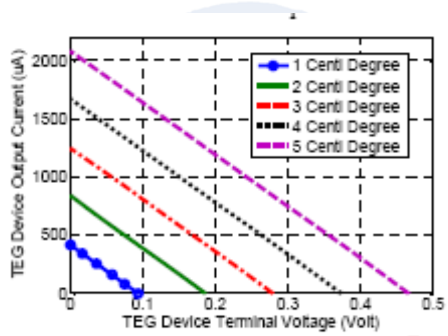

Figure 5: I-V characteristic of the thermoelectric for different values of ΔT

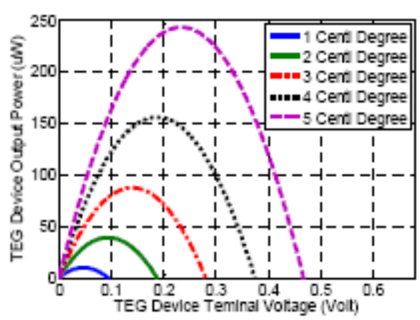

Figure 6: Output power of the thermoelectric as a function of output voltage for different temperature gradient (ΔT)

Using a simulation tool, various output voltage has been measured and captured in-order to characterize the thermoelectric with different temperature gradient using the proposed design technique. Figure 5 shows the current-voltage characteristic of the thermoelectric for different values of ΔT and Figure 6 plots the output power of the thermoelectric as a function of the output voltage for different values of ΔT. From the figures we can observe the thermoelectric works as a voltage source in series with an internal resistor, where the voltage source is proportional to temperature gradient according to that equation:

$$V_{TEG,\,OC} = \alpha \Delta T \, \chi \, N_{LEGPAIRS}$$

It is also evident from the figures, for small temperature gradients the output voltage of the thermoelectric is very small (< 0.5V) and the output power is only a few hundred μW. The output voltage and power of the thermoelectric with the temperature gradient enhancement technique can be derived as:

$$V_{TEG} = V_{TEG,\,OC} - \beta \, I_{TEG}$$
$$P_{TEG} = I_{TEG} \, V_{TEG}$$

As shown in Figure 3, the power conditioning circuit is used to extract energy (i.e. charge) from the thermoelectric and using the resonant voltage step-up boost converter low level voltage source will be step-up and transform to certain higher level ratio controlled by a switching duty cycle feedback controller function (i.e. ON/OFF pulses switch). The generated voltage than will be regulate and stabilize as a voltage source for powering electronics system operation.

Conclusion

The design approach that has been introduced is a way to expedite know how understanding and evaluate the thermal powered micro-energy harvesting system. In order to enhance temperature gradient that can cause to increase output voltage generated by the thermoelectric, we presented the prototype system that consists of the model temperature gradient amplification module and the low voltage step-up DC-DC converter with power manager controller system design based on the LTC3108 to control and generate regulated voltage source for powering the wireless sensing-based monitoring system for precision agriculture application. Experimental shows the resonant voltage step-up topology operates from minimum voltage source as low as 300mV and can delivered output voltage of 5V as a voltage source to charge storage element. We have chosen super-capacitor with working voltage rating condition is 5.5V with maximum operating temperature is 70°C to ensure the storage element can be fully charge by the V_{STORE} voltage up to 5V.

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PROPERTY ASSESSED CLEAN ENERGY FINANCING IN ITALY

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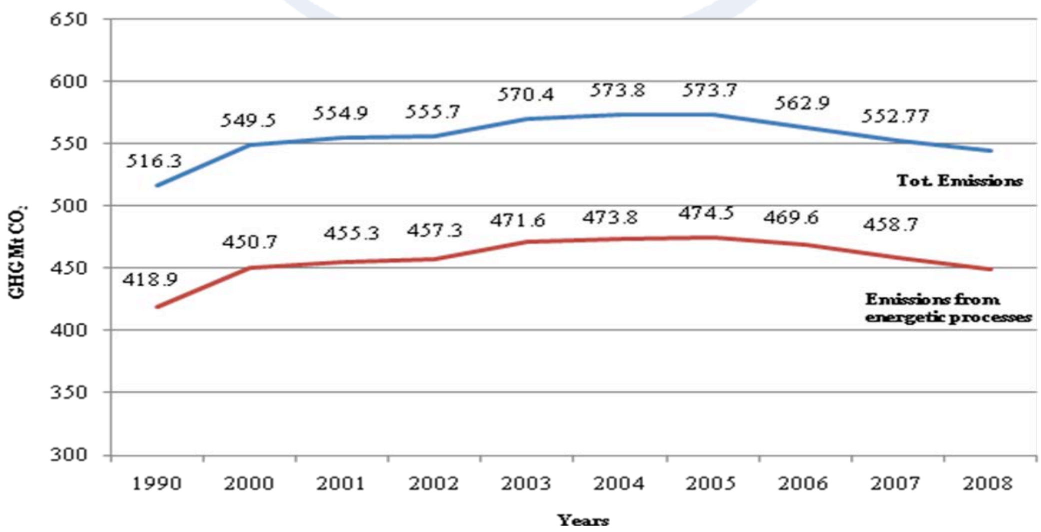
Background

The Kyoto Protocol and UE Burden-Sharing Agreement require Italy to follow a strict greenhouse (GHG) trajectory. Under its obligations Italy has a target to reduce emissions by 6.5% below the base-year level over the first commitment period of 2008-2012, a reduction of 483 Mt CO_2 (Chart 1). According to the National Agency for New Technologies, Energy and Environmental forecasts, in order to meet this target Italy must cover a gap almost 60 Mt CO_2[i] corresponding 12.64% above the target.

The European Union's climate and energy package increased this challenge. In January 2008 the European Commission proposed a legislation to implement the "20-20-20 plan"[ii]: it was approved by the European Parliament and Council in December 2008 and became law in June 2009. The energy-climate package embodies the EU policies of reducing greenhouse gas emissions, achieving sustainable development, and ensuring energy security. Italy's commitment is to reduce the country's emissions by 13 percent compared to 2005 levels from the sector outside of the UE-ETS[iii].

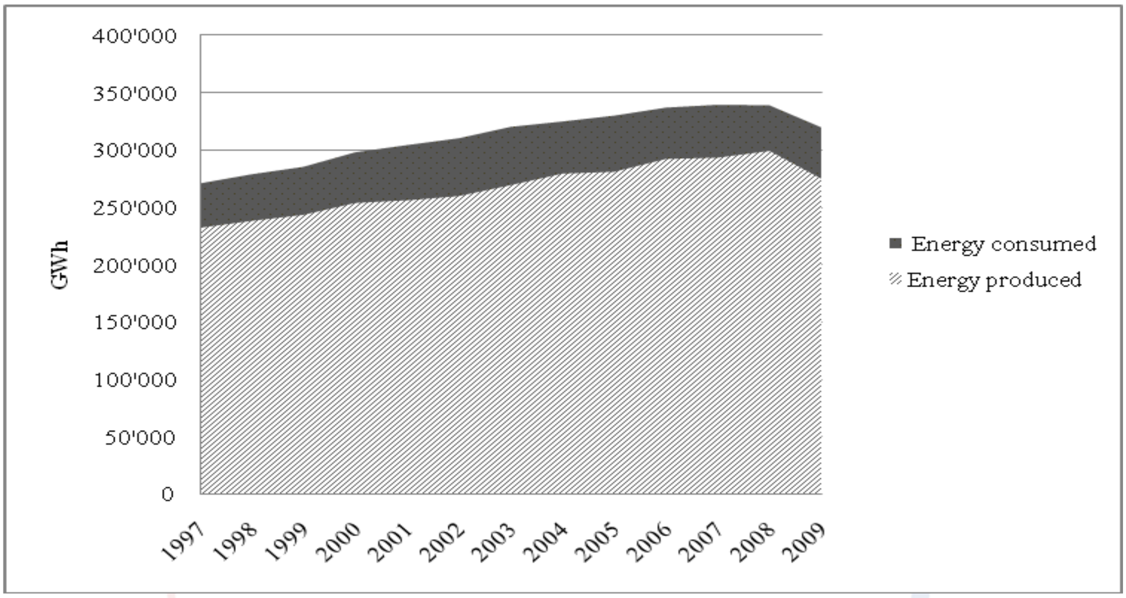
Chart 1 – Italy emissions profile: Kyoto target



Source: ISPRA, Annuario dei dati ambientali 2009

Analyzing Italy's energy profile, the country is among the largest electricity consumers in Europe with structural dependency of 14% in the last 10 years. Electricity consumption increased constantly between the period 1997-2008, in 2009 the net electricity production was 275.3 TWh, a reduction of 8.06% under the previous year while the final consumption reduced approximately 6% (Chart 2).

Chart 2 – Italy's Electricity Balance



Source: TERNA – Bilancio dell'energia elettrica in Italia (1997-2009)

Table 1 shows forecasts of electricity demand and electricity intensity (a measure of the energy efficiency of a nation's economy, calculated as units of energy per unit of GDP) for the period 2009-2020 in two different scenarios:

- Advanced scenario: electricity demand growth 2.3% per year corresponding to 410 TWh on 2020;
- Basic scenario: electricity demand growth 1.3% per year corresponding to 370 TWh on 2020.

On 2015 Italy's projected electricity demand for the advanced scenario is 362.1 TWh with an average annual rate of 2.1% for the period 2009-2015 and 2.5% for the period 2015-2020. In this scenario the demand level of 2007-2008 will catch up again in 2012.

In the basic scenario, considering a limited electricity intensity, Italy will have the same demand level on 2014.

Table 1 – Forecast electricity demand, GDP and Electricity intensity

	Electricity Demand		GDP		Electricity intensity	
	TWh	percentage variation compared to previous year	Million €	percentage variation compared to previous year	kWh/€	percentage variation compared to previous year
1990	235.1	-	1 017 384	-	0.231	-
1995	261	2.1%	1 083 763	1.3%	0.241	0.8%
2000	298.5	2.7%	1 189 898	1.9%	0.251	0.8%
2005	330.4	2.1%	1 243 764	0.9%	0.266	1.2%
2008	339.5	1.4%	1 270 898	0.7%	0.267	0.6%
2009	320.3	-5.7%	1 206 868	-5.0%	0.265	-0.6%
			Advanced scenario			
2015	362.1	2.1%	1 222 037	1.6%	0.277	0.7%
2020	410	2.5%	1 435 803	1.6%	0.286	0.7%
			Basic scenario			
2015	343.3	1.2%	1 307 512	1.6%	0.263	-0.3%
2020	370	1.5%	1 435 803	1.6%	0.258	-0.3%

Source: Prometeia, Scenari di previsione – Bologna July 2010

Table 2 – Advanced scenario, Consumption by sector

	2009		2015		2020		% Variation by sector 2009-2020
	TWh	%	TWh	%	TWh	%	
Agriculture	5.6	1.9	5.9	1.7	6.0	1.6	-15.8
Industry	130.5	43.5	142.4	42	153.4	39.8	-8.5
Tertiary	94.8	31.6	115.2	33.9	139.7	36.3	14.87
Residential	68.9	23	75.9	22.4	85.9	22.3	-3.04
Total Consumption	**299.9**	**100**	**339.4**	**100**	**385.0**	**100**	
Energy Losses	20.4		22.6		25.0		
Italy	**320.3**		**362.1**		**410.0**		

Source: Terna, "Previsioni della domanda elettrica in Italia e del fabbisogno di potenza necessario, anni 2010-2020", September 2010

Italy's electricity consumption is projected to increase by about 28 percent (advanced scenario) or 15.5 percent (basic scenario) compared to 2009 levels. Consumption will also shift somewhat by sector: residential and commercial building are going to consume about 60% of electricity use while the industrial sector almost 40%.

Improving efficiency and energy supply security will be the main priorities for policy makers: Italy's electricity system is fragile, combined with growing dependence on imports and the lack of domestic generation capacity[iv].

International Energy Agency recommend pushing forward to improve Italy's domestic energy supply and establishing a policy framework in line with the UE target.

PACE – Property Assessed Clean Energy

Many obstacles hinder the realization of energy improvements, such as financial barriers, insufficient information/knowledge and analytical capacity, transaction costs, uncertainly of savings. While most energy efficiency measures are cost-effective with positive net present value life-cycle costs, there is a substantial "efficiency gap" between a consumer's actual investment in energy efficiency and those that appear to be in the consumer's own interest.[v]

Property Assessed Clean Energy policy focuses on the upfront cost in energy improvements: it is a model structured to enables local governments to raise money through the issuance of bonds to fund clean energy projects. The financing is repaid over a set number of years through a "special tax" or assessment on the property tax bill of property owners, who choose to participate in the program. The financing is secured with a lien on the property, and then if the property is sold before the end of the repayment period, the new owner inherits both the repayment obligation and financed improvements[vi].

PACE is an addition to existing state laws that already authorize the creation of "land secured" financing districts to pay for improvements in public interest.
Critical aspects distinguish the PACE plan. First, it is a voluntary program; if the property owners "opt in", they pay an additional property tax for the value of project. Second, the repayment is secured by a lien on the property, thus the property tax obligations transfer with property if it is sold, rather than being due on sale. Third, there is the longer repayment period compared to standard five or seven years of conventional loans, making energy efficiency improvements affordable.

To establish these programs it is important to evaluate the cost of energy projects and resulting energy savings. In order to be cost-effective, the net present value of energy saving must be larger than the cost of the property tax payment. The annual special tax amount is calculated on the cost of the energy project installed, the interest rate paid on special bonds and an annual administrative charge levied by the city and financing partner.

In the analysis we consider the following parameters and program design options:

- SIR – Saving to Investment Ratio should be greater than one, thus for each extra dollar spent the amount saved will be greater[vii];
- Financing should be for high-value investments that have well-documented efficiency gains;

- The term of the assessment should not exceed the useful life of the improvements to avoid creating an imbalance between the value of the asset and the amount of the liability;
- The assessment should be of appropriate size, generally not exceeding 10% of property's estimated value;
- An assessment reserve fund should be created to protect investors from late payment or non-payment;
- Non-acceleration upon property owner default, in case of foreclosure the next owner is responsible for the future assessment payment, the liability for the assessment is limited to the amount in arrears at the time;
- Quality assurance concerning licensed contractor, attestation of property, estimate of house's appraised value[viii].

Well structured PACE programs minimize risks for homeowner, lenders and local government:

- They increase property value, house or building with best energy performance classified in highest ratings;
- Their energy cost savings improves homeowner cash position, especially during time of inflation time, tax assessment remains fixed against the increase energy cost[ix].

To assess the impact of clean energy municipal financing on residential customers, our research team at the University of California, Berkeley, created a model to compare the net present value of annual cash flows over 25 years for the energy retrofit[x]. Model assumptions are summarized in table 3. Marche region's data represent the baseline.

Table 3 – Model assumptions (Marche region's data baseline)

Model assumptions – Italy	
Energy consumption	For the Marche case, consumption is based on 2009 ISTAT[xi] Environmental Data. Family (2-3 people) average consumption is 2.700 kWh/year and 1.497 m^3/year of natural gas.
Electricity price	The electricity price is based on AEEG[xii] residential rate of 0.1583 €/kWh (average rate for 2.700 kWh/year consumption)
Gas prices	The gas price is based on AEEG residential rate of 0.7234 €/m^3 (average rate for 1497 m^3/year consumption)
Solar PV system	Solar size depends on percentage supplied by solar PV with an installed cost of 4.20 €/W
Solar power production	- According to UNI 10349 – Solar radiation - Default correction for Azimuth South and 30° Tilt - Increase production of 20% relative to fixed system - General system losses of 20%
Solar performance	PV system life of 25 years, with a performance degradation of 0.83 percent/year
Inverter	Inverter replacement in year 12 for approximately 600 €/W
Solar Thermal system	Solar thermal size depends on the household size with an installed cost of 1000 €/m^2
Solar Thermal production	- According to UNI 10349 – Solar radiation - Default correction for Azimuth South and 30° Tilt - Designed according to Itaca Protocol - Inlet and outlet water temperature ranging from15°C to 40°C, according to UNI 11300:2008
Solar Thermal performance	Solar thermal system life of 25 years, with a performance degradation of 0.83 percent/year
Rebate and revenues	- Feed-in tariff is paid for electricity produced by solar PV over a period of 20 years - CCS (Contributo Conto Scambio) is paid for energy exported to the grid - GSE guarantees minimum prices for electricity sold
Tax Credit	Tax credit of 55 percent improvement cost is allowed for energy efficiency
Financial parameters	- Average inflation rate of electricity price of 3 percent - Average inflation rate of gas price of 5 percent - General inflation rate is not considered - Discount rate of 5 percent - Interest rate of 5.5 percent with a term of 20 years

GSE (Gestore dei Servizi Elettrici, Italian energy authority) supports photovoltaic solar generation under a feed-in tariff scheme (“Conto Energia”). The scheme is regulated by the Interministerial Decree of 19 February 2007. On August 2010, the Minister of Economic Development authorized the Conto Energia implement the program from 2011 to 2013, which regulates the new tariffs and mechanism for solar photovoltaic production (Table 4).

Table 4 – Model assumptions Conto Energia 2011/2013

Model assumptions – Conto Energia 2011/2013						
Solar PV	- Power output size limited to 3.000 MW - Minimum power size is 1 kW - Feed-in tarif is paid for electricity produced by solar PV over a period of 20 years					
Basic tariff						
Size	**First four months 2011**		**Second four months 2011**		**Third four months 2011**	
	On building	**Other**	**On building**	**Other**	**On building**	**Other**
[kW]	**[€/kWh]**	**[€/kWh]**	**[€/kWh]**	**[€/kWh]**	**[€/kWh]**	**[€/kWh]**
1≤P≤ 3	0.402	0.362	0.391	0.347	0.380	0.333
3<P≤20	0.377	0.339	0.360	0.322	0.342	0.304
20< P≤200	0.358	0.321	0.341	0.309	0.323	0.285
200<P≤1000	0.355	0.314	0.335	0.303	0.314	0.266
1000<P≤5000	0.351	0.313	0.327	0.289	0.302	0.264
P>5000	0.333	0.297	0.311	0.275	0.287	0.251
Additional premium	- Removing asbestos (+10%) - Installation on special area (+5%) - Profile Predictable exchange - Premium for energy performance - Local government < 5000 people					

Energy System	
Scambio sul posto	For consumers who install solar PV for personal needs. It allows export of energy to the grid depending on solar production and energy consumption. It is composed of two parts: - Energy quota - Service quota The formula is: $$CCS = min\left[C_{ew}; V_{ef}\right] + C_s * E_e$$ Where: - *CCS* Contribution Conto Scambio, Revenues from energy system that guarantees the equivalence between energy exported to and energy withdrawn from grid - C_{ew} Cost of electricity withdrawn from grid (Electricity withdrawn * Electricity tariff) - V_{ef} Value of electricity fed into grid (Electricity fed * Local electricity price) - C_s Unit Cost of Service (transportation and distribution) - E_e Energy exchanged with the grid corresponding of $min\left[E_{fed}; E_{withdrawn}\right]$ In the case where electricity fed exceeds electricity withdrawn, it represents a credit for the future.
Ritiro dedicato	For consumers who install solar PV for selling electricity to the grid. Minimum prices are guaranteed if solar size < 1 MW

For an average household in Italy, the net present value was calculated for solar photovoltaic installation only; and for solar thermal and solar photovoltaic installation, in different scenarios:

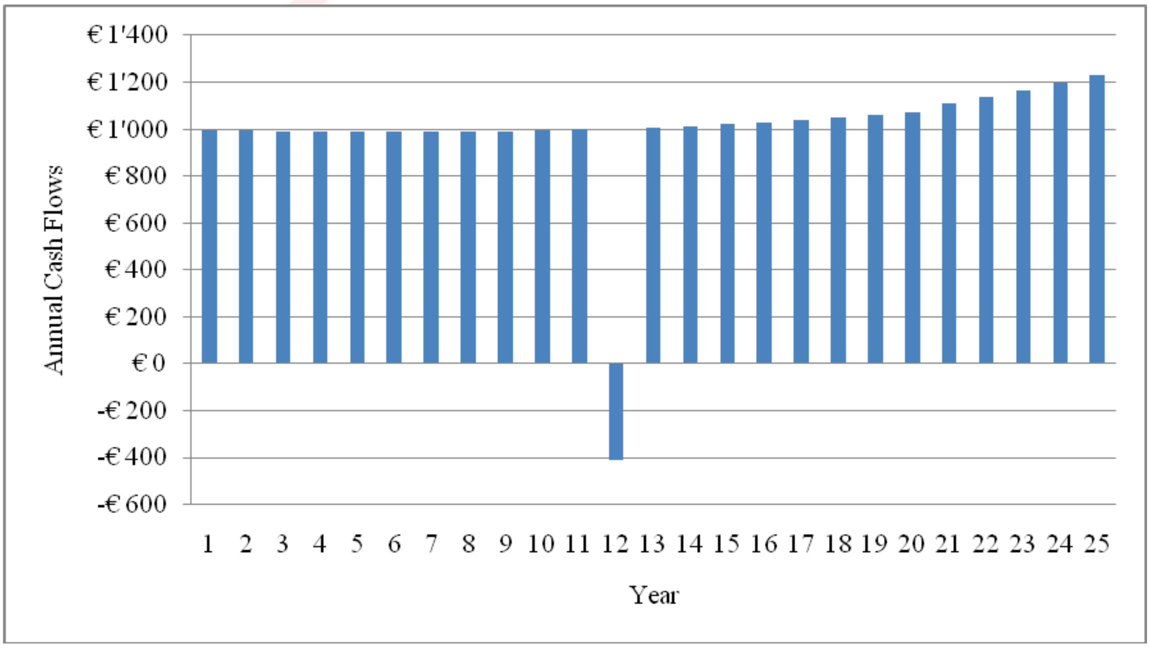
1. Year of installation;
2. Interest rate applied;
3. Electricity and gas price inflation.

Table 5 – Net present value comparison

Basic Scenario

	Year of installation				
	I quad 2011	II quad 2011	III quad 2011	2012	2013
Solar PV	13.353 €	12.843 €	12.333 €	11.266 €	10.200 €
Solar PV and Thermal	13.625 €	13.115 €	12.605 €	11.539 €	10.472 €

Chart 3 – Annual cash flows: solar photovoltaic and solar thermal installed first four months 2011



As shown on the previous table and chart, solar photovoltaic and solar thermal always have a positive cash flow except in year 12 then the inverter is replaced.
The feed-in tariff scheme, revenues from energy savings and from the energy system guarantee positive net present value.

Scenario for different interest rates applied

Year of installation	

	I 2011	II 2011	III 2011	2012	2013	Interest rate
Solar PV	12.776 €	12.266 €	11.756 €	10.689 €	9.623 €	6%
Solar PV and Thermal	12.917 €	12.407 €	11.897€	10.831 €	9.765 €	6%
Solar PV	11.590 €	11.080 €	10.570 €	9.504 €	8.437 €	7%
Solar PV and Thermal	11.462 €	10.952 €	10.442 €	9.376 €	8.309 €	7%
Solar PV	10.363 €	9.853 €	9.343 €	8.277 €	7.210 €	8%
Solar PV and Thermal	9.956 €	9.446 €	8.936 €	7.870 €	6.803 €	8%

Scenario for Electricity and gas price escalation

	Year of installation						
	I 2011	II 2011	III 2011	2012	2013	Electricity price	Gas price
Solar PV	11.532 €	11.022 €	10.512 €	9.445 €	8.379 €	0	-
Solar PV and Thermal	11.673 €	11.163 €	10.653 €	9.587 €	8.520 €	0	0
Solar PV	12.302 €	11.792 €	11.282 €	10.216 €	9.149 €	+2%	-
Solar PV and Thermal	11.497 €	10.987 €	10.477 €	9.411 €	8.344 €	+2%	+2%
Solar PV	13.322 €	12.812 €	12.302 €	11.236 €	10.169 €	+4%	-
Solar PV and Thermal	13.102 €	12.592 €	12.082 €	11.016 €	9.949 €	+4%	+4%

All projected scenarios demonstrate positive net present value, especially if the energy improvements are realized during 2011. The incentive tariff “Conto Energia” declines in steps over time every four months in 2011, and annually for 2012 and 2013.

Case studies

PACE’s spread since the Berkeley pilot started, has been notable: it was applied in several US regions like City of Berkeley, CA; Palm Desert, CA; Boulder County, CO and Babylon, NY; Sonoma launched its program in March 2010. To date 24 states have authorized PACE legislation: 20 states have passed legislation and one has incorporated it into existing law.

The program has taken a different approach in each area. Local governments that choose to offer a PACE financing program must determine the eligible energy efficiency or renewable energy technologies, identify a funding source, and develop the terms of the loan and program specifics.

Assembly Bill 811 is the environmental law that authorizes the creation of energy financing district in California within property owner could establish contractual assessment to finance energy efficiency improvements and renewable energy generation. Governor Arnold Schwarzenegger signed it into law on July 20, 2008.

The table below (Table 5) shows states that have authorized PACE: 24 States authorized PACE and Washington DC (24 states have passed legislation and Hawaii permitted it based on existing law).

Tab. 3 States that have authorized PACE program

2008	2009	2010
California	Illinois	Florida
Colorado	Louisiana	Georgia
	Hawaii	Maine
	Maryland	Minnesota
	New Mexico	Washington DC
	New York	New Hampshire
	Nevada	Michigan
	North Carolina	Missouri
	Ohio	
	Oklahoma	
	Oregon	
	Texas	
	Vermont	
	Virginia	
	Wisconsin	

Source: Database of States Incentives for Renewable and Efficiency, update January 2011

BERKELEY FIRST, Berkeley – California

The Berkeley City Council approved the formation of special tax district based on Mello Roos Community Facilities District Act of 1982. The Act allows counties and cities to establish a special tax district for the purpose of financing public facilities and services.

Berkeley FIRST - Financing Initiative for Renewable and Solar Technology, was launched in November 2008 and initially included 38 residential projects with an average project value of $ 28,000. One million dollars have been committed through micro bonds which support each solar photovoltaic project[xiii]. Interest rate applied is a comparison between interest rate equal to 3.25% above the 10-year U.S. Treasury Note or 6.75% whichever is greater, in addition to about 1% for administrative fees. Financing comes from by Renewable Funding LLC which buys, aggregates and resells the micro bonds on the market, it is under contract with the City of Berkeley as a third party. Renewable Funding also oversees the application process.

ENERGY INDIPENDENCE PROGRAM, Palm Desert – California

The Energy Independence Program (EIP) provides for the City of Palm Desert to make loans to property owners to finance the installation of distributed generation renewable energy sources or energy efficiency improvements. The City Council adopted Resolution No. 08-75 declaring its intent to establish the EIP pursuant to AB 811[xiv].

The Office of Energy Management (OEM) administers the program: $ 7.5 million have been committed in the first two phases for 206 projects in energy efficiency such as air conditioning, pool pumps, roof insulation, windows and solar, with an average project value of $ 36,000. The interest rate applied has been 7% for up to 20 years.

Funding comes from city's general fund for the first phase and from city's Redevelopment Agency for the second phase. On February 2010 City of Palm desert has announced $ 6 million in new funding: half will be dedicated to loans for energy efficiency improvements with the other half reserved for loans for solar projects.

CLIMATESMART LOAN PROGRAM, Boulder County – Colorado

In 2008, Boulder County staff worked with Representative Alice Madden, the Governor's Energy Office, Environment Colorado, and others to ensure the passage of HB 08-1350, which created the necessary state-level authority to run a local financing program for supporting energy efficiency and renewable energy measures. In November of 2008 Boulder County approved Ballot Measure 1A, which permits the county to sell up to $40 million in bonds to fund the ClimateSmart Loan Program[xv].

After the first phase $ 7.5 million have been committed for 393 projects with an average project value $ 19,000. Two types of bond have been issued: tax-exempt bonds for homeowners qualify as for "income qualified" fund fixed limit up to 115% of area median income and taxable bonds which have no income restriction. The Board of Commissioners set "not-to-exceed" interest rates of 6.75% for income-qualified loans and 8.75% for open loans; the real interest rates applied were 5.2% for income-qualified loans and 6.68% for open loans.

LONG ISLAND GREEN HOMES PROGRAMS, Babylon – New York

In 2006 Babylon adopted green building code requiring that all new construction meet ENERGY STAR standards and LEED standards for commercial and industrial buildings over 4,000 square feet. The State established a reserve fund for waste facility, for implementing PACE programs the town expanded the definition of solid waste to include energy waste in the form of CO_2. Two Million dollars from the solid waste reserve fund was allocated to revolving fund to finance the Long Island Green Homes program.
In Babylon's case $ 1.2 million has been committed for 169 projects in energy efficiency and solar with an average project value of $ 7,100. The interest rate is only 3% for administrative cost; assessment tax already exists for solid waste which is added to energy assessment.

The table below (Tab.4) shows the case studies comparison.

	Program launched	Source of capital	Financing mechanism	Collection mechanism	Eligible measure	Result as of august 2009

BERKELEY	Nov 2008	Micro bond sold to financial partner	Special tax	Property tax bill	Solar PV	38 projects $28,000 ave/per $1M committed
PALM DESERT	October 2008	City's general fund; Redevelopment Agency Bond; financing partner	Assessment	Property tax bill	Energy efficiency, solar thermal, solar PV	206 projects $36,000 ave/per $7,5M committed
BOULDER COUNTY	April 2009	Country issues bonds	Assessment	Property tax bill	Energy efficiency and renewables	393 projects $19,000 ave/per $7,5M committed
BABYLON	August 2009	Municipal solid waste revolving fund	Assessment	Separate bill	Energy efficiency, solar thermal, solar PV	169 projects $7,100 ave/per $1,2M committed

Historically, much of the attention on PACE focused on its applicability to residential properties, currently more attention has shifted to the commercial building market: there are four commercial PACE programs in operation and nine in design, many of which are expected to launch in 2011. To date active programs have approved $ 9.69 million of financing for 71 projects (Table 5)[xvi].

Table 5 – Summary of approved commercial PACE projects

Approved projects	Total approved funding	Average project size	Range of project size
71	$ 9.69 million	$ 138 K	$ 2 K - $ 2.3 M

The Federal Government and Department of Energy are allocating funds for supporting these programs: a considerable fraction of "American Recovery and Reinvestment Act" funds and "Energy Efficiency and Block Grant" funding has been committed for PACE programs; also the White House's "Recovery Through Retrofit" encouraged DOE to support pilot programs. Under the State Energy Program, DOE has received approximately $80 million of applications for PACE-type programs to provide upfront capital, out of nearly $3.1 billion in total funding available[xvii].

The first implementation of these programs has generated a debate in United States concerning the constitutionality of PACE programs and the special assessment as first lien mortgage. In June of 2009, the Federal Housing Finance Agency (FHFA) - the federal government agency that regulates Fannie Mae, Freddie Mac and the Federal Home Loan Banks - wrote a letter expressing concern that PACE programs could put owners and lenders at risk of fraud, property loss and also they offered resistance to having PACE be a senior lien since it would be a major alteration of traditional mortgage lending practice.
Important challenges for the future will be to design new best practices and guidelines for standardizing steps and the mechanism. DOE and White House are working to evaluate the efficacy of these programs.

Conclusion

Renewable energy sources will have to play a central role in moving the world into a more secure, reliable and sustainable energy path. The potential is large, but how quickly their contribution to meeting the world's energy needs can increase hinges critically on the strength of government support to make renewable cost-competitive with other energy sources and technologies, and to stimulate technological advanced.[xviii]

In the recent years, Italy started a devolution process in key sectors: energy legislative power is divided between the Ministry of Environment, Land and Sea, responsible for overall climate policies coordination; the Ministry of Economic Development, responsible for national energy policy, at regional level PER (Regional Energy Planning) represent the main tool for establishing guidelines and to step forward energy initiatives[xix].

PACE programs are a powerful policy for regional governments for increasing the accessibility and affordability of energy saving measures.

The economic benefits of energy cost saving is distributed over time but upfront cost is required to begin those improvements. This model corrects this disconnection and allows the costs of the clean energy installation to be distributed over time just the benefits are[xx].

The implementation of this model will enable several benefits in terms of:

- Promoting energy efficiency, energy consumption reduction and bill saving;
- Reduction in greenhouse emissions in regard climate change;
- Achieving national energy policy goals towards energy independence;
- Green job creation, as well as local economies growth.

Local government are called to play a key role to improve supply security in the electricity sector, the Italian energy position remains vulnerable in several regards and energy security is major concern: understanding the benefits of clean energy retrofit and how to get the work done, is the way to meet these needs and transform them in national objectives.

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[i] Source: Inventario annuale delle emissioni di gas serra su scala regionale, "Le emissioni di anidride carbonica dal sistema energetico". Rapporto 2010, Erika Mancuso – ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile).

[ii] "20-20-20 plan": 20% reduction in greenhouse gas emissions, a 20% improvement in energy efficiency, and a 20% share for renewables in the EU energy mix.

[iii] The EU Emissions Trading Scheme covers the following sectors and installations: Energies Activities, Ferrous metals production, Cement and Lime, Ceramics, Bricks, Glass, Pulp and Paper.

[iv] IEA "Energy Policies for IEA Country", 2009

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v "Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency", William H. Golove and Joseph H. Et LBNL, 1996

[vi] Guide to Energy Efficiency & Renewable Energy Financing Districts – for local governments, September 2009 (REAL, renewable and appropriate energy laboratory by Merrian C. Fuller, Cathy Kunkel, Daniel Kammen).

[vii] SIR= [Estimated savings over the life of the assessment, discounted back to present value using an appropriate discount rate] divided by [Amount financed trough PACE assessment]

[viii] "Policy Framework for PACE Financing Programs", October 2009 - White house. "Guidelines for Pilot PACE Financing Programs", DOE Washington DC, May 2010.

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[x] "Municipal Financing for Energy efficiency and Solar power" by Merrian C. Fuller, Stephen Compagni Portis, Daniel Kammen.

[xi] ISTAT is the National Statistical System.

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[xiii] The pilot program will provide funding only for solar photovoltaic systems.

[xiv] Staff Report, City of Palm Desert, August 2008.

[xv] Report CliamteSmart Loan Program Overview.

[xvi] Policy brief "Property Assessed Clean Energy PACE financing: update on commercial programs", Lawrence Berkeley National Laboratory, March 2011.

[xvii] Recovery Through Retrofit, October 2009, Middle Class Task Force – Council on Environmental Quality.

[xviii] Source: World Energy Outlook 2010, OECD/IEA.

[xix] Italy is organized in 20 regions.

[xx] "The constitutionality of Property Assessed Clean Energy Programs under Federal California Law". Sanjay Ranchod, Jill E.C. Yung, Gordon E. Hart. White paper - May 2010.

Renewable energy: the Indian perspective

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Renewable energy: the Indian perspective

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Abstract:

Currently, India is the world's 11th largest economy which, according to projections, is poised to become the 2nd largest by the year 2050. Since the economic liberalization, initiated in the early nineties, the country has been growing at an average growth rate of about 8%. And this growth story is likely to continue in the foreseeable future. Needless to say, this quest for economic upsurge would require an enormous amount of energy to be spent. The demand for primary energy in India is expected to grow at close to 5% for the next few decades.

For a country of India's size and population, the primary energy demand cannot be met with one or two sources of energy only. On the fossils front our country's petroleum resources are far inadequate and the Indian coal is of an inferior quality only. Thus we are largely dependent on imports for conventional sources of energy which are fraught with geopolitical uncertainties. Also, in recent times the debate on greenhouse gas emission driven climate change has forced us to rethink. The National Action Plan on Climate Change was launched by the Prime Minister Mr. Manmohan Singh on June 30, 2008. To quote him "we must pioneer a graduated shift from economic activity based on fossil fuels to one based on non-fossil fuels and from reliance on non-renewable and depleting sources of energy to renewable sources of energy."

Renewable energy forms an integral and very important part of the national energy paradigm and is being earnestly pursued. India is a sun drenched country with most parts receiving 4-7 kWh per m^2 per day. Harnessing solar energy is our top priority. Besides solar, the selected pockets in the country, especially along the coast, is well endowed with wind energy sources. The country has made decent progress in developing hydropower with untapped potential still existing. Biomass constitutes another important renewable energy source in India that can be crucial for rural economy. This paper presents a status review of renewable energy sources and their harnessing in India.

Introduction

India is the world's second most populous country. Currently, it is the world's 11^{th} largest economy, expected to be the second largest by 2050. The country aims to achieve an average growth rate of 9% in the short term [1]. For this security of energy supply is a key requirement. Availability of affordable energy is critical for our growth, according to the Planning Commission [1]. While contributing about 2.5% of annual global energy production the country accounts for about 3.5% of annual global energy consumption. Thus we are net importers of energy. But it is worthwhile to mention here that the per capita energy consumption in India is one of the lowest in the world. To make the matters worse, in terms of purchasing power parity, power tariffs in India are among the highest in the world [2]. The requirement of commercial primary energy is estimated to be 1351–1702 MToE in 2030 which is two to three times the energy demand in 2007 [2]. 30 – 60% of this requirement is projected to be met through imports. Further, the Planning Commission emphasizes the need for environmental protection for sustainable inclusive growth. In this context the green house gas (GHG) emission induced climate change is one of the critical concerns. India accounts for only about 4% of global GHG emission and we are justified in our claim to 'equal per capita entitlements of global environmental resources to all countries' [3]. Still, we are consciously aware of our responsibility as a nation and strive to reduce the emission intensity of GHGs [1]. The National Action Plan on Climate Change stipulated a minimum of 5% of total power purchased by the distributing agencies to be renewable derived in the year 2010. Further, this amount is to increase by 1% every year [4]. Harnessing of renewable energy sources is not only important but inevitable.

Ministry of New and Renewable Energy (MNRE), Govt. of India is apex body coordinating the development of renewable energy sources. Projections made in the Integrated Energy Policy Report (IEPR) reveal that to achieve its development goals, the country would need to rely increasingly on imported oil, gas and coal in the medium term (2032) [2]. But, this in no way undermines the significance of renewable energy in fulfilling the total energy demand which would be in excess of what could be met with fossils alone. Thus, the impetus of renewable energy programme in India is irrespective of whether it replaces fossils or not [5]. IEPR stresses the "the need to maximally develop domestic supply options as well as the need to diversify energy sources [2]. And, from being the marginal source in the short and medium term, renewable energy is likely to take centrestage in the long term. Further, development and use of renewable energy sources often have very encouraging social dimensions. The approach for deployment of new and renewable energy systems/devices during the 10th Plan and before focused on a mix of subsidy, fiscal incentives, preferential tariffs, market mechanism and affirmative action by way of legislation and policies [5]. In case of subsidies the MNRE envisages their continuance in the short and medium term to support the growth of these nascent industries, and then slowly to taper them off. However, there is a growing consensus among policymakers that these subsidies should be linked to desired outcome [5]. Further, the subsidy is proposed to be sourced through cess on non-renewables [2]. In the short term (11^{th} five year plan) the MNRE plans for the development of the renewable energy sector through five focussed programmes which are

- Grid-Interactive and Distributed Renewable Power
- Renewable Energy for Rural Applications

- Renewable Energy for Urban, Industrial & Commercial Applications
- Research, Design & Development for New & Renewable Energy
- Supporting Programmes

The ministry aimed for 14500 MW installed capacity addition in grid interactive and distributed renewable power during the 11th five year plan (2007-2012) which is about 20% of the total capacity addition envisaged. The estimated investment was Rs. 60000 Crore. Of this, a subsidy to the tune of Rs. 3925 Crore was to be extended by the Govt. For rural applications, especially in remote areas still lacking effective access to commercial energy, SPV based lighting, solar thermal, and household or community level biomass energy systems are the priority areas for renewable energy with Rs. 2250 Crore estimated budgetary support from the Govt. This paper presents an overview of the development and future directions for different renewable energy sources in India.

Hydropower

It is seen that even if India succeeds in exploiting its full hydro potential of 150,000 MW, the contribution of hydro to the energy mix would be around 5-6% [2]. Though its contribution to energy requirement is small, hydro electricity's flexibility and suitability as a peaking power make it valuable. Moreover, hydro development especially storage schemes are critical for India as India's per capita water storage is the lowest among all its comparators. Creating such storages is critical to India's water security, flood control and drought control. Capital costs for small hydro projects in India vary between Rs. 5-6 crore/MW with generated electricity costing between Rs. 1.5-2.5/kWh [2]. For small hydro projects subsidy is sought to be given only in cases where the installed equipment conforms to International Electromechanical Commission (IEC) standards. 1400 MW of additional installed capacity in small hydropower projects is targeted for the 11th five year plan increasing the total installed capacity to about 3000 MW. Facilities with up to 5 kW capacity are termed as watermills. These are eligible for Central Financial assistance in the form of capital subsidy; Rs. 35000 per watermill for mechanical output devices and Rs. 110000 per watermill for electrical output types. For micro hydel projects up to 100 kW capacity capital subsidy varies from Rs. 40000-100000 per kW based on location and priorities [6]. In addition financial assistance is also extended for exploring and identifying potential sites. Large hydropower projects have serious environmental implications that include loss of pristine forests and precious biodiversity. They also have high social costs as vulnerable communities are displaced.

Solar energy

India is a sun drenched country with most parts receiving 4-7 kWh per m^2 per day [7]. The present unit cost of Solar Photovoltaics (SPV) power is around Rs.20/kWh (without battery back-up) and Rs.30/kWh (with battery back-up). However, it has immense long term potential. Jawaharlal Nehru National Solar Mission (JNNSM) is the flagship program of Govt. of India for promoting and developing solar energy in the country. It will adopt a three phase approach; 1st phase up to 2012-13, 2nd phase 2013-17, and the 3rd phase spanning 2017-22 [7]. The total target is to deploy 20000 MW of solar power by 2022. Immediate target is installing 1,000 MW grid connected (33 KV and above) solar power plants by 2013 which can increase up to 3000-10000 MW by 2017. Based on the lessons from the first two phases the ambitious target would be to achieve 20000 MW by 2022. The other immediate objectives include 100 MW of roof top and small solar plants connected to LT/11 KV grid, 200 MW capacity equivalent of off grid solar applications and 7 million sq. meters of solar thermal collector area during the first phase till March, 2013 [8]. In the case of solar thermal collectors the targets for the 2^{nd} and 3^{rd} phases would be 15 million sq. meters and 20 million sq. meters, respectively [7]. It also targets to bring down the cost of solar power to achieve grid parity by 2022 and parity with coal based thermal power by 2030 [7]. Budgetary provision of Rs.4337 crore is earmarked for these activities. Benchmark cost of solar PV systems with and without battery storage has been worked out as Rs. 300/W_P and Rs. 210/W_P, respectively. Of this, Rs. 70-90 would be made available by the Govt. as capital subsidy and the rest through interest subsidy in the form of soft loans at 5% per annum interest rate. This ambitious mission amalgamates the plethora of schemes and programmes which were earlier in place. A list of these schemes is provided in Table 1. One of the important aspect is the fact that the mission is giving due recognition to off grid and decentralized solar application. Rooftop PV & Small Solar Power Generation Programme falls under this initiative which supports SPV installations up to 100_P per site [8].

Table 1. Miscellaneous Govt. schemes in place from time to time for the promotion of solar energy

Scheme	Highlight
Accelerated development and deployment of Solar Water Heating Systems in Domestic, industrial and commercial sectors	Total budget outlay Rs. 15 crore.
Promotion of Solar Thermal Systems for air heating/Steam generating applications, Solar buildings and Akshay Urja Shops	Total budget outlay Rs. 10 crore.
Incentives to Banks/ Micro Financing Institutions to support installation of Solar Home Lighting & other small Solar Systems through loans in the country	Total budget outlay Rs. 224 crore.
Solar Photovoltaic (SPV) Programme	Total budget outlay Rs. 64.8 crore.
Solar Thermal Energy Demonstration Programme	Total budget outlay Rs. 4.43 crore.
Solar Lantern Programme	Total budget outlay Rs. 224 crore.

Solar thermal is lot more promising. There is a thinking in the government quarters to make it mandatory for factories and large buildings to have solar water heaters (SWH). In 2008, the Indian share of global SWH installed capacity was only 1.2% [9] at about 2.6 million m^2 collector area, which is insignificant. This is expected to grow to about 18 million m^2 by 2022. The JNNSM target is 20 million m^2. Needless to say, there remains a large untapped potential. Presently, the Govt. efforts in this direction are in the form of MNRE programme of Accelerated Development and Deployment of solar water heating system in Domestic, Industrial & commercial Sectors [10]. The target is to install 1.4 million m^2 of collector area by the end of March 2011. Incentives may be provided in various forms like property tax rebate and, concessional electricity connections. Under the JNNSM the offgrid solar thermal projects are entitled for capital subsidy of Rs. 2000-6000 per m^2 of collector area depending upon the type of project and would be limited to 30% of benchmark capital cost. In addition, interest subsidy is also available as in the case of solar PV. In the urban areas the Govt. has an ambitious plan of establishing 60 solar cities, with a population between 0.5 to 5 million, by the end of the 11th five year plan by enabling the urban local bodies. The target is to reduce the total demand of conventional energy by a minimum of 10% [11]. Budget outlay of Rs. 50 lakh per city is earmarked for this purpose.

Wind energy

At the end of 2008 India ranked 5th in terms of total installed wind energy capacity with 9645 MW of installed wind power capacity [12]. The total wind energy potential in the country is conservatively estimated at 48 GW by the Govt. However, the Indian Wind Turbine Manufacturers Association (IWTMA) estimates the total Indian wind energy potential as 65-70 GW citing advancements in wind turbine technology. So this sector is poised for impressive growth at least in the short and midterm. In India, the wind energy projects typically incur capital expenditures ranging between Rs. 4-5 crore/MW. The cost of generated electricity lies between Rs. 2-3/kWh [2]. The average capacity of wind turbines in India in 2008 was 1 MW whereas the largest turbines available for commercial use are up to 6 MW capacity [12]. The average capacity is projected to increase to 2 MW by 2030. Similarly, the average capacity factor for wind turbines in India is 20.5% at present. This is expected to improve to 25% by 2021 and 27.5% by 2026 owing to technological advancements [12]. The 11th plan targeted additional installed capacity of 10500 MW of grid integrated and distributed power from wind [5]. A limited number of demonstration wind power projects are also to be subsidised in states with sizable potential but negligible commercial activity as yet. Elaborate exploratory work has been undertaken to identify potential wind sites using satellite based remote sensing and Geographical Information System. The data is compiled and made available for decision making by the Centre for Wind Energy Technology (CWET), the apex R&D organization under the MNRE, Govt. of India. India has identified 233 potential sites for wind power projects with wind power density more than 200 W/m^2 at 50 m height. Financial assistance and incentives are generation based; Rs. 0.50 per unit of electricity fed into the grid for a period not less than 4 years and a maximum period of 10 years in parallel with accelerated depreciation on a mutually exclusive manner, with a cap of Rs. 62 lakhs per MW [13]. In addition the Ministry of Environment and Forests has made special provision to allow some of the forest land in specified areas to be used for wind energy projects with lease up to a period of 30 years [12]. Like many other renewable energy projects, wind energy projects also qualified for carbon credits under the Clean Development Mechanism of the Kyoto Protocol. As of August 2009, as many as 301 wind energy projects amounting to 5.7 GW of installed capacity were registered with CDM executive board [12]. However, the first commitment period under the Kyoto protocol drawing to its end in 2012 and the inconclusive negotiations at Copenhagen has put a question mark over the future of the carbon market. Besides installation of wind turbines the country has also recorded impressive growth in the manufacturing and development of wind turbines as well. Presently, wind turbines worth 3000-3500 MW cumulative generation capacity are being manufactured in India by a wide spectrum wholly indigenous companies as well as joint ventures [12]. These are made both for the domestic market and export.

Biomass

Biomass has always been an important energy source in India. About 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs [14]. Availability of biomass in India is estimated at about 540 million tonnes per year [15]. A considerable part of this amount is utilized in an unorganized and inefficient manner for various purposes including animal feed and rural energy needs. But it still leaves about 150 million tonnes of biomass for possible energy applications. About 16000 MW of grid quality power can be generated using presently available technologies [15]. Depending on the choice of technology and available raw material, electricity generation from biomass requires about Rs. 2-4 crore/MW of capital expenditure providing electricity at Rs. 2.5-3.5/kWh. 2100 MW of installed capacity addition is planned for power generation from biomass in the 11th plan. An UNDP assisted project "Removal of Barriers to Biomass Power Generation in India" is currently underway to harness the biomass energy potential in the power sector [16] with an total outlay of USD 10.89 million. Industries are encouraged to set up biomass based cogeneration facilities for captive power generation. Bagasse is the most prominent of the biomass resources that is currently being used in cogeneration facilities. India is the world's second biggest producer of sugarcane and produced around 45 million tons of dry bagasse annually [17]. By conservative estimates, if bagasse is put to its full potential of cogeneration the country could generate an additional 6000-7000 MW of power. Non bagasse biomass based cogeneration is also promoted through the programme on "Biomass Co-generation (non-bagasse) in Industry" [18]. Govt. Provides capital subsidy to the extent of Rs. 20 lakh/MW upto a maximum of 5 MW ceiling. For a project to qualify for such assistance it should not use more than 25% conventional fuel. Some important biomass alternatives for such applications are rice husk, cane trash, cotton stalk, mustard husk, groundnut shells, coconut shells, poultry litter etc.

Biofuels are much talked about these days. National Policy on Biofuels was announced by Indian Govt. in July 2008 which contemplates 20% blending of biofuels – both ethanol (with gasoline) and biodiesel (with diesel) – by 2017. More importantly, the policy stresses on the growing of biomass for biofuel production on non agricultural land to avoid competition with food production. However, such lofty idealistic targets often contradict hard reality. For 20% blending in 2017–18, we would require about 4 million tonnes of fuel ethanol and 20 million tonnes of biodiesel. For this the country requires 1.07 million hectare land exclusively for sugarcane meant for ethanol. Similarly, to meet the biodiesel target nearly 30 million hectares of cultivable wasteland would be needed which far exceeds the estimated availability. These are certainly crucial and contentious issues. In recent years biodiesel has got a lot of attention from policy makers as well as scientists in India. On the policy front, mandatory blending with diesel along with tax exemptions are envisaged [2]. To help promote the cultivation of plants like Jatropha and Karanj, economic incentives to the farmers are also offered. Similar policy interventions are also in place for bioethanol. Similarly, involvement of village level cooperatives in tree plantation for fuelwood is encouraged. One such successful venture is National Tree Growers Cooperatives Federation [19].

One of the policy thrust areas is the promotion of community level biogas plants run on cattle dung for which the Government provides many economic incentives. According to 2001 census, 625 million people in India did not have access to modern cooking fuel. It is estimated that 30 to 40 percent of rural cooking energy needs can be met by bio-gas through proper utilization of available animal dung [2]. National Biogas and Manure Management Programme (NBMMP) during the eleventh five year plan is the effort in this direction. The target is to promote the installation of 6.47 lakh family size biogas plants by the end of the plan period [20]. Under the scheme a family size biogas unit is eligible for financial assistance to the tune of Rs. 8000-12000. Utilization of small biogas utilities for power generation, in small capacity range of 3-250 kW, is promoted through the Biogas based Power Generation Programme. Capital subsidy up to 40% of the project cost is made available [21]. Another biomass to energy technology that can be used at household or community level for rural applications is the gasification. Gasifiers with output ratings as low as 3kWe are available in the market. Specific fuel consumption ranges between 1-1.5 kg/kWh. Besides woody biomass the gasifiers have been designed to operate on substances like bamboo, maize cobs, coconut shells, weeds like lantana camara, threshed mustard stalks, cotton stalks, maize stalks, groundnut shells and sun-flower husks, etc. [15]. The Indian Govt. promotes energy generation through the biomass gasification in the form of the schemes: Biomass Gasifier based Distributed / Off-grid power programme for Rural Areas, Biomass Gasifier based Grid Connected Power Programme, and Biomass gasifier based programmes in Rice Mills. Financial assistance is provided as post commissioning capital subsidy [22]. In addition biomass gasification for captive power production in industry is also encouraged with a maximum capacity ceiling of 5 MW for being eligible for capital subsidy. Energy generation from industrial wastes is another priority area where capital subsidy ranging between Rs. 0.2 crore to 1.0 crore per MW is made available [23]. There is a large untapped potential for energy generation from municipal solid wastes as well as other solid wastes from urban centres.

Other renewable energy sources

Off late MNRE has also concentrated on other renewable sources of energy. Among the chemical sources of energy hydrogen energy along with its utilization through fuel cells is being promoted. A National Hydrogen Energy Board was set up in 2003 as the apex policy making body under the MNRE. It drew the National Hydrogen Energy Roadmap [24]. The roadmap has identified two major initiatives namely Green Initiative for Future Transport (GIFT) and Green Initiative for Power Generation (GIP). The first initiative aims to bring one million hydrogen fuelled vehicles on Indian roads by 2020. The second initiative envisages 1000 MW of hydrogen based power generation by 2020. The establishment of National Hydrogen Energy and Fuel Cell Centre is also proposed [25]. Harnessing tidal energy is still in its infancy in the country whereas an estimation of the overall potential is being worked out.

Conclusion

As a nation with population of more than one billion on a high growth trajectory, India's primary energy demand is to grow tremendously in the medium as well as long term. This energy demand cannot be met with a single source of energy. Thus, without downgrading the importance of conventional exhaustible sources of energy, India is earnestly striving to harness its renewable energy sources. In this context it is well endowed with solar energy and biomass with reasonably good wind energy and hydro energy potentials. Economically, the renewable energy projects often find themselves at a position of disadvantage in comparison to conventional energy projects. Govt. of India is making efforts in this direction on the policy and administrative fronts and trying to ensure that these new ventures are well nurtured in their nascent years.

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SUSTAINABLE SPATIAL DEVELOPMENT IN THE DANUBE DELTA BIOSPHERE RESERVE: PLANNING, ARCHITECTURE, SEISMIC, CONSTRUCTION AND ENERGY-RELATED CRITERIA

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Topic: Environmental Sustainability & Environmental Management: Land Use & Misuse

Sustainable spatial development in the Danube Delta Biosphere Reserve: planning, architecture, seismic, construction and energy-related criteria

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Abstract. The Danube Delta Biosphere Reserve represents a complex of ecosystems embedding a biome that had been included on UNESCO World Heritage list due to its global environmental importance. The outstanding natural diversity, including ecosystems, habitats and species situated at the top of European and International conservation lists, is mixed with an equally rich and important cultural (ethnic and religious) diversity of the human communities inhabiting the area. According to the guidelines of the Man and the Biosphere Programme of UNESCO, the biosphere reserves including human settlements should be managed such that they could constitute an example for what sustainable development means. Starting from the spatial dimension added to the traditional socioeconomic, ecological and cultural pillars of sustainable development, the paper examines planning, architecture, seismic, construction and energy-related criteria that could substantiate a sustainable development model applicable to the Danube Delta, and counter the effects of clime change in the area. The results suggest that the traditional practices of the inhabitants could offer sustainable solutions and help preserving the natural and cultural diversity of the region.

Keywords: Danube Delta, land cover, land use, cultural diversity, constructions, planning

1. Danube Delta Biosphere Reserve: Geographical, Administrative, and Ethnic Particularities

The Danube Delta is situated in the East of Romania, the last of the ten European countries crossed by the Danube (Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, Moldova, Ukraine, and Romania), second longest river after the Volga. The Danube Delta marks the confluence between the river and the Black Sea (*Figure 1*), with elevations ranging from 0 to 75 m, higher in the north of the area (*Figure 2*).

From an administrative standpoint, the territory of the Danube Delta Biosphere Reserve spans, according to the classification of the Statistical Office of the European Communities (EUROSTAT), over two NUTS (Nomenclature of Territorial Units for Statistics) level 3 units (in Romania, counties), namely Constanța and Tulcea, including 4 and, respectively, 26 NUTS level 5 units (in Romania, base administrative units - cities and communes), covering a total area of 580000 hectares (*Figure 3*), making it the second largest wetland and the first Biosphere Reserve with respect to the size (Petrişor, 2007).

The territory is inhabited by a population totaling 14583 at the 2002 census, with a very high ethnic diversity, including Romanians, Lipovans (Russians), Ukrainians, Roma people, Greeks, Turks, Hungarians, Bulgarians, Germans, Armenians, and other ethnic groups - *Figure 4* (Danube Delta Biosphere Reserve Authority, 2011). If Shannon's informational entropy index is computed for the ethnic data displayed in *Figure 4*, its value is 0.5, while for the different Romanian regions of development (NUTS 2 units), the values range between 0.1 and 0.8 (Petrişor and Ianoş, 2010). The result underlines that the area is characterized by a high diversity of the human population, due to its ethnic structure.

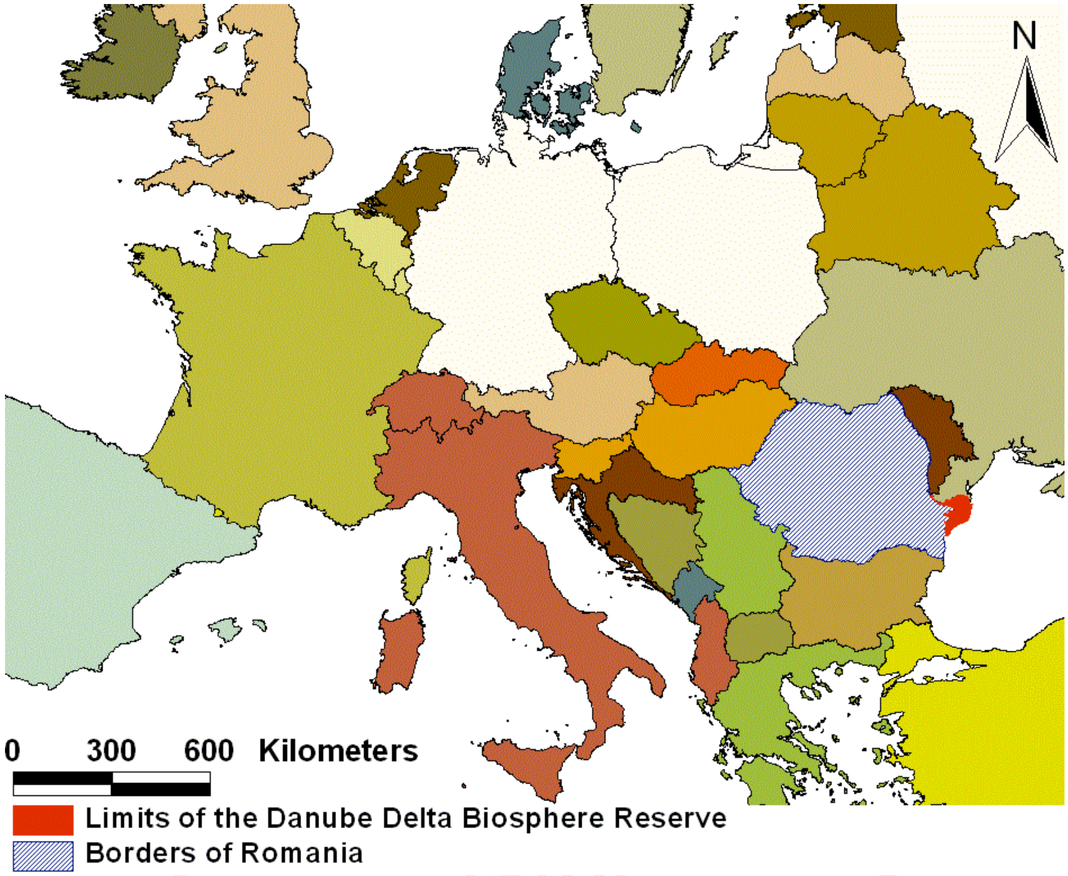

Figure 1. Indicating the geographical position of the Danube Delta Biosphere Reserve.

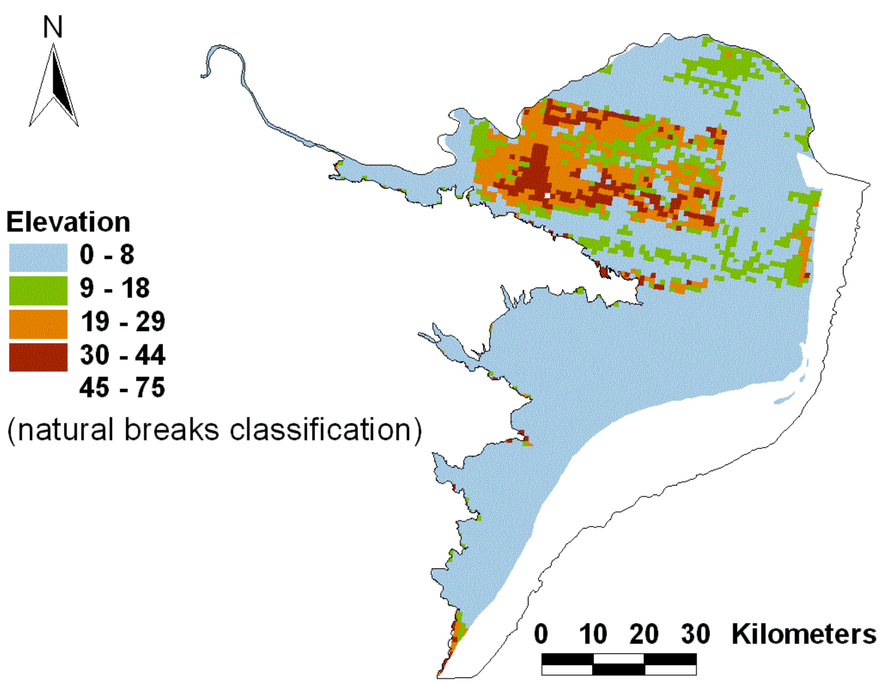

Figure 2. Indicating the elevation of the Danube Delta Biosphere Reserve.

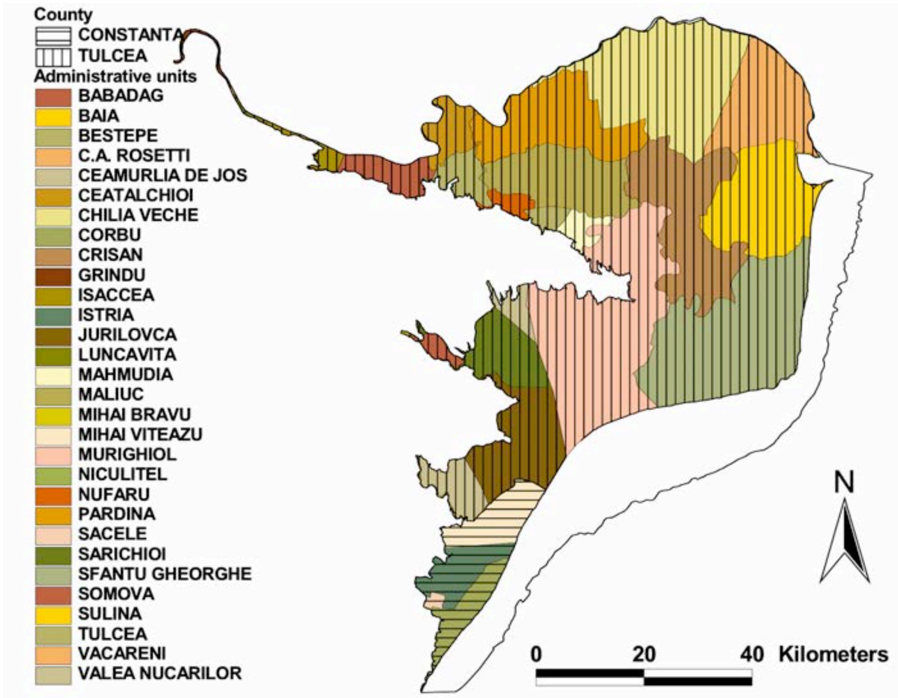

Figure 3. Displaying the territorial units in the Danube Delta Biosphere Reserve (based on NUTS Classification, Statistical Office of the European Communities, levels 3 - counties and 5 - base administrative units).

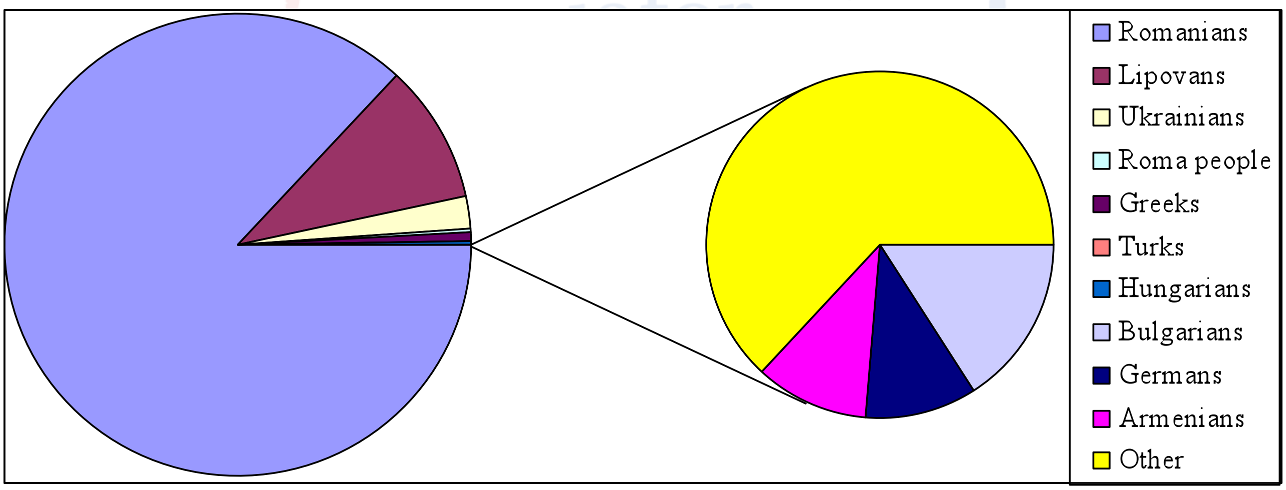

Figure 4. Showing the ethnic structure of the population of Danube Delta Biosphere Reserve (based on 2002 census data from the Administration of the reserve).

2. Danube Delta Biosphere Reserve: Ecological Characterization

At the scale of a landform unit such as the Danube Delta, the best ecological characterization is provided by its reference to major biogeographical and ecological units (*Figures 5-6*), as well as to the land cover and use (Petrişor, 2008) - *Figure 7*. Land use shows how man uses land; land cover indicates what lies on that surface, from a biophysical viewpoint (Jensen, 2000). When using the CORINE (Coordinated Information on the European Environment) data to analyze land cover and use, land cover is reflected by the first level of CORINE classification: artificial areas, agricultural regions, forests/semi-natural areas, wetlands, water), while land use is reflected more or less detailed by the last two CORINE levels which indicate the designation of each parcel based on the type of geosystem, i.e., "natural use" in natural or less anthropized systems that preserved their structure in time, and socioeconomic use for medium/strongly anthropized systems (Petrişor *et al*., 2010).

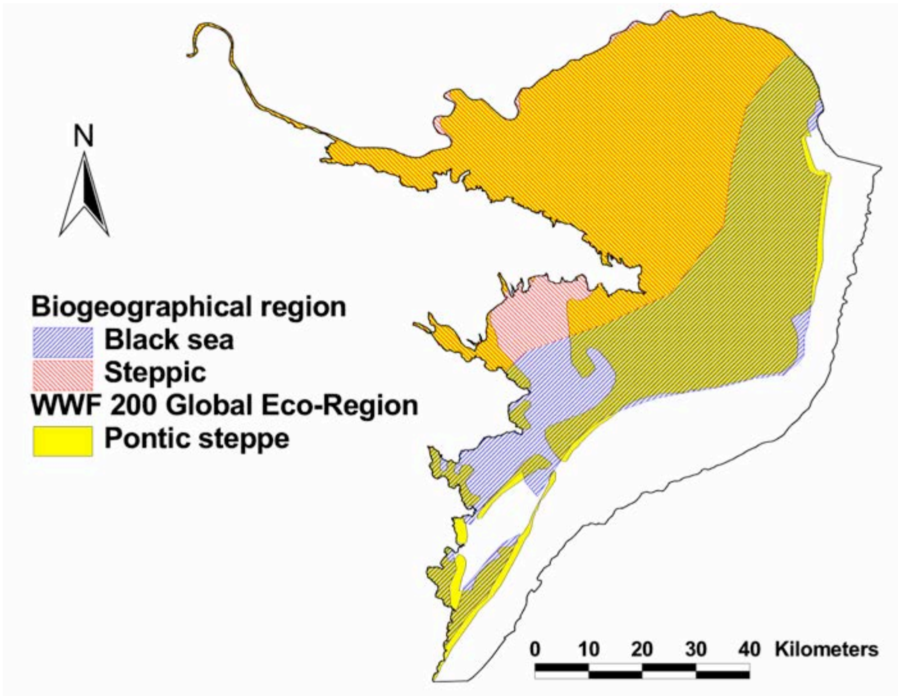

Figure 5a. Presenting the biogeographical and ecological regions in the Danube Delta Biosphere Reserve (based on 2005 data from the European Environment Agency and 2000 data from the World Wide Fund For Nature).

The situation displayed in the figures depicting land cover and use is summarized in *Table 1*. It can be seen that most land is covered by wetlands and water bodies, covering almost 80%, followed by agricultural and natural areas, each covering around 10%. When detailing the classification, inland marshes represent almost 50% of the total land, followed by coastal lagoons (15%), water bodies (10%), and non-irrigated arable land (10%).

CORINE data can be used to monitor long-term environmental changes reflected by land cover and use (Petrişor *et al*., 2010). Land cover changes tend to cover lesser areas, but have more impact, while land use changes are more frequent, but have lesser impact (Petrişor, 2009). *Figure 8* displays both 1990-2000 and 2000-2006 changes in the Danube Delta Biosphere Reserve, focusing on the area where changes exhibited a higher density. Most of these changes are due to the urbanization, but some are due to the abandon of agricultural crops and forestry practices.

In addition to these changes, provided that in a broader context the ecosystems within the area were connected to the lakes of the floodplain of Danube, their reclaiming for agriculture in the beginning of the Communist regime in Romania (the 50's) resulted into the loss of many species in the Danube Delta and a decline of the fish harvest (Brezeanu and Cioboiu, 2010). In reverse, their ecological restoration in the 90's seems to have led to a positive trend, however still slowly increasing.

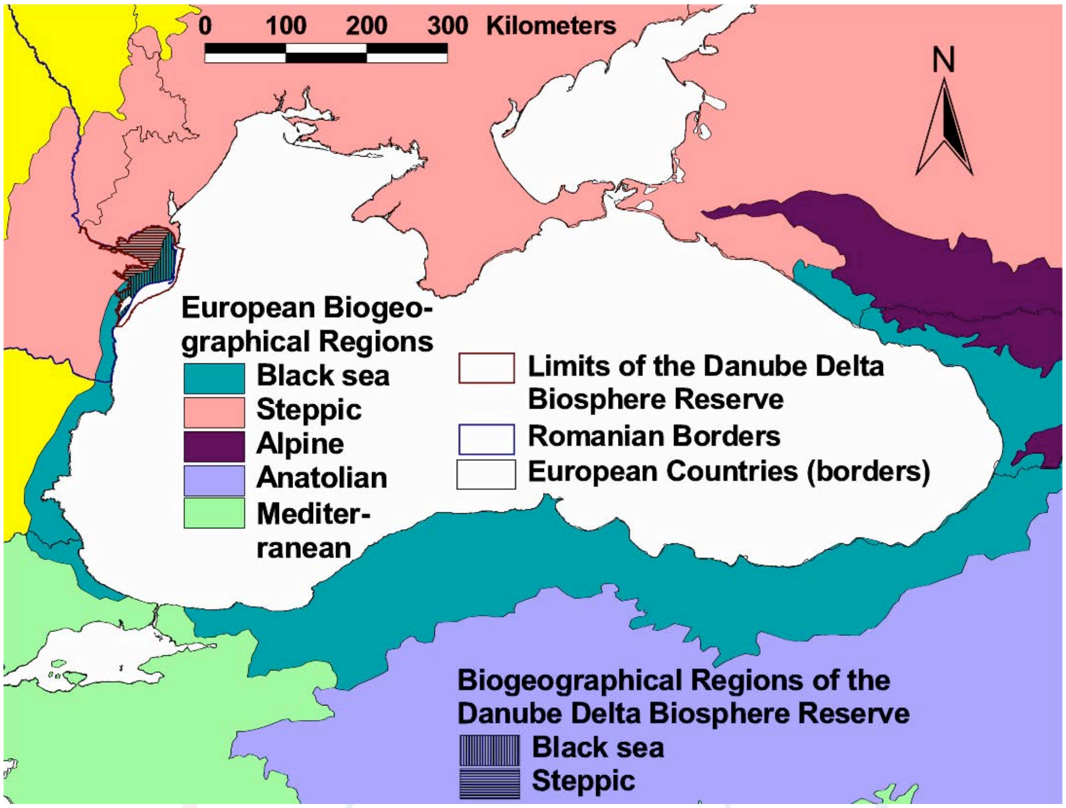

Figure 5b. Presenting the biogeographical regions in the Danube Delta Biosphere Reserve compared to their continental distribution (based on 2005 data from the European Environment Agency).

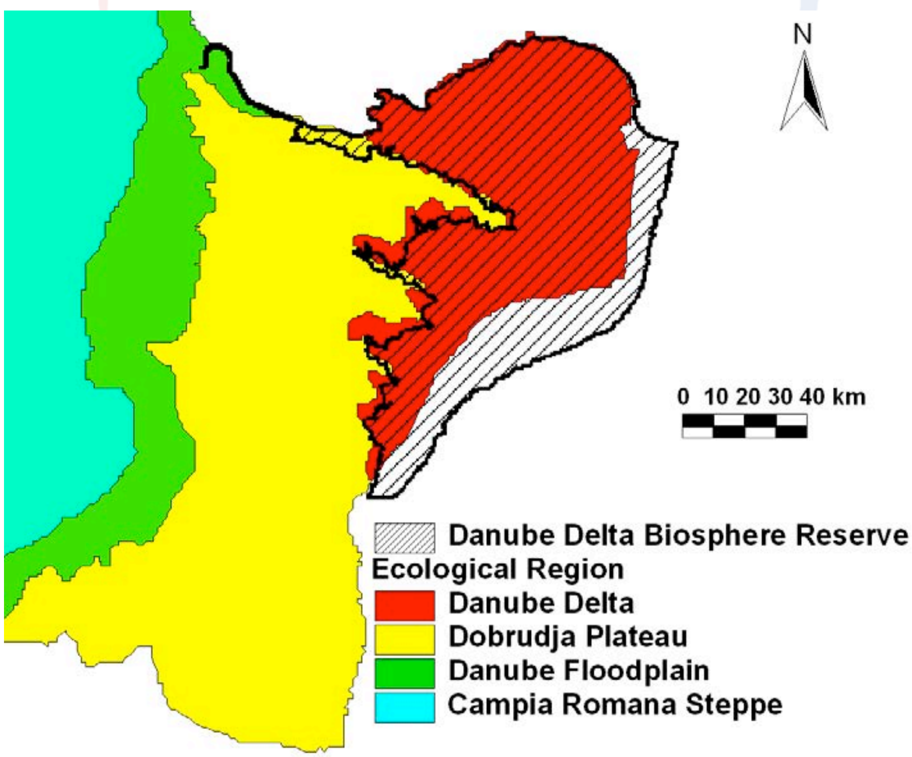

Figure 6. Showing the ecological regions in the Danube Delta Biosphere Reserve based on the Romanian classification.

In addition to land cover and use, the biological diversity of the Danube Delta Biosphere Reserve was investigated by looking at the habitats and species within the natural protected areas within. While the total area is designated as a Biosphere Reserve, several sites were included in other categories (*Figure 9*), either according to the Romanian and European Union classifications or to the categories established by the International Union for the Conservation of Nature (IUCN). The studies developed within these areas, especially the NATURA 2000 sites (SCI - Romanian acronym for Areas of Special Conservation Interest and SPA - Romanian acronym for Special Protection Areas), revealed the presence of 29 habitats, out of which 7 of communitarian interest, and 119 Red List species (*Table 2*).

Table 1. Presenting the land cover and use in Danube Delta Biosphere Reserve based on CORINE Land Cover and Use data, 2006, European Environment Agency

<table>
<tr><th>Level 1 class</th><th>Level 2 class</th><th>Level 3 class</th><th>Area (ha)</th><th>Area (%)</th></tr>
<tr><td rowspan="7">Artificial surfaces (383.24 ha, 0.91%)</td><td>Urban fabric</td><td>Discontinuous urban fabric</td><td>272.73</td><td>0.65</td></tr>
<tr><td rowspan="2">Industrial, commercial and transport units</td><td>Industrial or commercial units</td><td>43.67</td><td>0.10</td></tr>
<tr><td>Port areas</td><td>13.20</td><td>0.03</td></tr>
<tr><td rowspan="3">Mine, dump and construction sites</td><td>Mineral extraction sites</td><td>14.32</td><td>0.03</td></tr>
<tr><td>Dump sites</td><td>15.26</td><td>0.04</td></tr>
<tr><td>Construction sites</td><td>5.08</td><td>0.01</td></tr>
<tr><td>Artificial, non-agricultural vegetated areas</td><td>Sport and leisure facilities</td><td>18.99</td><td>0.05</td></tr>
<tr><td rowspan="7">Agricultural areas (4462.07 ha, 10.61%)</td><td>Arable land</td><td>Non-irrigated arable land</td><td>4170.26</td><td>9.92</td></tr>
<tr><td rowspan="2">Permanent crops</td><td>Vineyards</td><td>4.26</td><td>0.01</td></tr>
<tr><td>Fruit trees & berry plantations</td><td>3.27</td><td>0.01</td></tr>
<tr><td>Pastures</td><td>Pastures</td><td>240.96</td><td>0.57</td></tr>
<tr><td rowspan="2">Heterogeneous agricultural areas</td><td>Complex cultivation patterns</td><td>11.15</td><td>0.03</td></tr>
<tr><td>Land mainly agricultural, with significant natural vegetation</td><td>32.18</td><td>0.08</td></tr>
<tr><td rowspan="5">Forest and semi natural areas (4522.66 ha, 10.76%)</td><td>Forests</td><td>Broad-leaved forest</td><td>1858.37</td><td>4.42</td></tr>
<tr><td rowspan="2">Scrub and/or herbaceous vegetation associations</td><td>Natural grasslands</td><td>1756.83</td><td>4.18</td></tr>
<tr><td>Transitional woodland-shrub areas</td><td>368.91</td><td>0.88</td></tr>
<tr><td rowspan="2">Open spaces with little or no vegetation</td><td>Beaches, dunes, sands</td><td>535.96</td><td>1.27</td></tr>
<tr><td>Sparsely vegetated areas</td><td>2.60</td><td>0.01</td></tr>
<tr><td rowspan="2">Wetlands (20806.10 ha, 49.48%)</td><td>Inland wetlands</td><td>Inland marshes</td><td>20297.87</td><td>48.27</td></tr>
<tr><td>Maritime wetlands</td><td>Salt marshes</td><td>508.24</td><td>1.21</td></tr>
<tr><td rowspan="4">Water bodies (11872.32 ha, 28.24%)</td><td rowspan="2">Inland waters</td><td>Water courses</td><td>939.96</td><td>2.24</td></tr>
<tr><td>Water bodies</td><td>4285.06</td><td>10.19</td></tr>
<tr><td rowspan="2">Marine waters</td><td>Coastal lagoons</td><td>6228.25</td><td>14.81</td></tr>
<tr><td>Sea and ocean</td><td>419.05</td><td>1.00</td></tr>
</table>

3. Danube Delta Biosphere Reserve: Clime Change

Clime data were downloaded from the DIVA-GIS project developed by Robert Hijmans, freely available from http://www.diva-gis.org in a format readable by a Geographical Information Systems (GIS) application called DIVA-GIS. The program can be downloaded from the same webpage and used free of charge. In addition, the software is compatible with other GIS-type products (Hijmans *et al*., 2001), including ESRI ArcView 3.X used to change the spatial projection was from WGS-1984 to the Romanian National System, STEREO 1970 and clip a subset for Romania using the Geoprocessing Wizard. The actual clime data set described by Hijmans *et al.* (2005) includes two subsets, referring to temperatures and precipitations, computed for a 2.5^0 longitude × 2.5^0 latitude grid and covering the period 1950-2000; predicted climate data for 2100, described by Govindasamy *et al*. (2003), are based on $2\times CO_2$ concentration and CCM3 model, and use SSTs based on those from NCAR coupled model, Climate System Model (CSM), computed for a 2.5^0 longitude × 2.5^0 latitude grid. In addition, the differences between current and predicted values were computed. The results are displayed in *Figure 10* as maps depicting each time five classes, defined using the "natural breaks" option in ArcView, based on applying Jenk's optimization formula to minimize the variability of each category (ESRI, 1996).

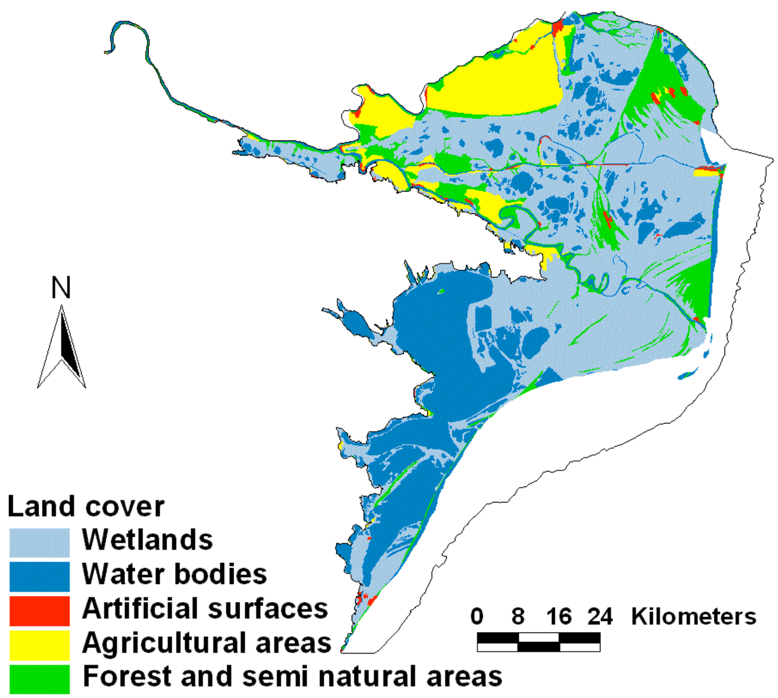

Figure 7a. Displaying land cover in the Danube Delta Biosphere Reserve (based on CORINE Land Cover and Use data, 2006, European Environment Agency, level 1).

Even though making harder a comparison between different features (*e.g*., the pattern displayed by the differences between current and predicted values of either temperature or precipitations is not obvious when examining the distribution of current and predicted values separately), the images underline some patterns. While temperatures (actual and predicted) tend to increase from the northeast to the southwest and precipitations from east to the west, the differences between current and predicted temperatures increase from south to the north, and precipitation differences show a circular pattern with the highest temperatures in the center, located in the north. These patterns do not appear to be influenced by the elevation, perhaps excepting for the differences between actual and predicted precipitations, where high differences (indicating more precipitations in the future) correspond somewhat to higher altitudes.

Table 2. Important habitats and species in the Danube Delta Biosphere Reserve, according to data from studies developed within the NATURA 2000 sites

1. Habitats (bold indicates priority habitats)	
1. Natural dystrophic lakes and ponds	
2. Pannonic sand steppes	
3. Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*	
4. Riparian mixed forests of *Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)	
5. Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)	
6. Sandbanks which are slightly covered by sea water all the time	
7. Annual vegetation of drift lines	
8. *Salicornia* and other annuals colonizing mud and sand	
9. Mediterranean salt meadows (*Juncetalia maritimi*)	
10. Pannonic salt steppes and salt marshes	
11. Embryonic shifting dunes	
12. Fixed coastal dunes with herbaceous vegetation ("grey dunes")	
13. Dunes with *Hippophaë rhamnoides*	
14. Humid dune slacks	
15. Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*	
16. Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation	
17. Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	
18. Rivers with muddy banks with *Chenopodion rubri* pp.p. and *Bidention* pp.p. vegetation	
19. Ponto-Sarmatic steppes	
20. *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	
21. Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*	
22. Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	
23. Alluvial meadows of river valleys of the *Cnidion dubii*	
24. Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)	
25. Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.	
26. Coastal lagoons	
27. *Salix alba* and *Populus alba* galleries	
28. Ponto-Sarmatic deciduous thickets	
29. Eastern white oak woods	
2. Species	
Mammals	*Mustela eversmannii, Vormela peregusna, Spermophilus citellus, Lutra lutra, Mustela lutreola*
Birds	*Accipiter brevipes, Alcedo atthis, Anser erythropus, Aquila clanga, Aquila heliaca, Aquila pomarina, Ardea purpurea, Ardeola ralloides, Aythya nyroca, Botaurus stellaris, Branta ruficollis, Burhinus oedicnemus, Buteo rufinus, Charadrius alexandrinus, Chlidonias hybridus, Ciconia ciconia, Ciconia nigra, Circaetus gallicus, Circus aeruginosus, Circus cyaneus, Circus macrourus, Circus pygargus, Coracias garrulus, Cygnus columbianus bewickii, Cygnus cygnus, Dendrocopos medius, Dendrocopos syriacus, Dryocopus martius, Egretta alba, Egretta garzetta, Emberiza hortulana, Falco cherrug, Falco columbarius, Falco naumanni, Falco peregrinus, Falco vespertinus, Gallinago media, Gavia arctica, Gavia stellata, Gelochelidon nilotica, Glareola pratincola, Haliaeetus albicilla, Hieraaetus*

	pennatus, Himantopus himantopus, Ixobrychus minutus, Lanius collurio, Lanius minor, Larus genei, Larus melanocephalus, Larus minutus, Limosa lapponica, Lullula arborea, Melanocorypha calandra, Mergus albellus, Milvus migrans, Numenius tenuirostris, Nycticorax nycticorax, Oenanthe pleschanka, Oxyura leucocephala, Pandion haliaetus, Pelecanus crispus, Pelecanus onocrotalus, Phalacrocorax pygmeus, Phalaropus lobatus, Philomachus pugnax, Picus canus, Platalea leucorodia, Plegadis falcinellus, Pluvialis apricaria, Porzana parva, Porzana porzana, Porzana pusilla, Puffinus yelkouan, Recurvirostra avosetta, Sterna albifrons, Sterna caspia, Sterna hirundo, Sterna sandvicensis, Sylvia nisoria, Xenus cinereus
Amphibians and reptiles	*Bombina bombina, Testudo graeca, Emys orbicularis, Vipera ursinii, Triturus dobrogicus*
Fish	*Gobio albipinnatus, Aspius aspius, Rhodeus sericeus amarus, Misgurnus fossilis, Sabanejewia aurata, Cobitis taenia, Gymnocephalus schraetzer, Zingel streber, Pelecus cultratus, Zingel zingel, Alosa pontica, Gobio kessleri, Gymnocephalus baloni, Alosa tanaica, Umbra krameri*
Invertebrates	*Lycaena dispar, Osmoderma eremita, Theodoxus transversalis, Ophiogomphus cecilia, Morimus funereus, Arytrura musculus, Catopta thrips, Colias myrmidone, Coenagrion ornatum*
Plants	*Marsilea quadrifolia, Aldrovanda vesiculosa, Centaurea jankae, Centaurea pontica, Echium russicum*

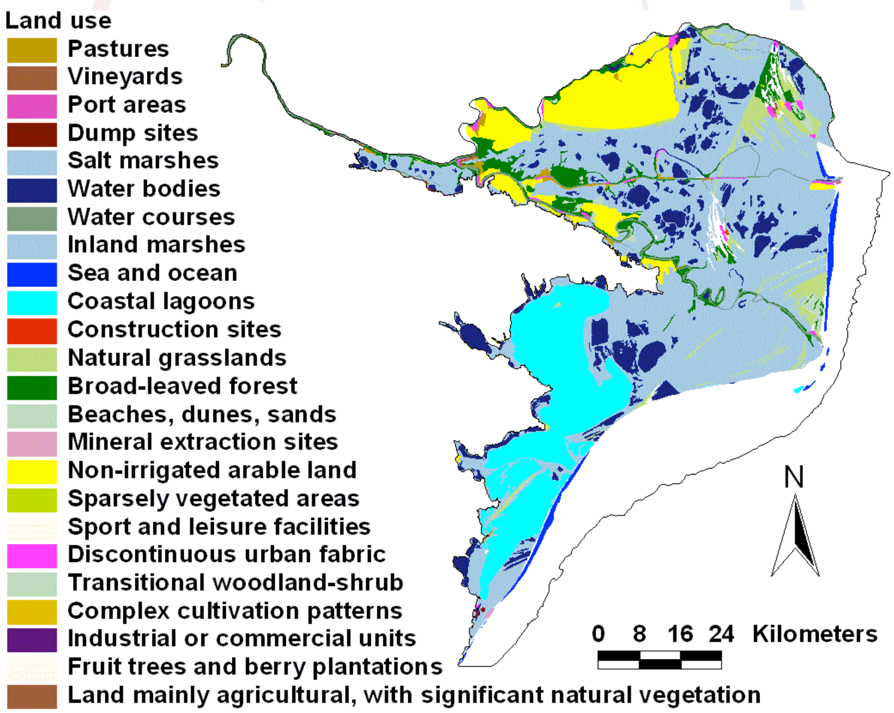

Figure 7b. Displaying land use in the Danube Delta Biosphere Reserve (based on CORINE Land Cover and Use data, 2006, European Environment Agency, level 3).

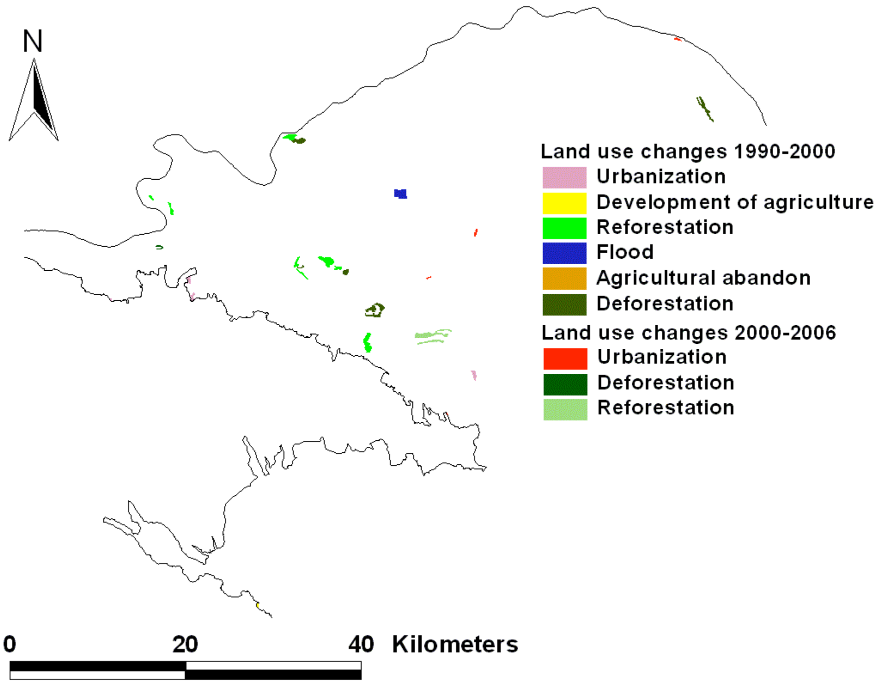

Figure 8. Showing land cover and use changes in the Danube Delta Biosphere Reserve between 1990 and 2006 (based on CORINE Land Cover and Use Changes data, 1990-2000 and 2000-2006, European Environment Agency). The image displays the area with most changes.

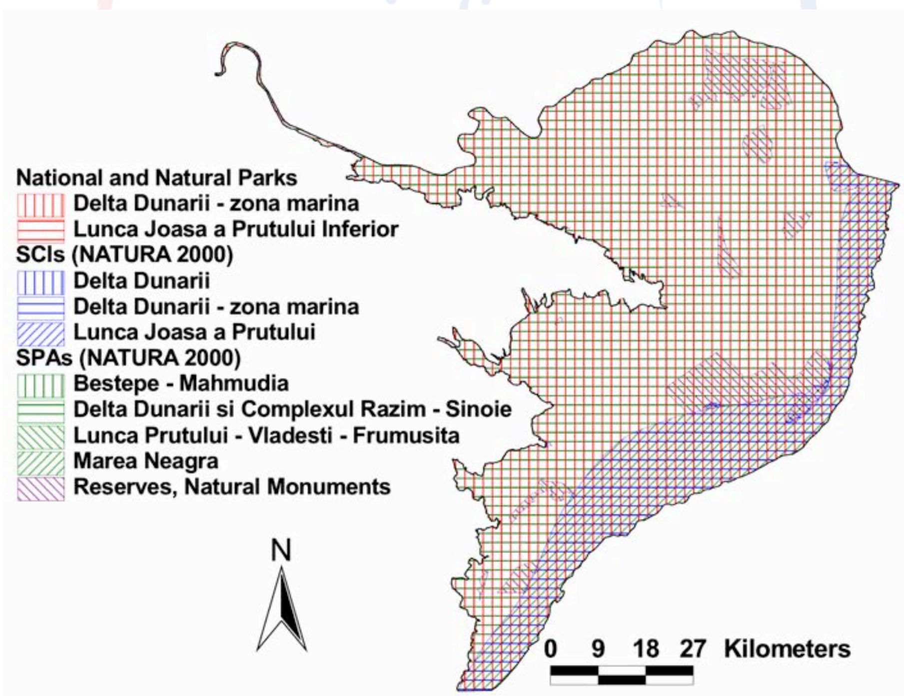

Figure 9. Displaying the natural protected areas within the Danube Delta Biosphere Reserve (based on data from the Romanian Ministry of the Environment and Forests, 2011, excluding local reserves with a total area less than 5 hectares).

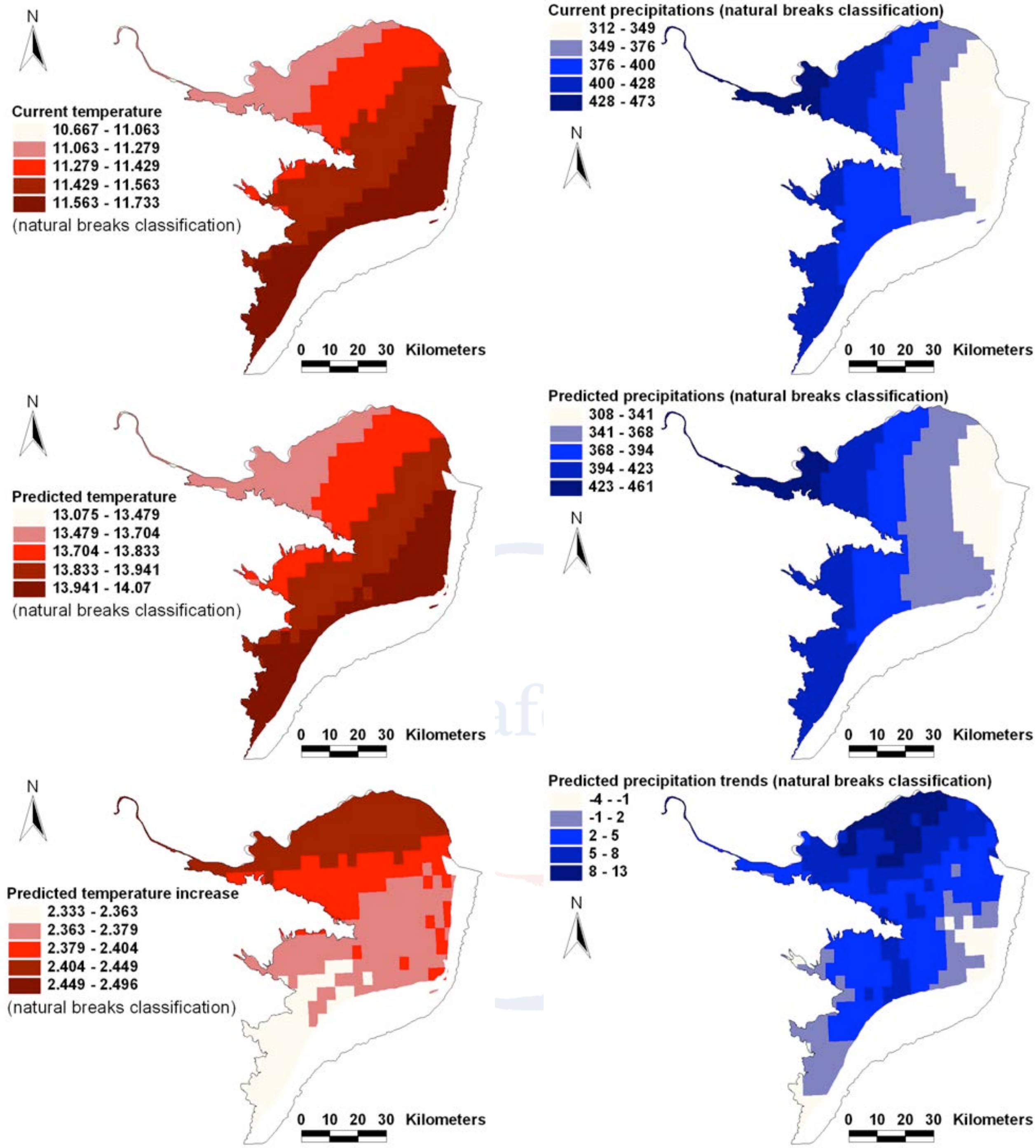

Figure 10. Presenting actual and predicted temperatures and precipitations, and clime change based on the difference between current and predicted values in the Danube Delta Biosphere Reserve (present situation based on data from Hijmans *et al*., 2005 and prediction based on data from Govindasamy *et al*., 2003).

4. History of Socio-Cultural Development in the Danube Delta Biosphere Reserve and the Human Pressure

Given its natural assets and geographic position, the Danube Delta played always an important economic, politic, and strategic role. The area has called for the presence of people through the diversity of relief, productive soil, mild climate and varied natural richness. The products were known and sought for in the farthest areas, since the maritime and river routes intersected the terrestrial ones, helping out the trading activities. Moreover, the Danube Delta and its adjacent floodplains (Brăila and Ialomița) also represented final destinations for transhumant shepherding (Meiță, 2010).

For a long time, the pressure induced by the humans was not felt, since resources were used in traditional manners by a reduced population.

- *The first significant impact* occurred in the end of the 19th century, when Sulina Canal became available for navigation. The cutting of meanders and consolidation of banks broke the unity of the Danube Delta and change the flow regime.
- *The second significant impact* was started by Grigore Antipa in the beginning of the 20th century in order to increase the productivity of fisheries and consisted of cutting canals totaling several tens of kilometers to ensure the circulation of water between the arms of Danube and shallow lakes.
- *The third significant impact* occurred during 1950-1970 and was caused by the exploitation of reed. Dikes were raised, new canals were cut, and pumping stations were built to control the level of water in the areas circled by dikes. At the entrance of Sulina Canal, the dikes protecting the entrance advance 250-300 m per year, determining changes in the seaside area. The nesting colonies of pelicans, shags and herons were destroyed and hundreds of thousands of birds shot. If in the beginning of the 20th century there were some 10-15 million birds, only some 7 million remained at the end of World War II, and 500,000 in the 70's. Very aggressive human activities affected the entire area in this period, leading to the most intense transformations from its history.
- *The fourth significant impact* took place in the 80's, when the large polders Sireasa and Pardina, as well as other 22 areas covering 53,505 ha, were surrounded by dikes and de-watered. The creation of other fisheries or forestry exploitations imposed the construction of new dikes, increasing the total area surrounded by dikes within the Danube Delta to 103,385 ha (Meiță, 2003).

5. The Local Seismic Culture concept for a sustainable living in Danube Delta Biosphere Reserve

The Danube Delta, as well as the surrounding area, can be subjected to two types of earthquakes:

- large magnitude ($M_w \geq 7.2$) Vrancea intermediate depth earthquakes ($h \geq 60$km), originating at some 150-200 km, at the curvature of Carpathian Mountains;
- shallow earthquakes (crust) earthquakes, originating at local faults.

Dobrudja area belongs to an older geologic block and four significant faults are considered to have played a major role in the tectonic evolution of Dobrudja area. The northern Adjud-Sfantu Gheorghe Fault is in fact along the Sfantu Gheorghe Branch of Danube and justifies the interest for its possible seismic activity.

The Tulcea earthquake of 13 November 1981 (M 5.2) occurred in the area Tulcea-Mahmudia-Bestepe, at 11 km depth, and caused local damage mostly in Tulcea with an intensity of VI-VII on Mercalli scale. While several brittle engineered buildings sustained heavy damage, the vernacular architecture houses, with solid walls made of local clay / earth behaved almost without cracks (Georgescu, 1982, 1986, 1997). It seems that the solid earth walls had an acceptable strength and shock damping capacity even under near-field earthquakes.

This peculiar case is in line with the analysis of vulnerability which proved that, as a general trend, the earthquake disasters were not a rule on Romanian territories; the inhabitants have built adequate houses using local materials, mostly wood, stone and earth, and, later on, bricks. The life preserving qualities of those houses under earthquake motions is obvious and the vernacular architecture is still proving this pattern nowadays. If one takes an ethnographic map of construction materials, there is a very good agreement of all construction elements with the seismic zoning map of Romania. The height, stiffness, placing of heavy and light materials are well correlated to the seismicity of each zone and the available materials and this is an overall measure of the Local Seismic Culture (LSC) level achieved in Romania (Georgescu, 1982, 1997).

Presently, the inhabitants of most villages and even of some urban suburbs near Danube Delta use the earth as a building material for their one or two storied houses in two ways:
- as adobe bricks, made of local yellow earth / clay, with straw, dried at sun;
- as plastic lumps, made of the same mixture, but placed in walls in wet state layers; after drying, the next layer is put; some kind of sliding formwork is used in some places.

The earth which is able for building purpose was identified by each village and not confused with loess. There is a very innovative capacity of local communities and it is proved by the use of some crushed shells and sand mixture to plaster the walls against rain, as well as by wall foundations that are made of raw stone, while a collar beam of concrete is laid over the walls, under wood roof structure.

The recovery of vernacular techniques and combination with locally available materials may enhance the ecological pattern of future developments.

6. Principles for a Sustainable Socio-Economic Development in the Danube Delta Biosphere Reserve

Tourism. Its influence is due to:
- Circulation: mainly the general river transportation, and lesser tourism.
- Equipment: increased comfort assumes better water supply and distribution systems, water treatment, and leisure infrastructures. Their creation could lead to pollution and degradation of the local environment. Tourism infrastructure should be located far away from the wildlife and especially protected areas. Tourism-related activities must be organized and monitored.
- Water leisure and transport infrastructure: should include oar boats, hydro-bicycles, and motor boats with diminished impact.

Only organized tourism can valorize the natural potential without altering its quality, with benefits for its population; the economic independence and increased welfare could reduce the loss of rural population due to the migration to urban places offering better life standards (Meiță, 2010).

Urbanism. The following criteria must be accounted for:
- Placement: far from transportation, so that the places are not included in tourism circuits affecting the life of inhabitants by pressures and pollution;
- Living rules: educate future inhabitants on basic ecological principles;
- Information technology: allow the area benefit upon 21st century technology;
- Administration: good repartition of tasks for local authorities over the entire area;
- Circulation: designed to shorten distances and reduce impact on settlements;
- Water supply: cannot generalize or opt for individual vs. collective models; however, the latter presume sewerage and treatment of wastewaters;

- Forest: current European guidelines show that the trees within the settlements should be seen more as foresters than green spaces or leisure areas;
- Solid waste: managed and stored at the local level;
- Education: the curricula must reflect adaptation to the ecological habitat;
- Architecture: influenced by the local specific and materials should make it comfortable (Meiță, 2010).

Settlements should be designed in terms of location and materials to reduce the damage due to natural causes such as storms, floods, earthquakes, and land slides. Also, land should be used in a way leading to long-term benefits. In order to minimize conflicts and choose the most efficient compromises and options, social and economic development must be connected to the protection of the environment: first account for the protected areas, but also for the private property and rights of the indigenous population and other local communities, such as the Lipovans. The biological resources provide for food, habitat, medicine and spiritual nourishment are within natural ecosystems, such as forests (Letea), grasslands, pastures, open fields, lakes, river, and sea. The loss of biological diversity continues through the destruction of habitats, overexploitation of resources, pollution, and introduction of alien species. The loss of biodiversity is determined by people and constitutes a serious barrier against development. From the energy viewpoint, the Danube Delta, even though poor in classic energy (oil, coals, rivers), has many other natural sources (sun, wind, waves) able to provide for sustainable development (Meiță, 2003).

Architecture. The key issue in designing constructions suitable for the Danube Delta area is the compliance of rural and urban rules with the local tradition and ecological principles, taking the sustainability principles from the local construction system, based on the idea that traditional houses specific to the rural areas were not designed by specialists, but built by local craftsmen. Houses should be thought and designed based on the principle according to which they are to be lived in by three generations (children, parents, and grandparents), in all respects concerning family life, education by older generation, and economy of resources. The connections between the urbanization of the area must be linked to the requirements for a sustainable development and technology, in a long-term thinking based on eco-technical criteria (based on ecology, economy, technology and social sciences):
- Use all the positive architectural traditions, including the efficient orientation and organization of houses;
- Identify all elements compatible with the protection of the environment;
- Promote new materials contributing to the sustainability of human settlements, resistance to floods, and compatibility with the Western living standards;
- Use energy produced by unconventional sources: wind, sun, gas, and water;
- Conceive settlements depending mainly on local resources;
- Design multifunctional constructions for education, culture, administration, and different services (Meiță, 2010).

In time, constructors and architects considered the site and clime consequences as a natural feature due to many reasons, such as the slow pace of evolution, allowing for learning by attempts and errors, the local character of constructions and materials, and the need to use limited resources in the best way. The aesthetic quality can be achieved by simpler, natural, and sustainable means. Construction programs must be focused on local materials, energy efficiency, healthy and environmentally friendly materials and technologies based on manual works, creating more jobs. To reduce migration to larger cities, the government must improve the living conditions in rural areas and reduce the gap between rural and urban settlements. The environmental preference method, proposed by Chiel Boonstra, allows for selecting materials and products with a lower environmental impact compared to others designed for the same functions, for each element of the building separately (Anink *et al*., 1996).

Table 3. Principles of urbanism and ecological construction in the Danube Delta Biosphere Reserve (Meiță, 2003)

Needs	**Construction requirements**
Environmental protection	(1) Integration in the natural environment, (2) integration in the built environment
Functionality	(1) Surface, (2) volume
Safety	(1) Structural, (2) fire, (3) utilization
Hygiene	(1) Clean air, (2) clean water, (3) solid waste elimination, (4) waste water sewerage
Comfort	(1) Acoustic, (2) hygro-thermal, (3) visual, (4) anthropo-dynamic
Adaptation to its use	(1) Heating, (2) ventilation, (3) power
Optimization of power consumption	(1) Thermal insulation, (2) energy consumption

Principles of ecological urbanism and architecture in the Danube Delta

In order to create a sustainable society, its people must live a sustainable life. The quality of life is more important than consumption. Sustainable life must be a part of the system where people, their homes, and effluents interact with green houses, gardens, animals, and fisheries, influencing their mind, lifestyle, environment, and economy. To achieve it, the development must meet the principles of ecological construction, listed below and summarized in *Table 3*.

1. Each existing element must be carefully assessed in terms of its contribution to increasing the quality of life.
2. Each problem contains its solution.
3. Sustainable development is the key for urbanism and ecological architecture. Landscape and architectural planning can be conceived to respect diversity, improving the life of all species, reducing the fear for insecurity and increasing the hopes for a better future.
4. Each element must have more functions, and each function must be carried on by more elements, increasing flexibility and stability. Should a certain element fail, the others will take over its role. Instead of maximizing the function of a single element, we should optimize the whole by increasing the connections, requiring new technologies or adopting the traditional ones in a modern context.
5. A sustainable system reunites fundamental human, material, and psychological needs: clean air and water, sufficient and healthy food, serenity, contact with vegetation, animals and other people, security, participation, expression of individuality, identity, freedom, love, and beauty. The needs must be fulfilled for all; resources should be used within the limits of sustainability and equity; even though the fundamental needs are present in each culture in every period, cultures differ by the manner of satisfying them.
6. A sustainable system must rebuild the natural cycles of production and composition.
7. Diversity: a sustainable system must be open and flexible, allowing for expressing individual and collective differences, and manage conflicts as an integrant and healthy component of each process. Every human being and group is unique and must be provided for the means and freedom to act responsibly at his own will. Our hope is to build merely cyclic than linear

systems, heart and mind, joy instead of despair, green replacing the gray, fertile in place of the desert, life and not death, and balance instead of instability.

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Evaluation of Air Pollution Baseline from Bituminous Power Plant in Thailand

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Environmental Sustainability & Environmental Management: Atmosphere and Air

Evaluation of Air Pollution Baseline from Bituminous Power Plant in Thailand

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Abstract:

Thailand's electricity generation is typically based on thermal conversion of burning coal and natural gas. Natural gas alone has fuel share of 73.9 percent of total electricity generation capacity while lignite and coal is at 17.4 percent, followed by hydropower at 3.6 percent, fuel oil at 1.4 and other at 3.7 percent, respectively. The combustion of coal emits several of air pollutants. Therefore, an evaluation of baseline emission from coal-fired power plants is very important. This study used bottom-up approach together with site-specific data obtained from Continuous Emission Monitoring System (CEMs) to analyze baseline emission and site-specific emission factor of power plant over one year period from July 2009 to June 2010. This paper focuses only on Nitrogen Oxides (NO_x) and Sulfur Dioxide (SO_2) emission from bituminous power plants. As the results, this plant emitted a total of 14,649.39 tons of SO_2 and 12,670.05 tons of NO_x and has a site-specific emission factor of 1.53±0.35 g SO_2/kWh and 1.09±0.13 g NO_x/kWh for Unit 1. For Unit 2, it has emission factor of 1.65±0.50 g SO_2/kWh and 1.30±0.18 g NO_x/kWh. The increasing in SO_2 baseline emission observed is inconsistent with a trend of electricity generation, which stays constant. The surveillance of SO_2 concentration is recommended due to its fluctuation in concentration and could result in exceeding the emission limit. The result of this study will serve as reference baseline for policy makers and power plant managers to effectively monitor and mitigate potential environmental problems from power sector in Thailand.

Keywords: Site-specific Emission Factor, Nitrogen Oxides, Sulfur Dioxide, Bituminous Power Plant

1. Introduction

1.1 Coal Energy and Environment

Coals are classified by ranking according to their progressive alteration in the natural metamorphosis from Peat, Lignite, Sub-bituminous, Bituminous, to Anthracite. Coal rank depends on the volatile matter, fixed carbon and inherent moisture. Although no single parameter defines a rank of coal, typically, coal rank increases as the amount of fixed carbon increases and the amount of volatile matter and moisture decreases as seen in Table 1. Coal provides 27% of global primary energy needs and generates 41% of the world's electricity [1]. In 2009, Thailand consumed 33,611 kton of coal which divided into power generation sector by 81% and to industrial sector by 19%. Although, natural gas is major source in power generation sector followed by coal but coal is much more concerned due to its pollution generated after the combustion. [2]

The combustion of fossil fuel generally emits Nitrogen Oxides (NO_x), Sulfur Dioxide (SO_2), Total Suspended Particles (TSP) and Carbon Dioxide (CO_2) which is criteria pollutants and can lead to a serious health problem for community near power plant. To assess the total amount of pollutants discharged into the atmosphere and accumulating over time, it is important to carry out an evaluation of baseline emission from these fossil fuel power plants. Every year, the emission inventory of power sector is prepared based on top-down approach by many of government institutions such as Department of Alternative Energy Development and Efficiency (DEDE) and the Electricity

Generating Authority of Thailand (EGAT), which may not very accurate (either over or under estimated). By using bottom-up approach to estimates the emission from power plant will serve as reference baseline for policy maker and power plant manager to effectively monitor and mitigate environmental and health problems from power sector in Thailand.

Table 1 Chemical composition and rank of coal (wt %)

Coal Rank	C	H	O	N	S	Moisture
Peat	50-60	5-6	35-40	~2	~1	75-80
Lignite	60-75	5-6	20-30	~1	~5	50-70
Sub-bituminous	75-80	5-6	15-20	~1	~1	25-30
Bituminous	80-90	4-6	10-15	~1	~1	5-10
Anthracite	90-98	2-3	2-3	~1	~1	2-5

1.2 Air Emissions

Emissions from coal combustion depend on the coal rank and composition, the design type and capacity of the boiler, the firing conditions, load, the type of control technologies, and the level of equipment maintenance.

Nitrogen oxides or NO_x are general term of NO and NO_2 in air pollution. Usually nitrogen oxides are generated when fuel was combusted in high temperature and most of them are NO (about 95%). Afterward, these NO will be oxidized to NO_2 in the atmosphere and that is why emissions of NO_x from fossil fuel combustion are represented by NO_2. The formation of NO in flames can be described into three mechanisms: prompt-NO, thermal-NO and fuel-NO. Prompt-NO is the NO generated by the reaction of hydrocarbon radicals with N_2 within the air, the amount of prompt-NO in coal flame is of a few percents and can be almost always neglected. Thermal-NO is NO from the N_2 of air reacting with the O_2 of air in high temperature and the amount of NO generated by this way increases with the temperature. Fuel-NO is believed to be the main source of NO in pulverized coal combustion (about 95%), which generated from nitrogen components in coal reacting with O_2 during combustion. [3] [4]

Sulfur oxides (SO_x) emissions are generated during coal combustion from the oxidation of sulfur contained in the fuel. On average, more than 95 percent of the fuel sulfur is converted to SO_2 therefore the emissions of SO_x from conventional combustion systems are predominantly in term of SO_2. [4]

Exposure of NO_2 could cause adverse respiratory effects such as airway inflammation in healthy people and increased respiratory symptoms in people with asthma. Short-term exposures to SO_2 could also cause adverse respiratory effects and increased asthma symptoms. NO_x and SO_x can react with water, oxygen, and oxidants, result in forming of acidic compounds. These compounds fall to the Earth in either dry form (gas and particles) or wet form (rain, snow, and fog), so called acidic deposition or acid rain. Some are carried by the wind, sometimes hundreds of kilometers, across the country. Major human health concerns associated with their exposure to acid rain include effects on breathing and the respiratory system, damage to lung tissue, cancer, and premature death. In the environment, acid rain raises the acid levels of lakes and streams (making the water unsuitable for some fish and other wildlife). It also speeds up the decay of buildings, statues, and sculptures. [5]

1.3 Description of Bituminous Power Plant and Fuel Quality

The bituminous power plant in this study has 2 units with capacity of 700 MW each located in Rayong province. The reason why bituminous has been chosen to be fuel to produce electricity is because of it provides high heat value and low sulfur when burning. This power plant designed to use bituminous coal that has sulfur content of 0.27-0.7% by weight. Other properties of bituminous coal used in this power plant are shown in Table 2. Unlike lignite, which is abundant in Thailand, bituminous must be imported from Australia and Indonesia and delivered directly to power plant by ships which is located close to the eastern seaboard. From the coal yard, the coal is transported via conveyors to bunkers and coal pulverizers where it is ground to suitable size for inputting into boiler furnace. Combustion of coal provides heat which use in boiling water to produce steam. The steam will turn the turbine connected to the generator to produce electrical power.

Table 2 Ultimate analysis of bituminous coal used in power plant (wt %)

Source	C	H	N	S	O	Ash	Moisture
Clermont, Australia	64.53	3.77	1.47	0.27	6.96	8.50	14.50
Penang, Indonesia	63.43	4.20	1.21	0.40	11.56	5.20	14.00

Boiler furnace is a tangential fire single vortex type which can reduce NO_x by 60% compared with normal boilers. This type of boiler has a large sub-stoichiometric combustion zone. This leads to a lack of oxygen for combustion resulting in a reduction in flame temperature from 1,500 °C to 1,300 °C which minimizes NO_x generation after combustion. Upon completion of the sub-stoichiometric stage of combustion, more air is added higher up the furnace to complete burning of the fuel. This process is called low NO_x burners (LNBs) and separate overfire Air (OFA).

After combustion, while heavy ash called “bottom ash” settling at the bottom of the boiler furnace, fly ash will be carried with the flue gas through the boiler and will be trapped by electrostatic precipitator (ESP). The precipitators are of the rigid frame out-door type, each having four fields and each boiler has two electrostatic precipitators connected in parallel to give the efficiency of 99.67%.

Since the coal has sulfur as an impurity, combustion leads to emission of sulfur dioxide (SO_2). Therefore, a sea water flue gas desulfurization (FGD) plant is provided to trap SO_2 before it is emitted into the atmosphere. Each boiler is equipped with a single absorber and about 70% of the flue gas is pump to the absorber tower for treatment process. The absorber tower is of the packed type. Warm seawater from the condenser is supplied at the top of the absorber tower by booster pumps. The seawater is then sprayed down the absorber tower through the packing and flue gas flows up the tower in the opposite direction. This brings the seawater into contact with all of the flue gas to remove the SO_2 from the flue gas by using alkalinity in seawater. As the SO_2 is absorbed by the seawater, the pH of seawater decreased. Treated flue gas leaving the absorber tower is reheated by mixing with 30% untreated flue gas from the boiler, after which it is released into the atmosphere by 200 m stack.

2. Scopes and Objectives

The objective of this study is to evaluate baseline emission of criteria air pollutions in term of both concentration and total quantity from electricity generation by fossil fuel combustion and to determine the site-specific emission factors of the power plant. This study will focus on major air pollutants from the power plant, which consist of Sulfur dioxide (SO_2) and Nitrogen oxides (NO_x).

The fossil fuel investigative in this research is bituminous coal. This study used bottom-up approach together with site-specific data obtained from Continuous Emission Monitoring System (CEMs) to analyze baseline emission and emission factors of power plant over one year period from July 2009 to June 2010.

3. Methodology and Calculation

3.1 Data collection

All data are secondary data, which obtained from The Energy Regulatory Commission (ERC) and from power plant itself. These data consist of emission data from CEMs, electricity generation, plant configuration, fuel quality and pollution control system.

3.2 NO_x and SO_2 emissions

Emissions of NO_x and SO_2 that emitted from stack of power plant to the atmosphere are measured by CEMs instruments and expressed in term of concentration in unit of parts per million, volumetric dry (ppmvd) for every hour. The pollutant mass rates (PMR) of NO_x and SO_2 emissions for each hour are determined by converting from concentration to pollutant mass rate per hour by using Eq.1. [6]

$$PMR_s = C_d \times Q_{d,\,std} \times 10^{-6} \qquad (1)$$

Where: PMR_s is the pollutant mass rate standards (kg/hr); C_d is dry-basis pollutant concentration (mg/m^3) which is measured by CEMs; Q_d is the stack gas dry-basis volumetric flow rate corrected to standard conditions (Nm^3/hr). The concentration of NO_x and SO_2 emission is converted from ppmvd to mg/m^3 by using Eq.2.

$$C_d\ (\mathrm{mg/m^3}) = \frac{C_d\ (\mathrm{ppmvd}) \times MW}{V} \qquad (2)$$

Where: MW is the molecular weight in unit of g/mol (46.01 for NO_x and 64.06 for SO_2); V is the volume occupied by 1 mole of ideal gas at standard temperature and pressure (22.71108 L/mol).

The summation of pollutant mass rate for a given day, month or year is the amount of total emission, as seen in Eq.3.

Total emissions = *h=1*□□□□□*(h)* (3)

Where: h is the service hour of a given plant; m is the number of service hour in a given day, month or year. The daily, monthly and annual emission of NO_x and SO_2 is the summation of pollutant mass rate for every service hour in a given day, month or year.

According to regulatory requirement, all pollutant concentrations have to be reported at standard condition which is at pressure of 1 atmosphere, temperature of 25°C, on dry basis with 50% excess air or 7% excess oxygen. NO_x and SO_2 concentration that obtained from CEMs is already at standard condition and on dry basis but these concentrations have to be corrected to 7% O_2 by using Eq.4 below, before comparing with emission standard [6].

$$C_{d\ (\text{corrected to }7\%)} = \frac{C_d \times (20.9-7.0)}{(20.9-\%O_2)} \qquad (4)$$

3.3 Site-specific emission factors

Emission factor represents the mass of a pollutant emitted to the environment relative to the level of source activity in this case is mass of a pollutant per unit of energy or fuel associated with the production of energy. The emission factors are widely used to estimate the amount of pollution emission due to low requirement of data for the calculation. However, using conventional emission factors may cause some error in the result, since the conventional emission factor may not be representative enough of the source activity assumed, in reality, emissions depend on fuel types used, combustion technology, operating condition, control technology, quality of maintenance and age of the equipment used to burn the fuel. Derivation of site-specific emission factor should decrease the error related to local variation of the source. For this study, the site-specific emission factors of NO_x and SO_2 emission from bituminous fired power plant have been developed by using CEMs data and are calculated by using weight of pollutants divided by related activity of the source at a given time, as seen in Eq.4 [7-8]

$$\text{Site-specific emission factor} = \frac{PMR_s}{\text{Source activity}} \tag{4}$$

Where: PMR_s is the pollutant mass rate standards (kg/hr); Source activity is the related activity of power plant and can be categories in 3 cases: (1) gross electricity generation (MWh/hr); (2) bituminous coal consumption rate (ton/hr); and (3) heat input rate (TJ/hr). Therefore, site-specific emission factor can also be expressed in 3 units: (1) kg/kWh-gross electricity generation; (2) kg/ton-bituminous; and (3) kg/TJ-heat input, depending on the purpose of its use. This site-specific emission factor can also represent the efficiency of plant's pollution control system of performance of power plant.

4. Results and Discussion

The total emissions of bituminous power plant from July 2009 to June 2010 are shown in Table 3. Over one year period, this plant emitted a total of 14,649.39 ton of SO_2 and 12,670.05 ton of NO_x. These SO_2 and NO_x emissions are estimated by using data from CEMs, which are measured from the stack flue gas at the FGD outlets. This power plant has 2 units and each unit has its own FGD, which result in difference emission baseline as shown in Figure 1 and Figure 2. Figure 1 and Figure 2 present the emission baseline of SO_2 and NO_x together with electricity generation for Unit 1 and Unit 2. A trend of NO_x emission is consistent with that of electricity generation but a trend SO_2 emission (from February to June, 2010) seems increasing over time while the electricity generation stays constant. A drop in emission baseline around November, 2009 to December, 2009 of Unit 1 and October, 2009 of Unit 2 due to a long period shut-down for regular maintenance procedure. The increasing in SO_2 emission baseline may also represent the decrease in efficiency of FGD system in each unit and may result in major maintenance of FGD in the future. To be able to analyze the trend of this baseline more accurately, longer period of observation is needed.

Table 4 reports the site-specific emission factors of SO_2 and NO_x from both units in unit of g/kWh gross electricity generation and it is controlled emission factor. From this table, the performance and efficiency of Unit 1 are higher than Unit 2 which results in lower emission of SO_2 and NO_x. When comparing this result with other site-specific emission factors from lignite power plant which is 1.333±0.216 g SO_2/kWh and 2.507±0.720 g NO_x/kWh [7]. The emission factor shows that the lignite power plant has higher environmental performance and efficiency in term of SO_2 emission but lower performance in NO_x emission compare to this bituminous power plant. According to sulfur content in coal, the lignite that used in that plant has sulfur content around 5.42-6.23 % by weight but the bituminous that used in this plant has around 0.27-0.7 % by weight. From this information, lignite power plant seems to generate much higher SO_2 emission than bituminous power plant but the estimated emission factor showed unexpected results. The comparison of emission factors shows that lignite power plant emitted less SO_2 than bituminous power plant. The possible explanation is that the difference in their pollution control system. The lignite power plant used wet limestone FGD which has higher efficiency than sea water FGD that were used in this bituminous power plant. Furthermore, many potential factors can also affect the emission factors from each type of plant such as efficiency of pollution control system, fuel quality, and operation configuration. In the future, to compare domestic emission factor with other acceptable standard like AP-42 (U.S. EPA) which normally reported in unit of kg/ton-coal and kg/TJ-heat input, more information on fuel consumption rate and heat input rate is needed to be collected.

Table 3 Total emissions from bituminous power plant in Thailand from July 2009 to June 2010

Month	SO_2 (ton)		NO_x (ton)	
	Unit 1	Unit 2	Unit 1	Unit 2
Jul-09	671.64	718.95	605.47	673.27
Aug-09	681.05	502.81	540.14	618.75
Sep-09	575.89	448.68	521.56	644.30
Oct-09	573.19	234.68	552.38	301.85
Nov-09	207.41	400.56	192.10	534.33
Dec-09	96.24	509.68	128.19	482.98
Jan-10	625.58	653.99	551.49	614.58
Feb-10	502.91	546.47	427.61	502.32
Mar-10	574.29	632.16	563.60	677.46
Apr-10	695.72	933.34	468.19	638.00
May-10	915.50	1041.58	558.78	659.32
Jun-10	944.22	962.85	542.15	671.27
Sum	**7063.64**	**7585.76**	**5651.64**	**7018.41**
Total	**14649.39**		**12670.05**	

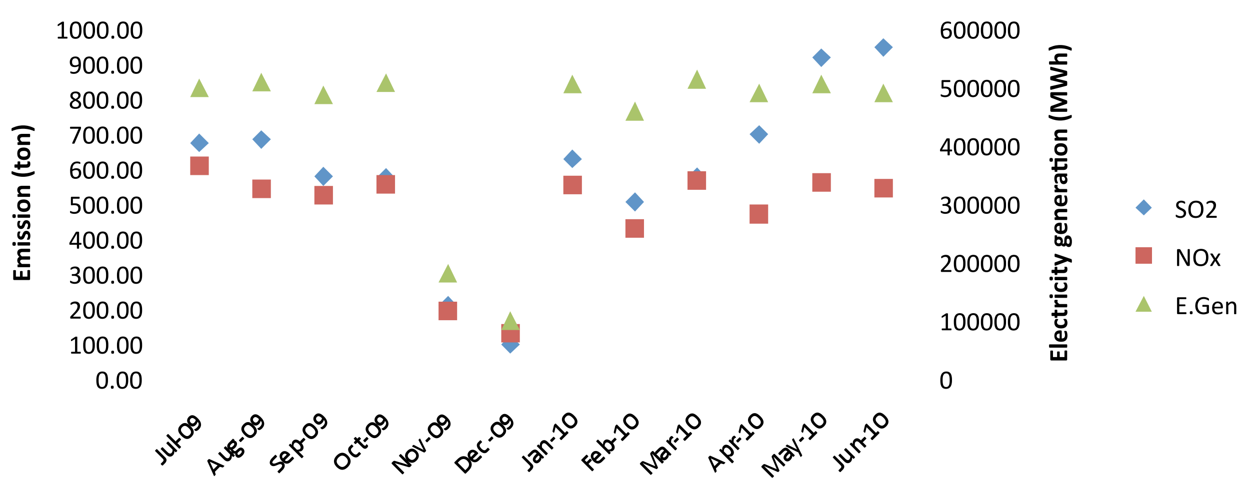

Figure 1 Emission baseline and Electricity generation of unit 1

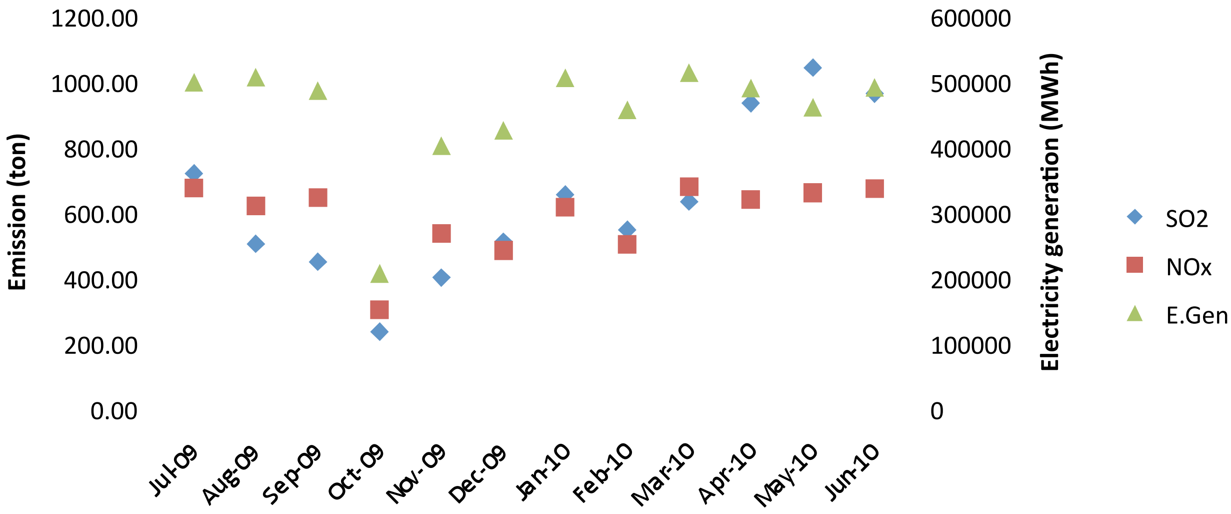

Figure 2 Emission baseline and Electricity generation of unit 2

Table 4 Site-specific emission factor of bituminous power plant in Thailand (controlled emission factor)

Unit	Capacity (MW)	EF SO_2 (g/kWh)	EF NO_x (g/kWh)
1	700	1.53±0.35	1.09±0.13
2	700	1.65±0.50	1.30±0.18

Figure 3 and Figure 4 report the concentrations of SO_2 and NO_x of Unit 1 and Unit 2. The bar chart represents the ranges of concentration in each month from minimum to maximum value. The "+" and "×" represent the average concentration in each month. The STD-line above the chart represents the emission standards announced by Ministry of Industry for coal-fired power plant, which are 320 ppm of SO_2 and 350 ppm of NO_x [9]. The EIA-line is stand for the level of emissions proposed by power plant itself in Environmental Impact Assessment (EIA) report together with other environmental mitigation procedures which are 262 ppm of SO_2 and 241 ppm of NO_x. Even through, the EIA level is lower than STD level but the actual concentration of SO_2 and NO_x still within the limit of EIA level. From observation of these two charts, the maximum concentration of SO_2 is very vary in each month in both unit, so it is confirmed that SO_2 emission is independent from level of electricity generation but subjected to efficiency of pollution control system and quality of fuel used in the process. As for NO_x emission, the maximum concentration is rather constant for each month. It can be seen from both charts that the minimum concentration can be lower as zero in some month due to the short period shut-down for maintenance procedure that month. Figure 3 also show that SO_2 concentration in some month almost reaches the limit due to its fluctuation and it has to be in highly surveillance for potential in exceeding the emission limits.

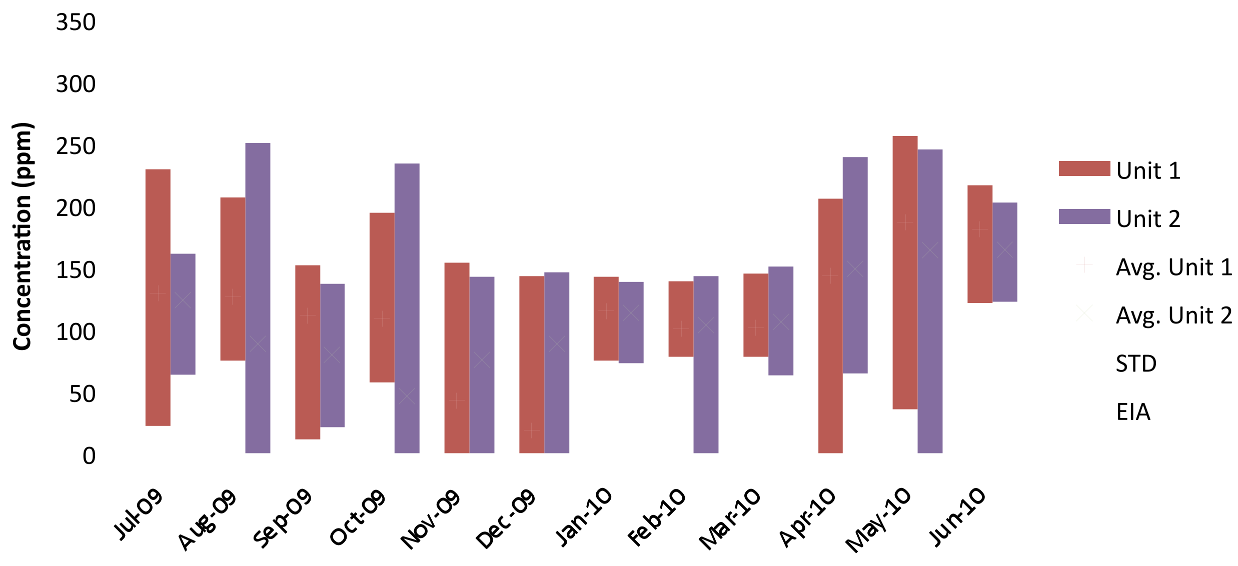

Figure 3 Sulfur dioxide (SO_2) concentrations

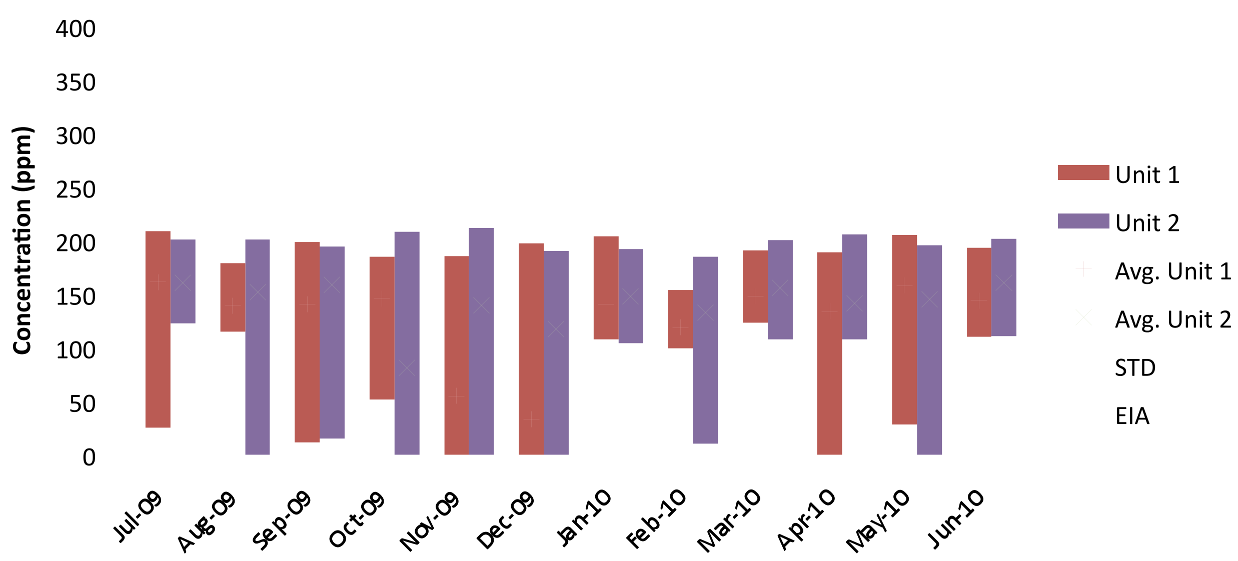

Figure 4 Nitrogen oxides (NO_x) concentrations

5. Further Works

This study has future plans and tasks to complete the investigation on emission baseline from bituminous fired power plants in Thailand, the further study is as the following:

- Physical and chemical properties of the fuel used at each plant, including secondary fuel.
- Fuel consumption rate and heat input rate, including secondary fuel.
- Operating condition and combustion technology of power plant.
- Extended to another criteria pollutant such as Total suspended particulate (TSP) and Carbon dioxide (CO_2).

6. Conclusion

This study focuses on evaluating the baseline emission of SO_2 and NO_x from bituminous power plant in Thailand. Using bottom-up approach, the results provide more precise emission baseline information. The continuous measurement from stack flue gas was collected from CEMs and used to estimate the total emission and baseline of SO_2 and NO_x for one year period from July, 2009 to June, 2010. Total emission of 14,649.39 tons of SO_2 and 12,670.05 tons of NO_x are emitted from 2 units of this plant. During February to June 2010, the result showed increasing in SO_2 baseline, which was not corresponding with steady trend of electricity generation. From the observed concentration of pollutants, concentration of SO_2 needs to be in closely monitored for potential in exceeding the emission limits due to its fluctuation. Emission factor of this plant is 1.53±0.35 g SO_2/kWh and 1.09±0.13 g NO_x/kWh for Unit 1. For Unit 2, it has emission factor of 1.65±0.50 g SO_2/kWh and 1.30±0.18 g NO_x/kWh. Site-specific emission factors between bituminous power plant and lignite power plant is slightly different. Many potential factors can affect the emission factors from each type of plant such as efficiency of pollution control system, fuel quality, and operation configuration.

7. Acknowledgement

The authors would like to thank The Energy Regulatory Commission (ERC) for providing emission data and information on their power generation licensees. Dr. Supichai Tangjaitrong, The Energy Regulatory Committee for supporting this study, valuable suggestions and comments, and Chulalongkorn University for the financial support of this research.

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THE EFFECT OF SEA LEVEL RISE ON FRESHWATER FLOODING, THE HUMAN POPULATION, AND NATURAL FOREST COMMUNITIES OF MIAMI-DADE COUNTY

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ABSTRACT

Predicted sea level rise (SLR) scenarios were implemented for Miami-Dade County (MDC), Florida, USA to evaluate the effects on human populations and natural forest communities. As with many vulnerable coastal areas, MDC will soon face tough decisions regarding the protection of its acreage from an encroaching sea. MDC will struggle to find balance between preserving lands for economic value or profit, societal equality or land rights, and for the protection of the natural environment. This study provides an overview of some of the systems affected by SLR and the interactions between them.

MDC's total population of over 2.25 million will be dramatically affected by SLR. With an increase of only 0.5 m the sea will claim 5,594 Census Blocks, affecting the lives of about 652,000 people. A SLR of 1.0 m will affect about 867,000 people and a SLR of 2.0 m will affect over 1.8 million people. Data from the SLR scenarios may suggest a racial distribution of the impacted population according to elevation above sea level.

SLR will affect the natural forest communities (NFCs) of MDC by flooding and isolating habitats. In MDC, NFCs are mostly discontinuous due to development and urban expansion. SLR can increase the discontinuity between NFCs by flooding corridors of community migration. Under 0.5 m and 1.0 m SLR scenarios, mostly coastal NFCs and parks will be affected by flooding with a few exceptions for the communities which fringe the wetlands in southern MDC.

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INTRODUCTION

Climate change predictions and their subsequent effects on human and environmental systems have been the focus of intense research efforts by the scientific community and government entities. Ocean thermal expansion resulting from atmospheric warming and glacial melts is leading to a rise in ocean water levels. The Intergovernmental Panel on Climate Change (IPCC) predicts a sea level rise (SLR) of 0.18 to 0.59 m by 2100 (IPCC, 2007). Takes glacial melting into consideration, the Miami-Dade County Climate Change Task Force predicts a SLR of about 1.5 m by 2100 (ICCG, 2009).

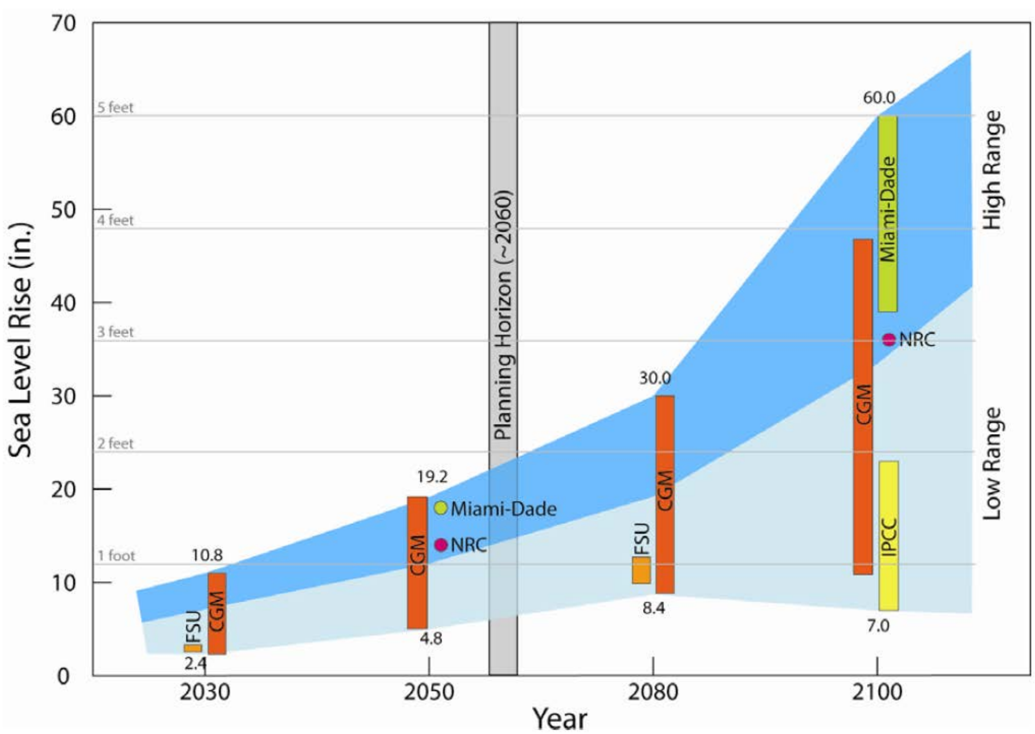

Figure 1. Compendium of current SLR projections from CERP Guidance Memorandum, Florida State University (FSU), National Research Council (NRC), Miami-Dade County, and the IPCC.

Data and computer modeling show that ocean rising rates are accelerating and can be attributed to increasing greenhouse gas concentrations in the atmosphere. In an attempt to characterize the trends of SLR, Walton et al. (2007) utilized monthly mean sea level time series from five recording stations across the state of Florida with 50 or more years of historical records. Their review of relative SLR estimates and forecasting model showed that sea level will rise approximately 0.3 m in Florida by 2080. Their results support more commonly used climate modeling scenarios, both stating that the trend is incremental and that deceleration has not taken place. This study concluded that SLR would have economic effects associated with inundation of low coastal areas, salt water intrusion, and beach and dune recession (Walton et al, 2007).

Coastal zones have been identified as one of the most vulnerable areas to SLR (Nicholls and Cazenave, 2010 through changes in seawater intrusion and flooding, displacement of homes and businesses, and depletion of natural areas important to commerce, aesthetic value, and recreation. Among these zones, Miami-Dade County (MDC) in South Florida has natural and anthropogenic characteristics that make it uniquely susceptible to impacts. Some of these characteristics include: 1) low land surface elevations; 2) a highly transmissive and susceptible aquifer system; 3) a highly managed surface water system, and 4) a thriving coastal ecosystem.

Nicholls and Cazenave (2010) showed that low elevation coastal areas are increasingly prone to submergence and flooding as a result of SLR. With forecasted SLR ranges of about 0.13 to 0.51 m by 2060 in South Florida, many low elevation areas in MDC including highly urbanized areas, recreational beaches, parks, and wetlands are likely to experience major changes.

The Biscayne Aquifer is a coastal surficial aquifer system and the primary source of drinking water in MDC. High hydraulic conductivity and high rainfall rates makes the Biscayne Aquifer one of the most productive as well as sensitive karst aquifers in the world. Price et al (2006) discuss the influence of anthropogenic activities contributing to saltwater intrusion pushing the freshwater lens further inland. The study detected a gradient of saltwater intrusion in the groundwater reaching further inland than the gradient found by Fitterman et al in 1999 (6 to 25 km versus 10 to 15 km, respectively). Although historical groundwater salinity concentrations are unknown, local anthropogenic activities such as groundwater pumping and surface water canalization have been shown to increase the extent of seawater intrusion by limiting aquifer recharge (Price et al, 2006).

South Florida watersheds are highly managed via canals and levees. Daily operations are based on precipitation events and water levels; however, there are grandfather operations that occur regardless of water levels. One example was studied in 2005 by Renshaw and Kearns of the National Park Service; they identify the almost century-long practice of draining South Florida wetlands for agricultural use as having a large impact on the Biscayne Aquifer. The system is managed to support the fall growing season by releasing billions of gallons of surface water at the end of the wet season, lowering the water levels in the Biscayne Aquifer. This process creates an unnaturally early dry season and can introduce problems for natural and human systems which rely on a constant source of freshwater (Renshaw and Kearns, 2005).

The combination of anthropogenic drying and SLR brings about adaptation challenges to natural ecosystems along South Florida's coasts. Coastal plant communities are dynamic systems driven by elevation, salinity levels, soil moisture, and precipitation. While physical, biological and chemical processes have evolved and adapted to the effects of daily tidal fluctuations, seasonal drawdowns, and periodic storm surges, increased seawater levels, seawater intrusion, and storm activities are going to play a role in altering coastal plant community composition and species abundance (Shirley and Battaglia, 2006; Teh et al, 2008; Engels and Jensen, 2010). Gaiser et al in 2006 used paleoecological analysis of mollusks along MDC coasts to assess the rate of inland migration and coastal zoning due to historic SLR. The presence of mollusks in sediment cores is uniquely correlated to past salinity concentrations, providing a snapshot of the historic coastal zone's location and health. They concluded that saltwater intrusion in the study area has occurred more rapidly in the last 70 years than when compared to historical records. Recent migration rates were estimated at 3.1 m/yr as compared to predevelopment migrations of 0.14 m/yr. Mangrove forests in MDC may not be able to keep up with the increased rate of SLR, and could collapse; including rare species (plant and animal alike) that thrive among them.

Many species in the low-lying South Florida coastal communities are unique. Over 170 state endangered and 7 federally endangered (*Amorpha herbacea* var. *crenulata, Chamaesyce deltoidea* subsp. *Adhaerens, Chamaesyce deltoidea, Galactia smallii, Jacquemontia reclinata, Polygala smallii,* and *Warea carteri*) and 1 federally threatened (*Chamaesyce garberi*) plant species exist in MDC (Gann et al. 2010), and, of those, many are restricted to areas with brackish or saline groundwater (Saha et al. *in press*). Rare species richness tends to be negatively correlated to salinity in coastal habitats (Saha et al. *in press*). The majority of these species are found in fragmented natural forest communities (NFCs) scattered across the greater metropolitan area. As of 2005, less than 2% of the natural plant communities in MDC remained as small NFC fragments interlaced in a matrix of wildland–urban interface (Bradley 2005). As SLR increases, NFCs found along the coast and low lying areas inland are in threat of freshwater and/or saltwater flooding that did not previously occur, driving shifts in species composition and abundance on those lands (Shirley and Battaglia, 2006; Teh et al, 2008; Engels and Jensen, 2010). Therefore, species with highly restricted ranges and short distance dispersal abilities may be in threat of extinction.

The unique hydrology of South Florida and MDC is an ideal area for SLR impact studies. The low-lying and highly developed coastal area, in combination with the vulnerable freshwater supply and highly managed surface water system, creates a distinct case-study that has yet to be examined in its entirety. This research focuses on the effects of SLR in Miami-Dade County, FL with an interest in providing understanding of the coupled human-environmental system responses to SLR for decision and policy makers. This paper addresses the question: How will projected sea level rise scenarios (0.5 m, 1.0 m and 2.0 m) affect the interactions between flooding, natural forest communities, and the human population of Miami-Dade County? To tackle this broad question, the project follows the structure shown in Figure 2. SLR scenarios were developed and flooding maps of MDC were created, these maps were then used to understand the effects on human population groups (2) and natural forest communities (3) and the link between the two (4).

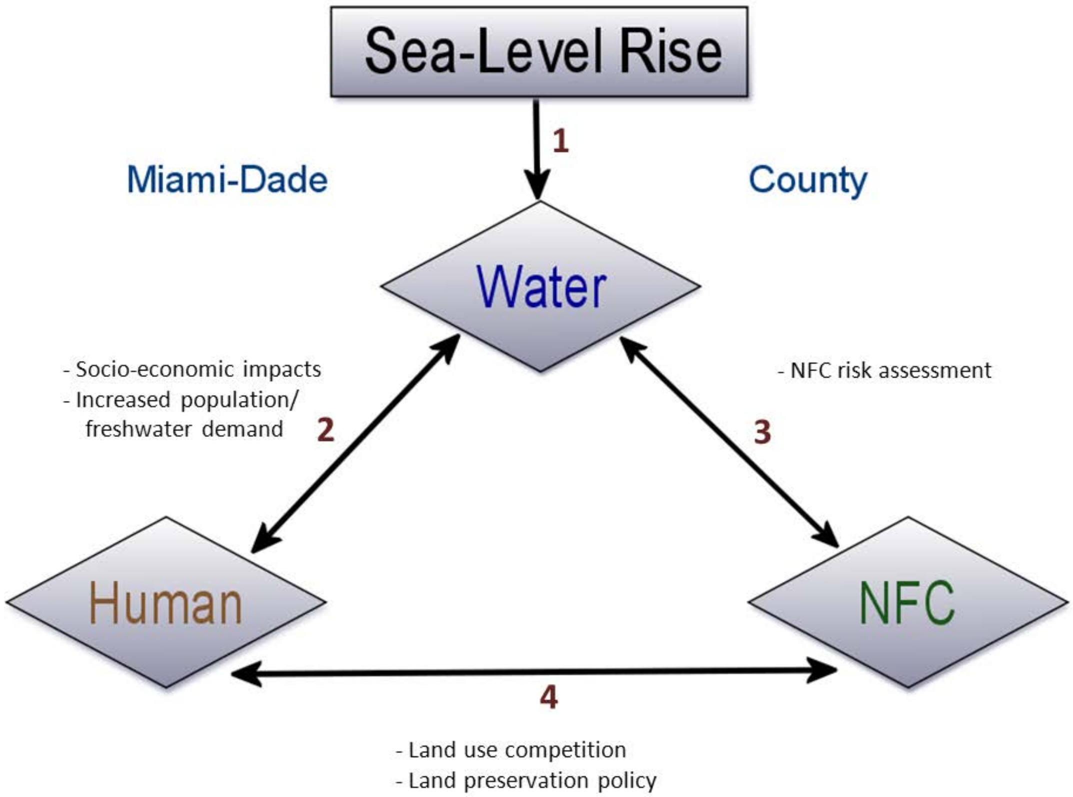

Figure 2. Project framework illustrating the four linkages evaluated in this work.

Additionally, this project serves as a study in the interdisciplinary interpretation of climate change and SLR effects. One aim was to link the rifting topics of anthropology, hydrology, and biology and create a broad, over-arching view of SLR effects in MDC. The results, and indeed the method in itself, can serve as a planning basis for future decision makers and stakeholders.

SLR IN MIAMI-DADE COUNTY

Worldwide, many SLR scenarios have been developed and accepted at many structural levels; including at the community, regional, and global scales. Due to the variety of plausible SLR predictions, it may be in the best interest of stakeholders and decision makers to plan and prepare for many scenarios which have the potential to manifest. This project identifies three possible SLR scenarios that are based on conservative, intermediate, and extreme events. While the IPCC's predicted SLR of about 0.5 m in one century is conservative, it does follow the observed SLR trends for Florida (Walton, 2007). Starting from the conservative 0.5 m, a 1.0 m and 2.0 m rise are also evaluated to represent the mid-range and high-range estimates of the NRC and MDC, respectively.

Flooding

Flooding of low lying coastal lands from SLR is one of the major consequences of this era's anthropogenic climate change. Different attempts to determine the spatial extent of flooding are inherently constrained by the uncertainties behind climate change scenarios. Continuous research efforts in downscaling techniques have allowed for more reasonable interpretations of climate change effects at the regional level. Using this downscaled dataset, studies have been able to show or suggest a more detailed region-specific representation of the spatial extent of SLR scenarios.

Kuleli (2010) used a 90 m digital elevation model as well as Landsat-based imagery to identify areas in coastal Turkey that are currently located below the 10 m contour line. A similar approach was followed in our study, where we created a geospatial model using a LIDAR dataset to delineate areas located below the 0.5 m, 1.0 m, and 2.0 m contour lines. These lines reflect a low, medium, and high SLR scenario by 2100 in MDC. Files for each scenario where thus created and represent the extent of surface saltwater flooding (Figure 3).

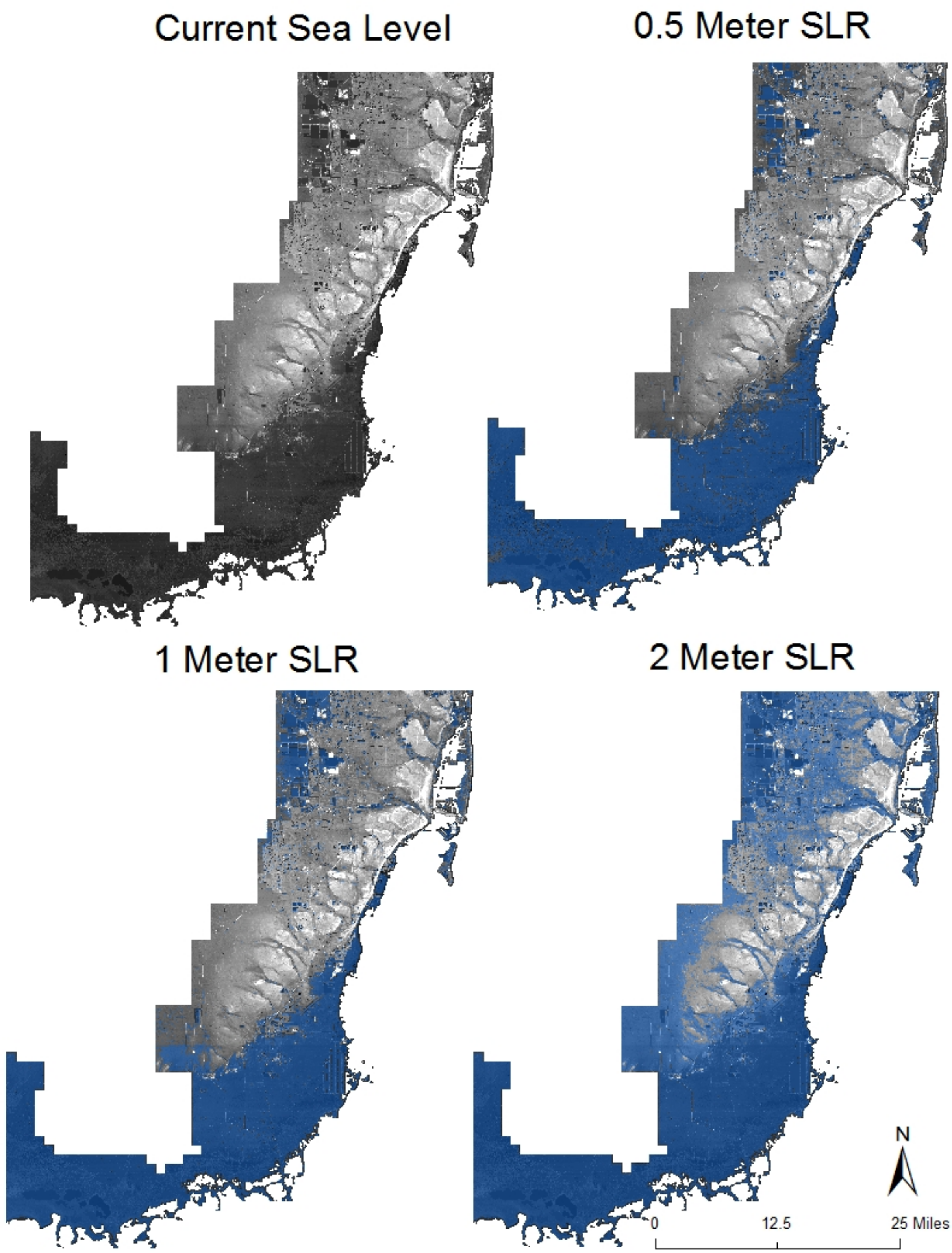

Figure 3. Extent of flooding with three SLR scenarios in MDC.

SLR TO HUMANS LINK

It is important to understand the effects of the three possible SLR scenarios on the human population of MDC. Potential stakeholders must be determined in order to create equitable solutions for mitigation, management, or adaption strategies for SLR. Those affected by SLR include businesses and residences losing property or access to property. Other indirect impacts include a loss of community or network, which can occur when critical components such as security, jobs, and desirability are threatened by encroaching shorelines. Even a sense of impending loss may lead to a displacement of people and deterioration of the community.

Creating the datasets

Data related to race/ethnicity, age distribution, household occupation and status were obtained for each Census Block (a total of 30,810 in MDC) from the Census 2000. Flooding of the Census Block units was considered when these units were either partially or completely affected by SLR.

Census Block Groups (a total of 1,220 in MDC) are generated through the aggregation of Census Blocks and provide income information. This information is obtained from a survey different than the Census Block. In order to compare both sets of data, an aggregation of the Census Block data in Block Census Groups was carried out.

Census Blocks

Percentage columns present in table 2 were obtained through two types of transformations. Population, Households, Families were obtained for the three SLR scenarios from the expression:

□□□□□□□□□□□=□□□□□□□□□□□ □□□□□□□□□ □□ □□□ □□□□□□□□□□□□□□ □□□□□□□□□□□ □□□□□□□ *2000×100%*

The percentages for the rest of distribution data were obtained from the expression:

□□□□□□□□□□□=□□□□□□□□□□□ □□□□□□□ □□□□□□□□□□□ □□□□□□□ *2000×100%*

Table 1 summarizes the information extracted from the Census Blocks. The racial distribution of Miami-Dade County is characteristic for its Hispanic (greater than 50%) black and white populations (20.3 and 12.4% respectively). It is a median aged community, with around a 59% of its population older than 30 years. Households tend to be occupied in property (52.7 versus 38.4% occupied by renters) mainly by married couples, half of them with children.

The effects of a sudden SLR would be catastrophic for MDC. With an increase of only 0.5 m 28.9% of the total population would be affected, and up to 38.5 or 80.1% in the case of the most extreme scenarios. The population distribution however, seems to be unaffected by SLR. The distribution of the different characteristics for the Census 2000 remains almost constant, only slight variations are appreciated when comparing the percentages for the Census and the three SLR scenarios.

Table 1. Population distribution and affected population by the three SLR scenarios.

	Totals				Percentages			
	Census 2000	SLR scenarios 0.5m	1m	2m	Census 2000	SLR scenarios 0.5m	1m	2m
Census Blocks	30,809	5,594	8,413	22,635				
Population	2,253,362	651,872	866,635	1,805,180		28.9	38.5	80.1
Race/Ethnicity								
White	278,821	126,547	146,214	225,981	12.4	19.4	16.9	12.5
Black	457,214	79,441	114,217	287,196	20.3	12.2	13.2	15.9
Hispanic	1,291,737	377,394	514,083	1,106,788	57.3	57.9	59.3	61.3
Gender								
Males	1,088,895	315,078	420,032	872,487	48.3	48.3	48.5	48.3
Females	1,164,467	336,794	446,603	932,693	51.7	51.7	51.5	51.7
Age								
Under 5	145,752	41,125	54,786	116,226	6.5	6.3	6.3	6.4
5-17	413,461	105,446	141,745	324,875	18.3	16.2	16.4	18.0
18-21	117,697	34,468	44,894	93,102	5.2	5.3	5.2	5.2
22-29	251,036	82,097	106,222	204,950	11.1	12.6	12.3	11.4
30-39	365,408	116,170	150,716	297,885	16.2	17.8	17.4	16.5
40-49	321,010	92,779	122,684	256,340	14.2	14.2	14.2	14.2
50-64	338,446	95,103	127,156	271,591	15.0	14.6	14.7	15.0
65 Up	300,552	84,684	118,432	240,211	13.3	13.0	13.7	13.3
Households	776,774	249,947	327,908	626,181		32.2	42.2	80.6
Single Male	82,474	33,710	43,922	66,598	10.6	13.5	13.4	10.6
Single Female	98,506	38,841	50,456	79,304	12.7	15.5	15.4	12.7
Married with children	175,547	51,589	67,193	144,815	22.6	20.6	20.5	23.1
Married no children	195,351	59,792	78,325	160,235	25.1	23.9	23.9	25.6
Single Male Children	16,889	4,690	6,397	13,238	2.2	1.9	2.0	2.1
Single Female Children	70,316	19,552	26,087	53,847	9.1	7.8	8.0	8.6
House Units	852,278	288,007	374,191	688,511		33.8	43.9	80.8
Vacant	75,504	38,060	46,283	62,330	8.9	13.2	12.4	9.1
Occupied by owner	449,325	138,320	174,572	363,064	52.7	48.0	46.7	52.7
Occupied by renter	327,449	111,627	153,336	263,117	38.4	38.8	41.0	38.2

The racial distribution does not meet this behavior, particularly in the case of the black and white populations. Although the affected percentage of black population increases with increasing SLR, these values are unusually low when compared to the other almost steady distributions. From a 20.3% in the Census 2000, the percentage decreases to 12.2, 13.2 and 15.9%, a unique feature for the whole range of results. An opposite trend is observed for the white population. From an original percentage of 12.4%, the affected population in the 0.5 m scenario increases to 19.4% and decreases progressively to 16.9 and 12.5%. These behaviors suggest that there is a relationship between the racial composition of MDC's population and their presence in areas susceptible flooding by an eventual SLR.

Census Block Groups

Although Census Blocks have been aggregated into Census Block Groups in order to compare the data, as commented previously, both datasets are obtained from different types of surveys and thus, differ in their population values. As an approach to compare the income data to the different SLR scenarios (which were obtained only at the Census Blocks level), a transformation of the Census Block Groups was carried out. As a first step, the percentage of population from each aggregated Census Block Group was calculated as follows:

$$[illegible] = [illegible] \; 2000 \times 100\%$$

The result for each Census Block Group was then used to calculate the transformed population for each SLR scenario:

$$[illegible] = [illegible] \times [illegible] 100$$

Table 2,3, and 4 show the effect of the three different SLR scenarios by income level for families, non-family households and income to poverty ratios, respectively. A code of colors facilitates the interpretation of the percentage differences between the three different scenarios, showing the evolution of the affected population distribution.

There is a clear relationship between the family income and the effect of SLR (Table 2). At the scenario 0.5 m, the wealthiest families are clearly more affected than those with low incomes. A plausible explanation is that families with low incomes have residences far from the coast, where SLR is more susceptible to happen, affecting the wealthy, with properties in coastal areas. The trend is inverted in the following two scenarios (1 and 2 m) suggesting that the areas where low income families live are prone to flooding. This would match those areas with high risk of flooding and lower property values.

This effect is not so clear for the most non-family household income levels (Table 3), although a clear relationship between income and SLR effects can be established for those households with an income lower than \$10,000. It seems that this sector of society is not so localized, allowing more similarities between the income levels higher than \$10,000. In this case, a clear relationship between income and SLR effects cannot be established.

Finally, Table 4 shows the effects of SLR on groups defined by the ratio of income to poverty level. The colors (with green indicating low values and red indicating high values) show how the effects of SLR have a lower impact with lower ratios. The effect is very significant for the group with an income to poverty level of 2.0 m. This is not strange as this group comprises almost 60% of MDC.

Table 2. Family income distribution and effects of the three SLR scenarios.

	Total population values				Percentages				Percentage differences		
	Census 2000	0.5m	1m	2m	Census 2000	0.5m	1m	2m	0.5-Census	1m-0.5m	2m-1m
Total families	552,484	159,746	211,539	444,722		28.9	38.3	80.5			
Less than $10;000	50,303	12,249	18,302	38,212	9.1	7.7	8.7	8.6	-1.4	1.0	-0.1
$10;000 to $14;999	37,093	9,200	13,544	28,973	6.7	5.8	6.4	6.5	-1.0	0.6	0.1
$15;000 to $19;999	38,600	9,880	14,229	30,365	7.0	6.2	6.7	6.8	-0.8	0.5	0.1
$20;000 to $24;999	40,944	11,217	15,524	32,649	7.4	7.0	7.3	7.3	-0.4	0.3	0.0
$25;000 to $29;999	38,051	10,273	13,969	30,681	6.9	6.4	6.6	6.9	-0.5	0.2	0.3
$30;000 to $34;999	35,902	10,422	13,990	29,153	6.5	6.5	6.6	6.6	0.0	0.1	-0.1
$35;000 to $39;999	33,468	9,956	13,070	27,475	6.1	6.2	6.2	6.2	0.2	-0.1	0.0
$40;000 to $44;999	31,628	9,343	12,239	25,956	5.7	5.8	5.8	5.8	0.1	-0.1	0.1
$45;000 to $49;999	25,996	7,543	9,877	21,483	4.7	4.7	4.7	4.8	0.0	-0.1	0.2
$50;000 to $59;999	47,917	14,168	17,910	39,288	8.7	8.9	8.5	8.8	0.2	-0.4	0.4
$60;000 to $74;999	53,408	16,459	20,624	44,127	9.7	10.3	9.7	9.9	0.6	-0.6	0.2
$75;000 to $99;999	50,597	14,985	18,935	41,377	9.2	9.4	9.0	9.3	0.2	-0.4	0.4
$100;000 to $124;999	26,131	8,010	9,948	21,094	4.7	5.0	4.7	4.7	0.3	-0.3	0.0
$125;000 to $149;999	13,134	4,544	5,528	10,729	2.4	2.8	2.6	2.4	0.5	-0.2	-0.2
$150;000 to $199;999	12,503	4,586	5,488	9,989	2.3	2.9	2.6	2.2	0.6	-0.3	-0.3
$200;000 or more	16,809	6,912	8,360	13,171	3.0	4.3	4.0	3.0	1.3	-0.4	-1.0

Table 3. Nonfamily household income distribution and effects of the three SLR scenarios.

	Census 2000	0.5m	1m	2m	Census 2000	0.5m	1m	2m	0.5-Census	1m-0.5m	2m-1m
Total Nonfamily households	224,894	87,804	114,464	181,170		39.0	50.9	80.6			
Less than $10;000	62,517	19,892	28,608	48,863	27.8	22.7	25.0	27.0	-5.1	2.3	2.0
$10;000 to $14;999	23,941	8,145	11,451	19,278	10.6	9.3	10.0	10.6	-1.4	0.7	0.6
$15;000 to $19;999	18,991	6,830	9,251	15,283	8.4	7.8	8.1	8.4	-0.7	0.3	0.4
$20;000 to $24;999	16,923	6,673	8,658	13,588	7.5	7.6	7.6	7.5	0.1	0.0	-0.1
$25;000 to $29;999	14,756	5,814	7,591	12,013	6.6	6.6	6.6	6.6	0.1	0.0	0.0
$30;000 to $34;999	13,086	5,766	7,064	10,820	5.8	6.6	6.2	6.0	0.7	-0.4	-0.2
$35;000 to $39;999	11,077	4,957	6,088	9,217	4.9	5.6	5.3	5.1	0.7	-0.3	-0.2
$40;000 to $44;999	10,040	4,464	5,392	8,248	4.5	5.1	4.7	4.6	0.6	-0.4	-0.2
$45;000 to $49;999	7,650	3,321	4,090	6,215	3.4	3.8	3.6	3.4	0.4	-0.2	-0.1
$50;000 to $59;999	12,359	5,578	6,773	10,108	5.5	6.4	5.9	5.6	0.9	-0.4	-0.3
$60;000 to $74;999	11,520	5,433	6,556	9,546	5.1	6.2	5.7	5.3	1.1	-0.5	-0.5
$75;000 to $99;999	9,387	4,452	5,280	7,726	4.2	5.1	4.6	4.3	0.9	-0.5	-0.3
$100;000 to $124;999	4,785	2,438	2,840	3,945	2.1	2.8	2.5	2.2	0.6	-0.3	-0.3
$125;000 to $149;999	2,049	943	1,144	1,587	0.9	1.1	1.0	0.9	0.2	-0.1	-0.1
$150;000 to $199;999	2,254	1,182	1,391	1,815	1.0	1.3	1.2	1.0	0.3	-0.1	-0.2
$200;000 or more	3,559	1,917	2,288	2,918	1.6	2.2	2.0	1.6	0.6	-0.2	-0.4

Table 4 Ratio of income to poverty level and effects of the three SLR scenarios.

	Census 2000	0.5m	1m	2m	Census	0.5m	1m	2m	0.5-Census	1m-0.5m	2m-1m
Total population	2,209,089	634,766	845,491	1,771,162		28.7	38.3	80.2			
Under .50	178,421	45,647	65,754	134,657	8.1	7.2	7.8	7.6	-0.9	0.6	-0.2
50 to .74	95,614	22,447	33,274	72,232	4.3	3.5	3.9	4.1	-0.8	0.4	0.1
75 to .99	122,960	30,081	44,882	95,590	5.6	4.7	5.3	5.4	-0.8	0.6	0.1
1.00 to 1.24	129,472	31,714	46,375	100,758	5.9	5.0	5.5	5.7	-0.9	0.5	0.2
1.25 to 1.49	131,379	33,519	47,621	104,779	5.9	5.3	5.6	5.9	-0.7	0.4	0.3
1.50 to 1.74	119,203	31,398	43,852	94,346	5.4	4.9	5.2	5.3	-0.4	0.2	0.1
1.75 to 1.84	49,822	13,409	18,453	40,720	2.3	2.1	2.2	2.3	-0.1	0.1	0.1
1.85 to 1.99	66,688	17,608	23,749	53,596	3.0	2.8	2.8	3.0	-0.2	0.0	0.2
2.00 and over	1,315,530	408,942	521,531	1,074,484	59.6	64.4	61.7	60.7	4.9	-2.7	-1.0

Table 5. Ratio of income to poverty level and effects of the three SLR scenarios in black population.

	Census 2000	0.5m	1m	2m	Census	0.5m	1m	2m	0.5-Census	1m-0.5m	2m-1m
Total population	443,740	73,770	107,497	278,267		16.6	24.2	62.7			
Under .50	58,039	7,837	12,743	33,529	13.1	10.6	11.9	12.0	-2.5	1.2	0.2
50 to .74	28,624	3,952	6,215	17,324	6.5	5.4	5.8	6.2	-1.1	0.4	0.4
75 to .99	31,987	4,897	7,465	19,733	7.2	6.6	6.9	7.1	-0.6	0.3	0.1
1.00 to 1.24	32,832	4,798	7,524	19,725	7.4	6.5	7.0	7.1	-0.9	0.5	0.1
1.25 to 1.49	30,353	4,974	7,433	19,127	6.8	6.7	6.9	6.9	-0.1	0.2	0.0
1.50 to 1.74	26,950	4,379	6,503	17,048	6.1	5.9	6.0	6.1	-0.1	0.1	0.1
1.75 to 1.84	10,163	1,640	2,484	6,664	2.3	2.2	2.3	2.4	-0.1	0.1	0.1
1.85 to 1.99	14,895	2,254	3,252	9,160	3.4	3.1	3.0	3.3	-0.3	0.0	0.3

2.00 and over	209,897	39,039	53,879	135,957	47.3	52.9	50.1	48.9	5.6	-2.8	-1.3

Table 6. Ratio of income to poverty level and effects of the three SLR scenarios in white population.

	Census 2000	0.5m	1m	2m	Census	0.5m	1m	2m	0.5-Census	1m-0.5m	2m-1m
Total population	273,730	123,255	142,973	222,162		45.0	52.2	81.2			
Under .50	11,234	7,244	8,058	9,965	4.1	5.9	5.6	4.5	1.8	-0.2	-1.2
50 to .74	3,690	2,572	2,816	3,335	1.3	2.1	2.0	1.5	0.7	-0.1	-0.5
75 to .99	4,763	3,490	3,645	4,292	1.7	2.8	2.5	1.9	1.1	-0.3	-0.6
1.00 to 1.24	5,786	3,784	4,202	5,003	2.1	3.1	2.9	2.3	1.0	-0.1	-0.7
1.25 to 1.49	7,485	4,025	4,393	6,247	2.7	3.3	3.1	2.8	0.5	-0.2	-0.3
1.50 to 1.74	7,573	4,074	4,570	6,330	2.8	3.3	3.2	2.8	0.5	-0.1	-0.3
1.75 to 1.84	3,746	1,867	2,145	3,173	1.4	1.5	1.5	1.4	0.1	0.0	-0.1
1.85 to 1.99	4,876	2,427	2,787	4,067	1.8	2.0	1.9	1.8	0.2	0.0	-0.1
2.00 and over	224,576	93,771	110,357	179,749	82.0	76.1	77.2	80.9	-6.0	1.1	3.7

Impact on Racial Groups

The two most sensitive groups to SLR, race/ethnicity and income, were compared. No significant results were obtained for the family and nonfamily household income group, but significant differences were obtained between the white and black racial groups at the ratio of income to poverty level. The results show almost opposite results for the two racial groups, indicating that there is a relationship between socioeconomic groups and SLR; whereas 82% of white population is well above the poverty limit of poverty, more than 27% of the black population is beyond this limit.

SLR TO NFCS LINK

For the analysis of the interaction or effect of SLR on NFCs, we examined the Miami-Dade NFC point data from the Department of Environmental Resources Management (DERM). Because the data was in a point format, we would be unable to determine the area that would be affected by the SLR scenarios. In efforts to address this problem, we used the County and Municipal Park boundary shapefiles for further analysis; spatially joining the NFCs with the park boundaries and determined the areas affected by each SLR scenario. If the parks were found to be inundated only partially, they were still considered to be affected.

Impacts to NFCs

When looking at NFC data from the 1980's under the three SLR scenarios, we found that MDC's NFCs and parks are threatened by SLR. There are 698 NFCs and 741 county and municipal parks in MDC. NFCs are found within 27 MDC parks. SLR scenarios of 0.5 m, 1.0 m, and 2.0 m will affect 1 %, 2.29 %, and 17.19 % of NFC's, respectfully, and 20 %, 51.85 %, and 85.19 % of parks containing NFCs (Table 7 and Table 8, Figure 4 through Figure 8). Figure 4 shows the dramatic increase in affected acreage of NFCs after a 2.0 m SLR. This demonstrates the topology of MDC, with flat expanses of low-lying elevations.

These NFCs and parks support rare and endemic species that are unique to South Florida. Though many of these fragments are under protection from Miami-Dade DERM, there may be no way to save those parks directly along the coast from transitioning into a more saline/wetland community from what it is today. With urban development abutting the coast, species with limited dispersal abilities may not be able to migrate on their own to higher ground. This may lead to increased threat and even extinction of some of South Florida's most vulnerable species (Saha et al, *in press*).

Table 7. Natural Forest Communities affected by SLR scenarios.

SLR scenarios	# NFCs affected	% NFCs affected	Acreage NFCs affected	% Acreage NFCs affected
0.5 m	7	1.0	69.39	2.58
1.0 m	16	2.29	87.77	3.26
2.0 m	120	17.19	577.7	21.48

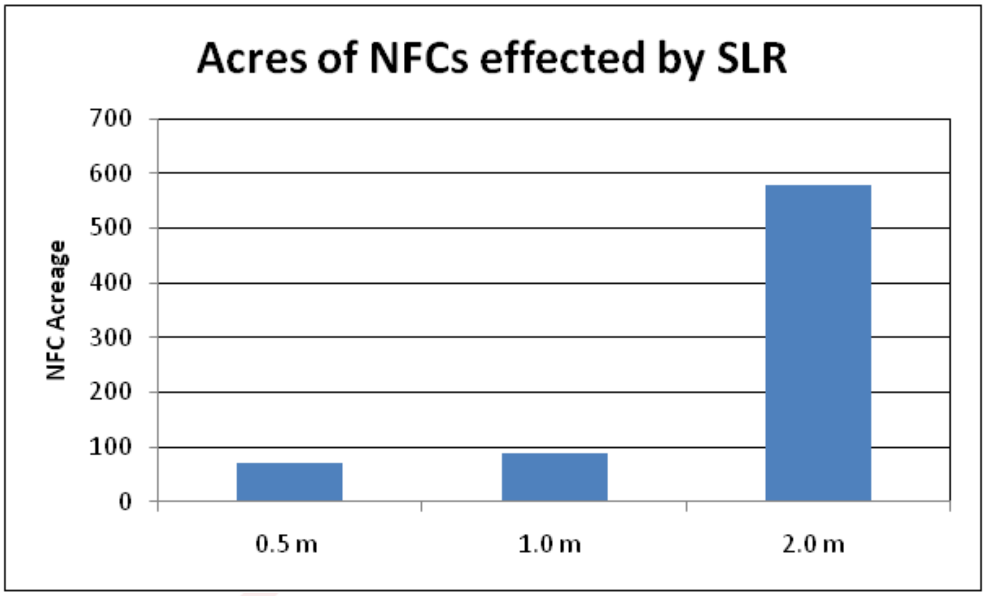

Figure 4. Acres of Natural Forest Communities affected by SLR scenarios.

Table 8. MDC and municipal parks affected by SLR scenarios.

SLR scenarios	# Parks w/ NFCs affected	% Parks w/ NFCs affected	Acreage parks w/ NFCs affected	% Acreage parks w/ NFCs affected
0.5 m	6	22.22	1745.47	43.11
1.0 m	14	51.85	3301.9	81.56
2.0 m	23	85.19	13706.51	97.13

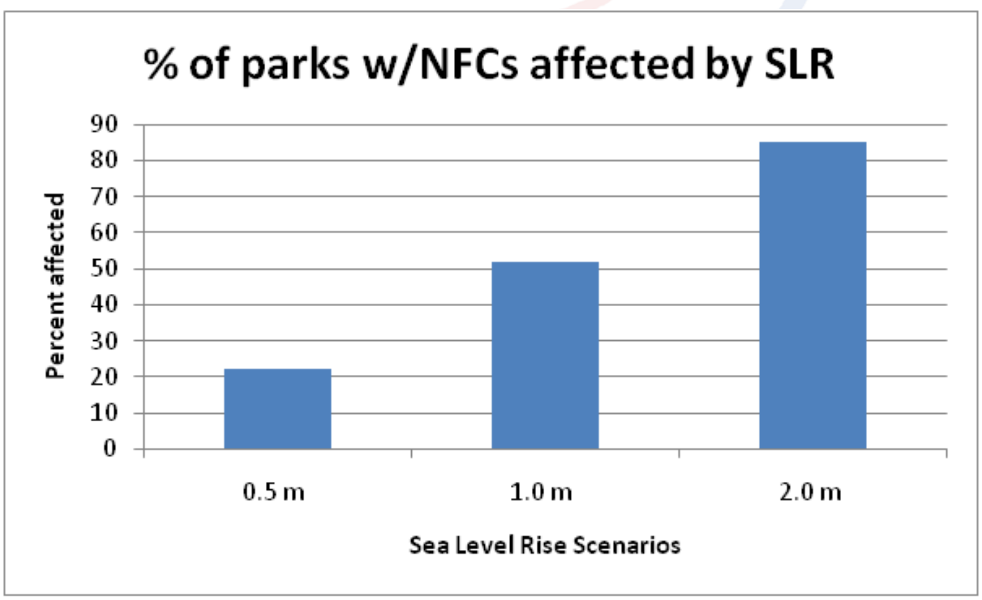

Figure 5. Percentage of parks with Natural Forest Communities affected by SLR scenarios.

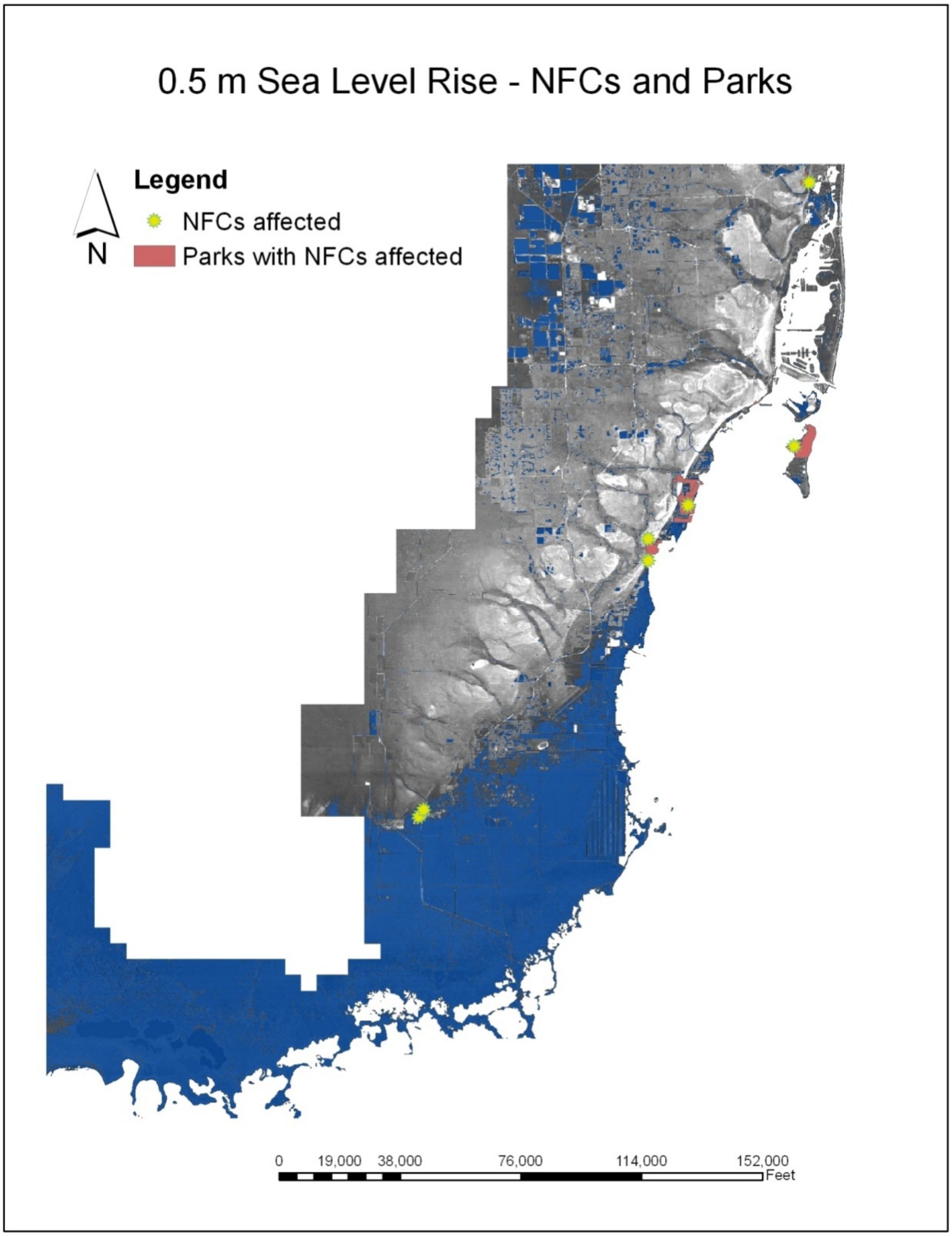

Figure 6. Natural forest Communities and parks containing NFCs affected by a 0.5 m SLR scenario.

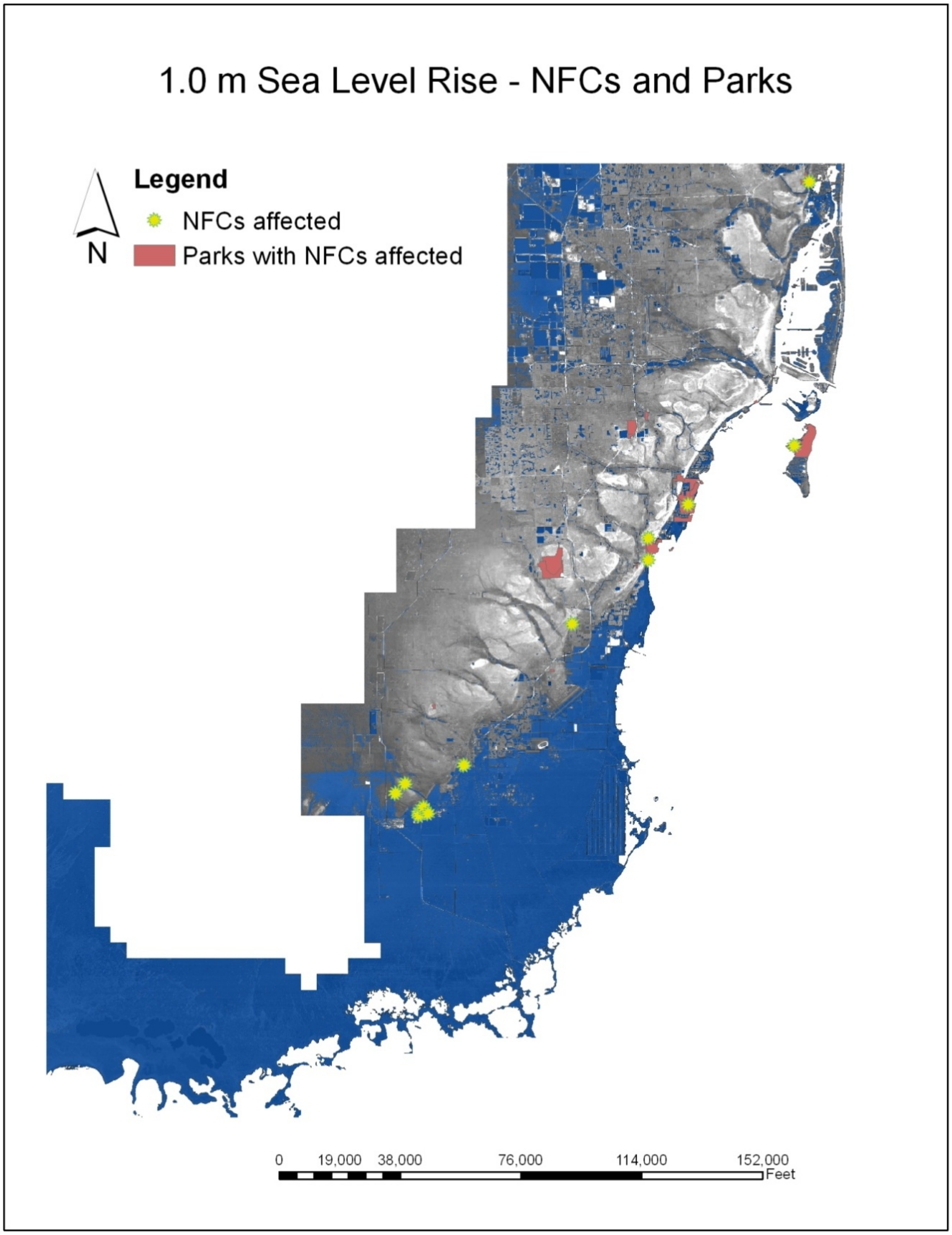

Figure 7. Natural forest Communities and parks containing NFCs affected by a 1.0 m SLR scenario.

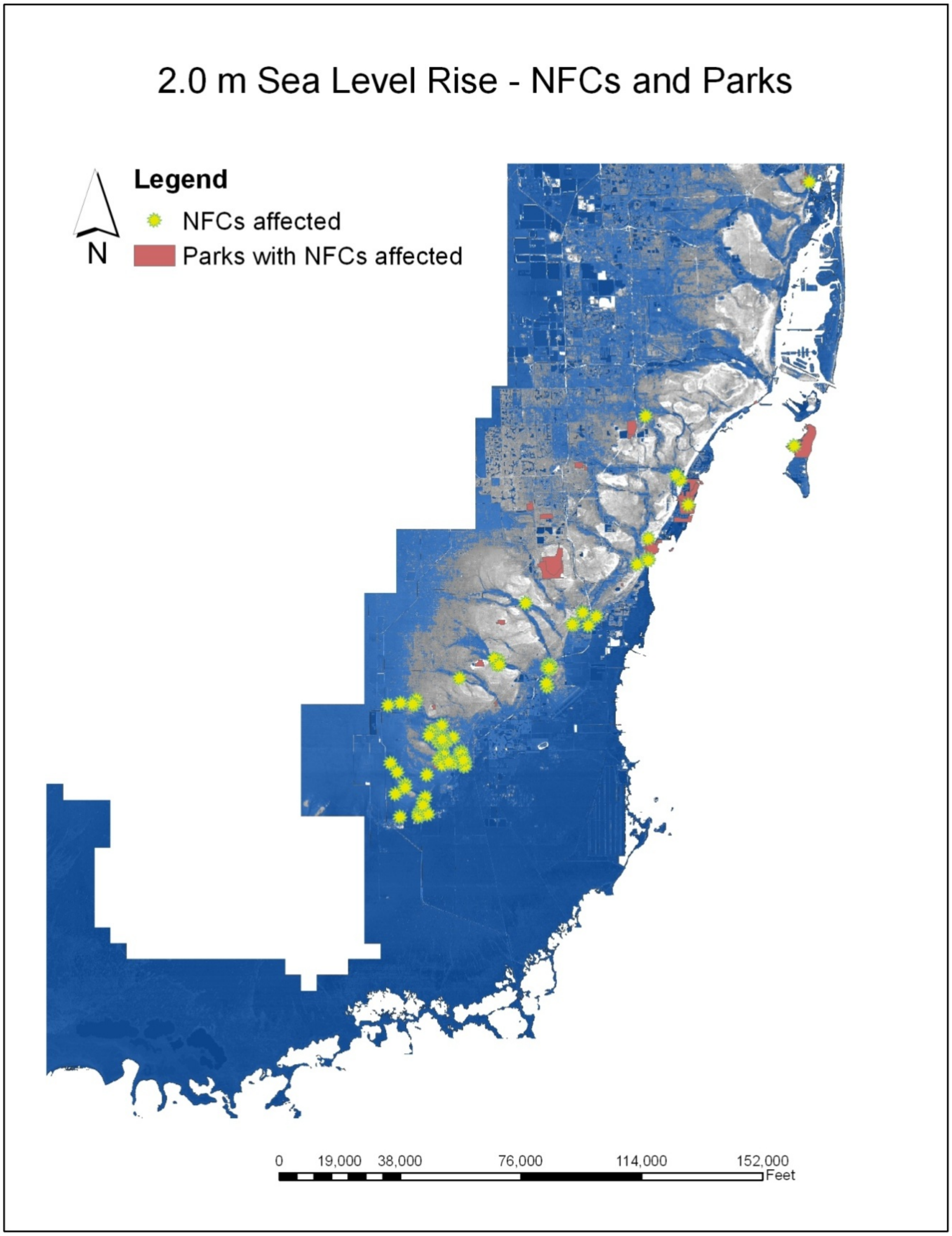

Figure 8. Natural forest Communities and parks containing NFCs affected by a 2.0 m SLR scenario.

HUMANS TO NFCS LINK

The analysis for the interaction between NFCs and Humans was performed in conjunction with the analysis for the interaction between SLR and NFCs. Parks and recreational areas provide the community with green space which can improve urban quality of life. To understand the impact of SLR on these important areas, the number of parks which contain NFCs and are affected by the SLR scenarios was determined. In addition to the data from these files, we used the September 2010 acquisition project list from the Environmentally Endangered Lands (EEL) program to see if any of the parks were acquired or managed by the program (Endangered Lands Acquisition Project list). We performed further research into the MDC sustainability programs available on the MDC website.

Out of the 741 County and Municipal Parks, we found that 27 parks contain NFCs. Of these 27 parks, 20 would be affected by the 2.0 m SLR scenario. Of these 20 parks, 15 parks have been acquired or are managed by the EEL program. There are 5 parks that are not found to be affected by any of the SLR scenarios but are managed or acquired by the EEL program.

Out of the 741 County and Municipal Parks, we found that 16 % would be affected by the 0.5 m SLR scenario, 25 % would be affected by the 1.0 m scenario, and 39 % would be affected by the 2.0 m scenario (Table 9). In terms of acreage, up to 10,866.13 acres would be affected. More than 35 % of the parks affected by the 2.0 m scenario are less than 5 acres and are mainly small neighborhood parks; this explains why there is not a more drastic increase in affected acreage from 1.0 m to 2.0 m SLR (Table 9). The largest park, Crandon Park, which is more than 900 acres, is located in Key Biscayne and is affected by the lowest SLR scenario. The EEL program manages 444 acres of Crandon Park (Endangered Lands Acquisition Project list).

Table 9. Summary of the park analysis.

SLR scenario	Number of parks affected (out of 741)	Acres of parks affected
0.5 m	118	9,009.3
1.0 m	186	9,858.5
2.0 m	289	10,866.1

MDC Sustainability Initiatives

The Environmentally Endangered Lands (EEL) program was initiated in 1990 as a trust fund (Division 3. – Environmentally Endangered Lands Program) that would be used to acquire and manage lands with features that make them worthy of preservation. These features include endangered species, endemic species, habitat for endangered or endemic species, and natural geologic features unique to the region. Once lands are given EEL status, a ten year management plan must be approved and renewed at least every five years. The Board of County Commissioners has the final word on how EELs will be handled if there is competition for land uses; thus, it is not impossible for an EEL acquisition to be overturned to development. However, reversal of EEL acquisition decisions are unlikely to be a problem because most EEL protected lands are in low-lying areas that are already vulnerable to inundation, which is in agreement with our analysis that most of the parks containing NFCs are likely to be affected by SLR but are also under EEL protection. These areas, in comparison to higher ground, would not be in competition for development as SLR manifests itself. As of September 2010, the EEL program has acquired or manages over 23,000 acres of land (Endangered Lands Acquisition Project list).

The Climate Change Advisory Task Force (CCATF) was created in 2006 and includes scientists, consultants, business representatives, city planners, and other experts. The CCATF's recommendations become part of the County's sustainability program called GreenPrint (Climate Change Advisory Task Force). MDC's GreenPrint assessed the CCATF's estimate of at least 0.45 m to as much as 1.52 m SLR by the end of the century and the current state of the Biscayne aquifer related to salt water intrusion (Milestone 1: Sustainability Assessment Report 2010). GreenPrint is in the process of formalizing an interagency working group to address issues related to salt water intrusion, monitoring the intrusion line, continuing support for the EEL program, examining the effect of SLR on vulnerable facilities (e.g., wastewater utilities), and the incorporation of climate change scenarios into maps, models, and other tools to aid MDC planning for the future (GreenPrint Implementation Table 2010).

MDC is also part of a regional compact called the Southeast Florida Regional Climate Change Action Plan. The compact was signed in 2009 and in addition to MDC includes Broward, Palm Beach, and Monroe Counties (Southeast Florida Regional Climate Change Compact). The compact calls on the four counties to collaborate in efforts to bring federal interest and funding to the Southeast Florida region for its vulnerability to the effects of climate change. The compact also calls for coordinated preparation for SLR and amplified tropical storm impacts.

Due to the importance of green space and recreational areas, a major goal of urban vegetation management is to improve the quality of life for residents. One of the drafted initiatives for implementation by GreenPrint is the conversion of "redfields to greenfields," which converts commercially distressed or vacant lots into urban parks (GreenPrint Implementation Table 2010). Even if the green space does not contain special features that would qualify it for EEL protection, the recreational space and vegetation for the enjoyment of urban residents make neighborhood parks worth maintaining.

MDC's management and adaption strategies related to climate change issues, paints a positive picture for the protection of natural forest communities and urban green space. The high level of collaboration between the Southeast Florida counties and between agencies at the County, State, and Federal levels in the GreenPrint implementation strategies is a positive beginning. Still, the real test for these sustainability initiatives is their implementation, which is yet to be seen.

CONCLUSIONS

Predictions for SLR were implemented for Miami-Dade County in order to evaluate the effects on human populations and natural forest communities. As with many vulnerable coastal areas, MDC will soon face tough decisions regarding the protection of its acreage from an encroaching sea. MDC will struggle to find balance between preserving lands for economic value or profit, societal equality or land rights, and for the protection of that which has no rights: the natural environment. This study provides an overview of some of the systems affected by SLR and the interactions between them. The following conclusions can be made from the four linkages.

The direct impact of SLR on the hydrology of MDC will be immediately visible with flooding. Inundation will initially occur in low lying coastal areas such as the highly developed islands in the northern Biscayne Bay area and the uninhabited coastal wetlands in southern MDC. As SLR increases, flooding will continue to threaten low lying areas, and more freshwater flooding will occur inland. Continued SLR will result in extensive flooding of MDC with only “islands” of dry land on the Miami Rock Ridge. SLR also threatens the health of MDC’s potable water supply due to the intrusion of saline waters into the aquifer. The extent of the increased saltwater intrusion could reach over 914 meters inland.

MDC’s total population of over 2.25 million will be dramatically affected by SLR. With an increase of only 0.5 m, the sea will claim 5,594 Census Blocks, affecting the lives of about 652,000 people. A SLR of 1.0 m will affect about 867,000 people and a SLR of 2.0 m will affect over 1.8 million people. The SLR scenarios seem to affect population groups based on race. This could suggest a racial distribution of the population according to elevation above sea level. Strange though this trend may seem, it is actually a logical interpretation as the more urbanized areas, which tend to have more historically black neighborhoods, fall along the raised Miami Rock Ridge—a limestone outcrop where much of Southeast Florida’s development has occurred.

SLR will affect the NFCs of MDC by flooding and isolating their habitat. In MDC, NFCs are mostly discontinuous due to development and urban expansion. SLR can increase the discontinuity between NFCs by flooding corridors of community migration. Under 0.5 m and 1.0 m SLR scenarios, mostly coastal NFCs and parks will be affected by flooding with a few exceptions for the communities which fringe the wetlands in southern MDC. However, a 2.0 m SLR will affect NFCs and parks more inland, including those in areas of lower elevation.

MDC acknowledges that climate change and SLR are real problems that require planning ahead and preparing a solid infrastructure to handle the impacts that the County will experience. MDC has been proactive in initiating plans in response to climate change and SLR. There are several programs aimed at protecting natural areas and to address planning for climate change. There is potential that MDC will follow through with these programs and not allow development on natural areas. However, it would require that these programs work together and that the governmental powers controlling these programs are not swayed by politics or diverge funding away from the programs in order for implementation of plans to be successful. Public pressure for preserving natural areas has been positive and an added encouragement for these programs to continue.

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No. 0055

Title:
An analysis of the landscape ecological effects of land-use changes in Dongshan River basin, Taiwan

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Topic: Environmental Sustainability & Environmental Management: Land Use & Misuse

An analysis of the landscape ecological effects of land-use changes in Dongshan River basin, Taiwan

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ABSTRACT

Dongshan River, located in the northeast part of Taiwan, was once notorious for its frequent floods before the 1970's. After a river reconstruction project along its middle and downstream sections, Dongshan River Park has become one of the most popular scenic areas in Taiwan since its opening in 1994. Dongshan River Park has successfully boosted local tourism and economic growth, however, the land uses in Dongshan River basin has also been changed dramatically from agricultural to recreational areas in the past decade. From the point of view of sustainable management, we need to pay close attention to these changes in land uses and the environmental issues involved. The purpose of this study is to apply the approach of landscape ecology in conducting a preliminary analysis of the spatiotemporal transition of all land-uses in Dongshan River basin after a period of tourism development. It is attempted to look into the whole landscape change in the river basin and its implications of ecological effects. FRAGSTATS, a computer software program working with ArcGIS, is used as a tool to compute landscape metrics. Selected metrics are calculated and compared with two land-use maps: the year of 1987 and 2003. The land use in the river basin is classified into six categories: paddy field, high-density vegetation, low-density vegetation, water, sandy beach, and built-up land. The result shows that, from 1987 to 2003, 5% of paddy field (about 300 hectares) had been replaced by the built-up land, which included the booming guest houses and the site of a traditional arts center. The other major change in the river basin landscape is a large increase in both the area and number of built-up patches. The result also shows a great tendency of disaggregation in built-up land. Finally, the ecological implications of these changes are discussed.

Keywords: landscape ecology, land use changes, GIS

INTRODUCTION

Dongshan River is located in Yilan County in the northeast part of Taiwan. It was once notorious for its frequent floods before the 1970's. After a river reconstruction project along its middle and downstream sections, Dongshan River Park has become one of the most popular scenic areas in Taiwan since its opening in 1994 (Yilan County Government, 2002). Dongshan River Park has successfully boosted local tourism and economic growth, however, the land uses in Dongshan River basin has also been changed dramatically from agricultural to recreational areas in the past decade. The change in land use can cause significant impact on the surrounding ecological environment; therefore, it is necessary to understand the spatial dynamics of ecosystem to ensure its ecological functions (Fang, et al., 2005).

Landscape ecology has become the fastest growing sub-discipline of ecology, since Troll, a German geographer, first proposed the concept in 1939 (Wu, 2003). It has been extensively applied to explore the relationships between land-use changes and ecological processes in specific ecosystems. In the past decades, the approach of landscape ecology has been applied to a wide range of problems, from the change of a single landscape pattern, the landscape and biodiversity protection, nature reserves management, to urban planning. It provides an important methodology for studying the relationship between land-use changes and ecological consequences. By using the quantitative methods, it is allowed to analyze the spatiotemporal transition of a landscape pattern or ecological processes (Turner and Gardner, 1991).

In general, landscape fragmentation is the main consequence of the disturbing process of land development on ecosystems. It can be induced by either natural or human agents, and has a negative impact on many species of plants and animals and on ecological processes (Farina, 1997). It increases the vulnerability of isolated patches to external disturbance, and threatens the sustainability of habitats and biodiversity (Nilsson and Grelsson, 1995). Therefore, from the point of view of sustainable management, we need to pay close attention to the changes in land uses in Dongshan River basin and the environmental issues involved.

Yilan County has been famous for its vast expanse of paddy landscape. The transformation of agricultural land to other land uses has been a key issue for the land-use management in Yilan County; and the rapid change in its rural landscape in recent years has drawn much attention from the public. Thus, the purpose of this study is to apply the approach of landscape ecology in conducting a preliminary analysis of the spatiotemporal transition of all land-uses in Dongshan River basin after a period of tourism development. It is attempted to look into the whole landscape change in the river basin and its implications of ecological effects.

It is a part of a study for the broader assessment of landscape change in Dongshan River basin.

METHODS

Study Area

Dongshan River is located in the northeast part of Taiwan and is the fifth longest river (25.3 km) in Yilan County (Yilan County Government, 2002). The study area includes the middle and downstream areas of Dongshan River, approximately covering Dongshan and Wujie two townships. Dongshan River contains some of the richest farming land in Yilan County. This area was mainly agricultural areas (mainly for rice cultivation) before the development of Dongshan River Park in the 1990s. It flows northeastward through the Lanyang plain before emptying into the Pacific Ocean. Elevation ranges from 3 to 15 meters above mean sea level.

Analysis Tool and Maps

FRAGSTATS is a computer software program designed to compute landscape metrics for categorical map patterns (McGarigal, Cushman, Neel, and Ene, 2002). It was used as an analysis tool for this study. Selected metrics were calculated and compared with two land-use maps: the year of 1987 and 2003 (Figure 1), which were derived from digitizing the hard copies of land-use map provided by National Land Survey and Mapping Center, Taiwan. They were further converted into ArcGrid format for metrics computation with FRAGSTATS. The land use in the river basin was classified into six classes: paddy field (1), high-density vegetation (2, woods and wind-breaking forest), low-density vegetation (3, bush and dry farms), water (4, river and fish ponds), built-up land (5), and sandy beach (6).

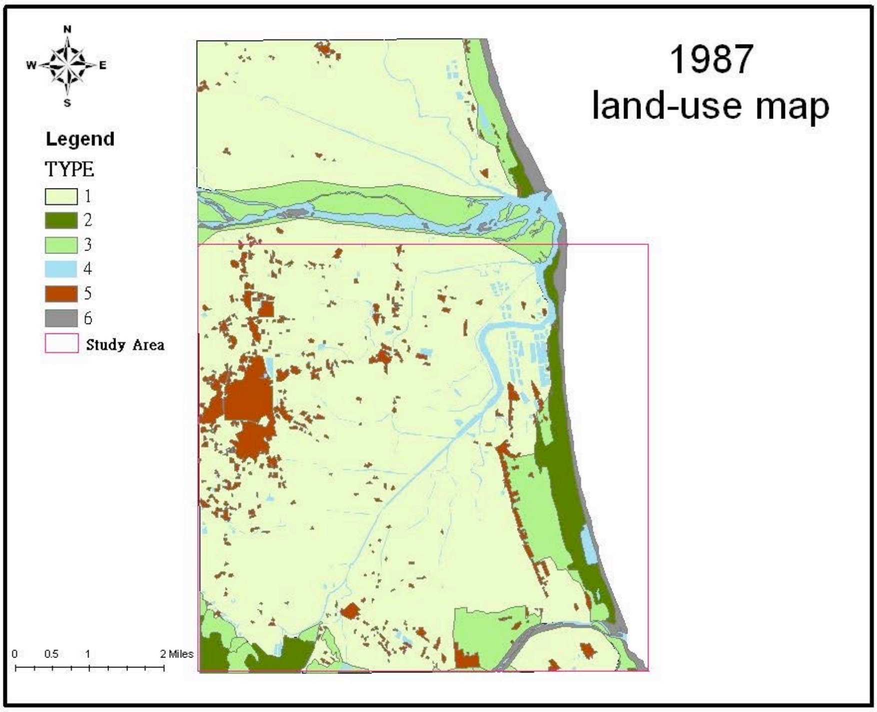

Figure 2. Land-use map of the study area in 1987

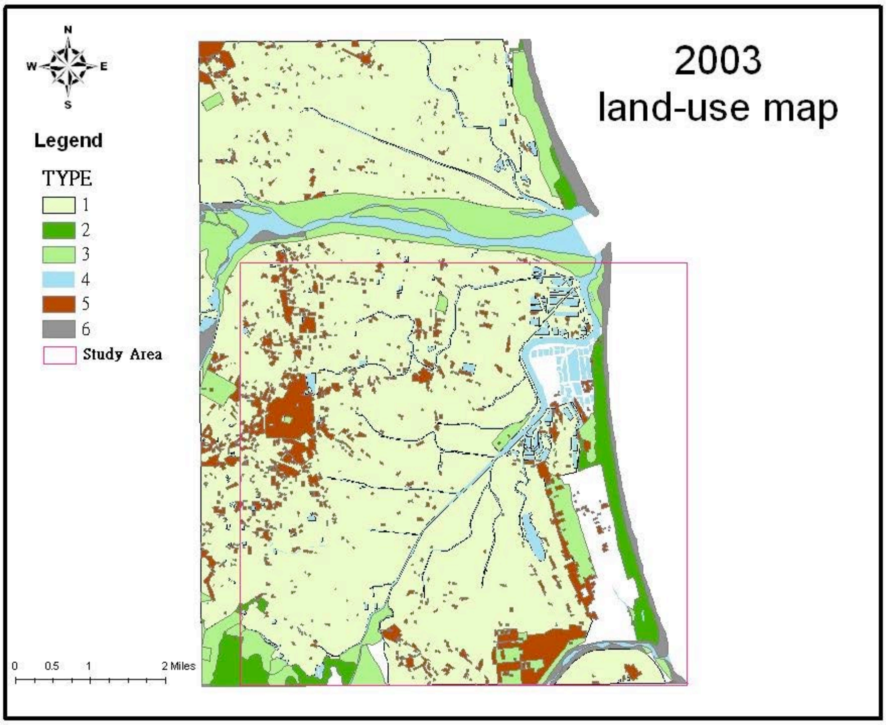

Figure 3. Land-use map of the study area in 2003

RESULTS

To give a basic overview of the land-use change in Dongshan River basin, a set of metrics concerning the area, number and shape of patch types (land uses) are selected for analysis. The results reveal the landscape structural change in river basin from 1987 to 2003.

Change in Class Area and Percentage of Landscape

The area of each patch is perhaps the single most important and useful piece of information contained in the landscape (McGarigal, Cushman, Neel, and Ene, 2002). Class area (CA) is the total areas of all patches of the corresponding land-use type. Percentage of landscape (PLAND) represents the proportion of the landscape occupied by certain land-use type (class). As shown in Table 1 and 2, paddy field is the land-use type dominating the river basin. It occupied almost three fourth of the landscape. However, it decreased by 5% in CA, that is, about 300 hectares of paddy field had lost from 1987 to 2003. The other major land-use change was the rapid increase of built-up land. It increased by 449% in CA and 471% in PLAND, although it still accounted for less than 10% of the landscape in 2003.

Table 1. Class Area (ha)

1987		2003		Change
Low-density vegetation	574.92	Low-density vegetation	440.05	-23%
Paddy field	5943.61	Paddy field	5642.31	-5%
Sandy beach	547.28	Sandy beach	135.41	-75%
High-density vegetation	314.53	High-density vegetation	307.09	-2%
Built-up land	128.19	Built-up land	704.22	449%
Water	423.97	Water	408.19	-4%

Table 2. Percentage of landscape (%)

1987		2003		Change
Low-density vegetation	7.25	Low-density vegetation	5.55	-23%
Paddy field	74.93	Paddy field	71.13	-5%
Sandy beach	6.90	Sandy beach	1.71	-75%
High-density vegetation	3.97	High-density vegetation	3.87	-2%
Built-up land	1.62	Built-up land	8.88	449%
Water	5.34	Water	5.15	-4%

Change in the Number of Patches and Patch Density

The most significant change in the number of patches (NP) was the increase of built-up land from 7 to 644, increasing 9100% (Table 3). There were also increases in low-density vegetation, paddy field, and water land. On the contrary, the NP of high-density vegetation land decreased from 235 to 5, and sandy beach decreased from 312 to 3. This result is reflected in a similar change in the patch density (PD, Table 4).

Table 3. Number of Patches

1987		2003		Change
Low-density vegetation	13	Low-density vegetation	19	46%
Paddy field	4	Paddy field	19	375%
Sandy beach	312	Sandy beach	3	-99%
High-density vegetation	235	High-density vegetation	5	-98%
Built-up land	7	Built-up land	644	9,100%
Water	20	Water	271	1,255%

Table 4. Patch Density (# / 100 ha)

1987		2003		Change
Low-density vegetation	0.16	Low-density vegetation	0.25	52%
Paddy field	0.05	Paddy field	0.25	394%
Sandy beach	3.93	Sandy beach	0.04	-99%
High-density vegetation	2.96	High-density vegetation	0.07	-98%
Built-up land	0.09	Built-up land	8.43	9,460%
Water	0.25	Water	3.55	1,308%

Change in Total Edge and Edge Density

Total edge (TE) is the sum of the lengths of all edge segments of the corresponding land-use type, and edge density (ED) is the total edge divided by the total landscape area. As shown in Table 5 and Table 6, all land uses increased in TE and ED, excluding sandy beach and high-density vegetation land.

Table 5. Total edge (m)

1987		2003		Change
Low-density vegetation	54962.5	Low-density vegetation	59137.5	8%
Paddy field	372125	Paddy field	426987.5	15%
Sandy beach	182862.5	Sandy beach	22162.5	-88%
High-density vegetation	205900	High-density vegetation	22512.5	-89%
Built-up land	27462.5	Built-up land	269687.5	882%
Water	32662.5	Water	190512.5	483%

Table 6. Edge density (m/ha)

1987		2003		Change
Low-density vegetation	6.93	Low-density vegetation	7.74	12%
Paddy field	46.91	Paddy field	55.91	19%
Sandy beach	23.05	Sandy beach	2.90	-87%
High-density vegetation	25.96	High-density vegetation	2.95	-89%
Built-up land	3.46	Built-up land	35.31	920%
Water	4.12	Water	24.95	506%

Change in the Landscape Shape Index

As indicated by McGarigal, Cushman, Neel, and Ene (2002), landscape shape index (LSI) equals the total length of edge (or perimeter) of corresponding class divided by the minimum length of class edge (or perimeter) possible for a maximally aggregated class. It provides a simple measure of class (land use) aggregation, that is, the increase of LSI value implies that the patch type becomes more disaggregated. The result shows that water and built-up land became more disaggregated in a relatively greater rate than other land uses from 1987 to 2003 (Table 7).

Table 7. Landscapes shape index (LSI)

1987		2003		Change
Low-density vegetation	6.35	Low-density vegetation	8.40	32%
Paddy field	12.63	Paddy field	14.91	18%
Sandy beach	19.57	Sandy beach	7.90	-60%
High-density vegetation	29.12	High-density vegetation	4.96	-83%
Built-up land	8.67	Built-up land	26.90	210%
Water	4.4	Water	27.58	527%

DISCUSSION

The land uses in Dongshan River basin has been changed dramatically from agricultural to recreational areas in the past decade. Although paddy field is still the land-use type dominating the river basin, tourism development may have caused a significant change in its landscape structure. From 1987 to 2003, 5% of paddy field (about 300 hectares) had been replaced by the built-up land, which included the booming guest houses and the site of a traditional arts center, a popular tourism destination in northeast Taiwan now. The other major change in the river basin landscape is a large increase in both the area and number of built-up patches. The result also shows a great tendency of disaggregation in built-up land. On the contrary, the area and patch number of high-density vegetation and sandy beach decreased, and both of them became more aggregated. The construction of an industrial park was perhaps the main contributor to the decrease of high-density and low-density vegetation area. However, the cause of the loss of sandy beach needs to be further investigated.

Apart from the consideration of agricultural production, the preservation of the ecological, aesthetic and cultural values of agricultural lands in Dongshan River basin has drawn much attention from the public. There has been a great deal of research on the ecological function and value of agricultural lands. For example, Joan *et al.* (2000) indicate that bird species richness is positively correlated with agricultural areas, and negatively correlated with urban areas. Some research in Taiwan shows that the area and number of agricultural patches are negatively correlated with the evenness of avian communities (Chiang and Chang, 2004). As a result, it is suggested that the ecological effects of the land-use changes need to be further assessed, and the future policy of land-use management in Dongshan River basin must take into account the ecological implications of these changes.

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The Impacts of Thai Household Smoking Spending on Expenditure Patterns and Health Care Costs

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Abstract

The research aims to explore the effects on Thai household expenditure patterns and to estimate its health care costs stemming from smoking tobacco products. The research employed the panel data household survey ranged by 2006 – 2007, surveyed by the National Statistic Office (NSO). The Fractional Logit model is set up to assess impacts on household expenditure patterns caused by its tobacco expenditure. The recycling method is also applied to estimate the marginal effect caused by a change in household's tobacco expenditure. The exposure to environment tobacco smoke (ETS) concept is employed to set up the log-linear model to estimate households' health care cost resulting in its tobacco product expenditure

The results show that, for the entire and rural households, their tobacco expenditure has positively relationship and statistically significant to all other expenditure categories. However, for urban household, only decoration spending category is not statistically significant with their tobacco expenditure. The log-linear model based on the ETS concept is set up to estimate the health care cost. The cost has positive relationship and statistically significant to the households' tobacco expenditure. For each THB increasing (decreasing) in tobacco expenditure, the health care cost will be raised (lessen) by THB 60.30 (USD 1.66), THB 83.77 (USD 2.31) and THB 50.96 (USD 1.41) for all, urban and rural household types, respectively. The policy recommendations are suggested by that policy campaign on reducing smoking should be more intensively supported, especially on the rural households. In addition, educating young people who persistent tobacco consumed with high volume to concern smoking harmful should be immediately implemented.

Keywords: Thai household tobacco expenditure, Fractional Logit model, Health care cost

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The Impacts of Thai Household Smoking Spending on Expenditure Patterns and Health Care Costs

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1. Introduction

Smoking would be a prevail problem in developing countries. The recent Thailand smoking survey by the Global Adult Tobacco Survey (GATS) in 2009 reveals that total current smoker is 12.5 million persons (23.7 per cent of total adult population) who have monthly expenditure on tobacco THB 575.7 (USD 16.77)[2], corresponding to the Thai National Statistics Office (NSO) survey on Thai people smoking behavior that current smokers daily consume 4.1 cigarettes. The survey also reveals that the poorest Thai household group has annual smoking expenditure is THB 6,921 (USD 201.57), equal to 13.55 per cent of their total income. In addition, the latest survey by NSO in 2010 reveals national Thai household has average monthly expenditure about THB 16,255 (USD 512.34) classifying into main items: the food and beverage including alcohol item by 33.5 per cent, the tobacco item by 1.40 per cent and the medical care cost item by 1.99 per cent. As comparing to studies from other countries reveal high percentage spending of tobacco expenditure. For instance, China, the share of total expenditures devoted to tobacco and alcohol was 9.9 percent of total expenditures (Song, Luo et al., 1998). Studies from New Zealand and Mexico indicate that expenditure on tobacco was about 9–22 per cent of households' total income (Thomson, Wilson et al., 2002; Vazquez-Segovia, Sesma-Vazquez et al., 2002). The United States, smoking expenditure was about 4 percent of total expenditures on tobacco (Busch, Bonet et al., 2005). By economics principle, the limited resource is a major essence leading to opportunity cost. This means spending on tobacco also has an opportunity cost because other desired goods or services must be foregone. Next, tobacco spending affects not only the smoker's consumption of other goods and services, but also consumption by other family members. (Wang, 2006) Lastly, smoking behavior has impact on health in a fashion that smoking may also result in ''indirect costs'' to households, particularly excess medical expenditure for treatment of smoking related diseases and conditions, as a result of both active smoking and exposure to *environmental tobacco smoke (ETS)* among other family members, especially households in developing countries. (Xin et al., 2009) Therefore, the objectives of the study are to examine the impact of Thai households' tobacco expenditure on other their expenditure and to estimate their health care cost resulting from smoking behavior. The paper is organized as follows. The review of related literatures is presented, followed the methodology and model specification. Next, data collection, data facts and method of estimation are introduced, followed by the empirical results and discussion. The summary and concluding remarks are in the last sections.

2. Review of Related Literatures

2.1 Review on Consumption patterns of food, tobacco and beverages

[2] Official exchange rate (FX) in 2009 is 34.3351 THB per USD; FX in 2010 is 31.7270 THB per USD

Selvanathan (2006) considers the consumption patterns of food, tobacco, soft drinks, and alcohol in 43 developed and developing countries. Such an analysis is important for policy issues associated with tobacco, alcohol, and soft drinks. The results show that consumers in the developing countries spend a much higher proportion of their income on food than consumers in developed countries. The proportion of expenditure allocated to the other three commodities, tobacco, alcohol, and soft drinks, are similar in the two groups of countries. On average, people around the world allocate about one quarter of their income on food, 2.6% on tobacco, 3.2% on alcohol and 1.2% on soft drinks. The income elasticity estimates reveal that food is a necessity in most countries, while tobacco and alcohol are necessities in most of the developed countries and luxuries in a majority of developing countries. Soft drinks are a luxury in a majority of the developing as well as the developed countries. The own-price elasticity show that demand for all four commodities is price inelastic in all countries.

2.2 Review on tobacco spending on household expenditure patterns

Wang (2006) examines the impact of tobacco spending on household expenditure patterns in rural China. China is a low-income country with a high prevalence of smoking, especially among men. The data, a sample of 4538 households, are from a household survey conducted in six townships in two provinces in rural China. Fractional Logit (Flogit) model is used as the estimation method. We estimate the relationship between tobacco spending and spending on 17 other categories, controlling for socio-economic and demographic characteristics of the household. The results indicate that spending on tobacco affects human capital investment (e.g. education and health), future farming productivity (e.g. farming equipment and seeds), and financial security (e.g. saving and insurance). Smokers also tend to spend more on alcohol, thus exacerbating the impact of addictive substances on spending on basic needs. Smoking expenses can harm other family members by reducing expenditures on basic needs such as foods, utilities, and durable goods consumption. Thus smoking can have important intra-family distributional impacts.

Xin (2009) study the impact of smoking and quitting on household expenditure patterns and medical care costs in China. Smoking remains very common in Chinese men, and the economic burden caused by cigarette consumption on smokers and their families may be substantial. Using a large nationally representative household survey, the third National Health Services Survey (NHSS, 2003), we estimated the economic impact of smoking on households. Methods: Smoking status of all household members (over 15 years) was collected by interview for the NHSS, and households classified into one of seven categories based on their smoking status. Information on household income and expenditure, and use of health services was also obtained. We assessed both the ‘‘direct’’ costs (reducing funds available for spending on other commodities such as food, education, medical care, etc, using a fractional logit model), and ‘‘indirect costs’’ (increasing medical expenditures, using a log-linear model). The Results showed that every five packets of cigarettes consumed per capita per month reduces household spending on other commodities, most notably on education (by about 17 yuan per capita per annum) and medical care (11 yuan). The effects are greatest among low-income rural households. Households with quitters spend substantially more on medical care than never-smoking households (64 yuan for households with two or more quitters). Conclusions: If a household member smokes, there is less money available for commodities such as education and medical care. Medical care expenditure is substantially higher among households with quitters, as ill-health is the main reason for quitting smoking in China. Smoking impoverishes a substantial number of poorer rural households.

2.3 Review on Economic Burden of Smoking-Related Disease

Jittrakul Leartsakulpanitch (2006) estimates the direct out-of-pocket medical costs of treating major diseases attributable to smoking in Thailand. A prevalence-based, disease-specific, approach was used to estimate the direct medical costs of treating lung cancer, chronic obstructive pulmonary disease (COPD), and coronary heart disease (CHD) attributable to smoking. Epidemiological parameters were obtained from the literature; historical out-of-pocket cost data were used to estimate 2006 expenditure. Results indicate that the out-of-pocket expenditures for treatment were 368.49 million THB for lung cancer, 7,714.88 million THB for COPD, and 1,773.65 million THB for CHD. Total smoking-attributable out-of pocket medical costs amounted to 9,857.02 million THB, 0.48% of GDP in 2006. The conclusions are that the health and economic impact of smoking in Thailand are substantial, and should be reduced by implementing smoking cessation and related tobacco control policies of the types found effective in reducing the prevalence of smoking in other countries.

3. Methodology and Model Specification

3.1 Smoking spending impacts on expenditure patterns

To estimate how household spending on tobacco affects spending on other goods and services when controlling for other household characteristics, a standard approach such as ordinary least squares (OLS.) normally will be applied. However, as our dependent variable is the per cent of total expenditure allocated to each expenditure category, by using the OLS estimation, the predicted values obtained might be outside the feasible range. To avoid this problem, *the Fractional Logit (Flogit) model* is rather applied to predict the effect of smoking on household expenditure patterns when controlling for other factors (Papke and Wooldridge, 1993; Mullahy and Stinnett, 2001). Using the Flogit model, the predicted values of these percentages will be bounded by the unit interval [0,1]. Therefore, the following model describing the predicted impacts of the household tobacco spending on each household expenditure category: Twelve categories including tobacco expenditure item of household spending are obtained and the following model on each expenditure categories, except for the tobacco spending is then estimated to predict the household tobacco consumption effects:

□□=□□□□□□□−□□□□=□□+□□□□+□□

∂□□□∂□=□□□□□−□□□+□□

Where L represents the logit function, Y represents the percentage of expenditures spent on each of our 12 categories, X represents tobacco consumption, as well as our control variables and μi is an error term. After construction of the prediction model for each expenditure category, a *''recycling''* prediction method was used to predict the percentage for each category based on the estimated coefficients, called "marginal effect". To fulfill the household tobacco spending effect in this study, three levels of households is classified and analyzed: entire, urban and rural households.

3.2 Health care expenditures associated with smoking and ETS exposure

There are two main approaches to assess the health care spending attributable to smoking which are the disease-specific and the inclusive approaches. The disease-specific approach attempts a priori to identify smoking-related diseases and their costs or uses the absolute death rates from lung cancer as an indicator of tobacco related deaths. Meanwhile, the inclusive approach applied to this study recognizes that the health effects of smoking are complex and multiple, and assesses the impact of smoking on all medical spending. It means that the latter approach does not require accurate disease diagnosis. Furthermore, the ETS concept implicitly implied that the more existence of household's tobacco expenditure category, the higher likelihood health care cost resulting from smoking. Therefore, to examine the effect of smoking corresponding with the ETS exposure concept, the following regression equation of medical care utilization is estimated using a log-linear equation

□□□□□□=□□+□□□□□□+□□

MED is the monthly health care expenditure of the currently smoke households; whereas TBE is households' monthly tobacco expenditure variable which is a binary variable, 1 for those households who have the monthly tobacco expenditure higher than mean value; 0 for otherwise. As a fact that, the demographic variables, such as respondent's age, gender, marital status, level of education, occupation of household collected from the panel data are derived from the identical household; therefore, no need to incorporate the vector variable as vector control variable into the model. To estimate the marginal change in health care expenditure associated with tobacco consumption expenditure, the estimated coefficient obtained from the model will then be applied to the TBE variable which value to be assigned as zero and one. The marginal predicted health care expenditure resulting from tobacco spending ultimately is a summation of a constant term and the product of estimated coefficient and value assigned.

4. Dataset

4.1 Data Collection and data facts

The data used in this study is the national Household Socio-Economic Panel Survey collected by the NSO in 2006 and 2007. Household expenditure was classified into 12 categories (Food and beverages, tobacco, housing, decorations, health care, personal expenditure, transport, education, recreational and religious activities, social expenditure, transfer money to other people outside household, and others). The total numbers of household panel surveyed in the 2006 and 2007 were 16,542 and 21,569 samples, respectively as described in table 1. Not only the household panel data is explained by household as a whole, but also is classified those households into urban and rural categorized which were proportionate about 37.67 and 62.33 per cent, respectively. As households' income aspect, average monthly household incomes of the entire household during the 2006-2007[3] were THB 10,764 (USD 283.79) and THB 12,198 (USD 352.91), respectively. In addition, the average monthly households' incomes of households lived in urban and rural areas in 2006 were roughly THB 16,983 (USD 447.76) and THB 6,904 (USD 182.03), respectively. In 2007, their average monthly income was reached to THB 18,995 (USD 549.57) and THB 8,165 (USD 236.23), respectively. Meanwhile, on their expenditure side, average monthly

[3] The reference FX in 2006 is 37.9286 THB per USD; the FX in 2007 is 34.5637 THB per USD; the average FX during 2006-2007 is 36.24615 THB per USD

expenditure of entire households during the 2006-2007 was THB 3,918 (USD 103.29) and THB 4,254 (USD 123.02), respectively. Also, the average monthly expenditure of households lived in urban and rural areas in 2006 were roughly THB 5,590 (USD 147.38) and THB 6,156 (USD 162.30), respectively. In 2007, their average monthly expenditure was increased to THB 2,880 (USD 83.32) and THB 3,126 (USD 90.44). In particularly, the average monthly expenditure on tobacco category in 2006 and 2007 were THB 30 (USD 0.79) and THB 29 (USD 0.84), respectively (equals to 0.5 per cent of their total expenditure). In addition, their monthly expenditure on the health care category was THB 71 (USD 1.87) in 2006 and declined to THB 68 (USD 1.97) in 2007 (approximate to 1.8 per cent of their total expenditure) as shown in table 2

Table 1: Number of Household Panel Data Surveyed

Year	Household Panel Data Classification					
	Entire		Urban		Rural	
	Number	%	Number	%	Number	%
2006	16,542	100.0	6,334	38.0	10,208	62.0
2007	21,569	100.0	7,713	36.0	13,856	64.0
Total	38,111	100.0	14,047	36.9	24,064	63.1

Sorce: Thailand NSO panel data

Table 2: Average Monthly Household Expenditure Categories in 2006-2007

Unit: THB

Expenditure Category	2006			2007		
	Urban	Rural	Entire	Urban	Rural	Entire
1. Food and beverages	1,938	1,141	1,447	2,090	1,199	1,531
% share	*34.7*	*39.6*	*36.9*	*33.9*	*38.4*	*36.0*
2. Tobacco	39	26	30	38	24	29
% share	*0.7*	*0.9*	*0.8*	*0.6*	*0.8*	*0.7*
3. Housing	686	290	441	670	255	410
% share	*12.3*	*10.1*	*11.3*	*10.9*	*8.2*	*9.6*
4. Decroration	74	53	61	70	47	56
% share	*1.3*	*1.8*	*1.6*	*1.1*	*1.5*	*1.3*
5. Health Care	108	47	71	100	49	68
% share	*1.9*	*1.6*	*1.8*	*1.6*	*1.6*	*1.6*
6. Personal	289	152	205	319	158	218
% share	*5.2*	*5.3*	*5.2*	*5.2*	*5.1*	*5.1*
7. Transportations	1,253	526	805	1,578	740	1,052
% share	*22.4*	*18.3*	*20.5*	*25.6*	*23.7*	*24.7*
8. Education	302	175	223	320	173	227
% share	*5.4*	*6.1*	*5.7*	*5.2*	*5.5*	*5.3*
9. Recreation and religious activities	133	38	74	121	43	72
% share	*2.4*	*1.3*	*1.9*	*2.0*	*1.4*	*1.7*
10. Social	150	139	143	156	140	146
% share	*2.7*	*4.8*	*3.7*	*2.5*	*4.5*	*3.4*
11. Trasfer payment to people outside household	256	115	169	280	112	175
% share	*4.6*	*4.0*	*4.3*	*4.6*	*3.6*	*4.1*
12. Others	362	178	249	415	187	272
% share	*6.5*	*6.2*	*6.3*	*6.7*	*6.0*	*6.4*
Total	5,590	2,880	3,918	6,156	3,126	4,254

Source: Thailand NSO panel data

5. Empirical Result and Discussion

5.1 Association household tobacco spending on other household's expenditure

Entire households: Total numbers of sampled household panel data are 38,111 households. Table 3 shows that household tobacco spending has positively and statistically significant affected on all other expenditure categories, indicated by the "*Odd ratio*" (the ratio of probability of households whom have tobacco expenditure category above and equal to mean value, and of households whom have tobacco expenditure lower than the mean value). All of the odd ratio values are nearly to one, indicate that tobacco expenditure category of those household whom have tobacco spending above and equal to mean value and those whom have lower than the mean value are alike. For the health care expenditure, the marginal effect of tobacco expenditure on the health care cost is 0.00236, indicating one percentage change of tobacco spending resulting in 0.00236 percentage change of health care spending. The predicted value is THB 0.00163 for additional spending on tobacco of households.

Urban households: Total numbers of urban household panel data are 14,047 samples. Table 3 reveals that the household tobacco spending has positively and statistically significant affected on all other expenditure categories, except their decoration expenditure category. Most of the odd ratio values are nearly to one, indicate that tobacco expenditure category of those household whom have tobacco spending above and equal to mean value and those whom have lower than the mean value are similar. Specially, the health care expenditure category is positively affected by 0.00257 per cent from one percentage change of the tobacco spending, equals to THB 0.00266 measured in monetary term.

Rural households: Total numbers of rural household panel data collected are 24,064 samples. Table 3 indicates that the household tobacco spending has positively and statistically significant affected on all other expenditure categories. All of the odd ratio values are nearly to one, indicate that tobacco expenditure category of those household whom have tobacco spending above and equal to mean value and those whom have lower than the mean value are identical. Specially, the health care expenditure category is positively affected by 0.00261 per cent for one percentage change of the tobacco spending, equals to THB 0.00125 measured in monetary term.

As a consequent, we can infer that tobacco expenditure of Thai household is statistically significant and has positive effect on other expenditure categories pattern, but rarely small magnitude impact.

Table 3: Impacts of Tobacco Expenditure on Other Expenditure Categories

Expenditure Category	Marginal Effect (dy/dx)					
	Entire Household		Urban Household		Rural Household	
	% Change	Monetary Value in THB	% Change	Monetary Value in THB	% Change	Monetary Value in THB
1. Food and beverages	0.04098	0.58927	0.02586	0.50185	0.05887	0.66688
3. Housing	0.01023	0.04354	0.00791	0.05367	0.01154	0.03141
4. Decroration	0.00093	0.00054	0.00057	0.00041	0.00284	0.00141
5. Health Care	0.00236	0.00163	0.00257	0.00266	0.00261	0.00125
6. Personal	0.00460	0.00971	0.00418	0.01271	0.00480	0.00744
7. Transportations	0.03593	0.33338	0.03438	0.48569	0.03600	0.22808
8. Education	0.00466	0.01051	0.00415	0.01289	0.00628	0.01092
9. Recreation and religious activities	0.00271	0.00198	0.00187	0.00238	0.00327	0.00131
10. Social	0.00467	0.00674	0.00360	0.00549	0.00993	0.01385
11. Trasfer payment to people outside household	0.00396	0.00681	0.00304	0.00814	0.00708	0.00803
12. Others	0.00732	0.01903	0.00528	0.02047	0.00923	0.01685
Total						

Source: Calculated by authors
Remark: Y variable is tobacco expenditure; x variable means each category of household expenditure

5.2 Association household health care expenditure with smoking and the ETS exposure

In general, monthly expenditure of Thai households on the health care category is more than their monthly tobacco spending as shown in the table 4. At the entire household, for example, monthly health care expenditure is THB 69.5 (USD 1.92); meanwhile the monthly tobacco spending is THB 29.5 (USD 0.81). In addition, 89.5 per cent of them (34,120 sample households) are the household who has the tobacco expenditure category less than the mean value; the remaining households (10.5 per cent, equal to 3,991 sample households) have their tobacco spending above the mean value. For the rural household, the total number are 24,064 samples, of which the 94.1 per cent (22,654 samples) is the households who have the tobacco expenditure category less than the mean value among rural households; otherwise of which 5.9 per cent (1,410 samples). For urban household, there are totally of 14,047 samples, of which the 81.6 per cent (11,466 samples) are the households who have the tobacco expenditure category less than the mean value among urban households; otherwise of which 18.4 per cent (2,581 samples).

The estimated coefficients of log-linear equation are statistically significant as appeared in the table 5. For the entire household, the marginal effect here is THB 60.30 (USD 1.66) per household, defined as the group of households who have the tobacco consumption expenditure higher than the mean value would have their health care expenditure greater than the group of households who have the tobacco consumption expenditure below the mean value by THB 60.30 As a result, if all entire households reduce the monthly tobacco consumption spending by only THB 1 total value of the health care expenditure then, to be saved is THB 2,298,093.0 (USD 63,402.41) per month, which is calculated by taking number of the entire household (38,111 households) multiply with the marginal effect (THB 60.3)

Table 4: Household average monthly expenditure on health care and tobacco spending

Item	Household Type		
	Entire	Urban	Rural
Average monthly tobacco expenditure (THB)	29.5	38.5	25.0
Average monthly health care expenditure (THB)	69.5	104.0	48.0
Number of household			
Monthly tobacco expenditure >= Mean value	3,991	2,581	1,410
% of total	10.5	18.4	5.9
Monthly tobacco expenditure < Mean value	34,120	11,466	22,654
% of total	89.5	81.6	94.1
Total number of Household	38,111	14,047	24,064
% of total	100.00	100.00	100.00

Source: Thailand NSO panel data

For urban household, the marginal health care expenditure resulting from an additional change in the tobacco spending is THB 83.77 (USD 2.09) per household per month. If all urban households lessen the monthly tobacco consumption spending by only THB 1, then the monthly health care expenditure to be saved is totally THB 1,176,717.19 (USD 32,464.75). In a similar fashion, for the rural household, the marginal health care expenditure resulting from an additional increase in the tobacco spending is THB 50.96 (USD 1.27) per household per month If all urban households lessen the monthly tobacco consumption spending by only THB 1, then the monthly health care expenditure to be saved is totally THB 1,226,301.44 (USD 33,832.74) as shown in the figure 1. Although the marginal effect of those rural household less than the marginal effect of urban household the value of health care to be saved of rural household might be great than the value of urban household because the number of rural household is 2.14 time of the number of urban household.

Table 5: Estimation results of the health care cost associate with smoking

Household Type	Variable	Estimated Coefficient	S.E.	Wald statistic	Marginal Effect (THB)
Entire	TBE	0.00281	0.00013	476.1	60.30
	Constant	4.09658	0.02956		
Urban	TBE	0.00226	0.00018	164.8	83.77
	Constant	4.42578	0.05414		
Rural	TBE	0.00321	0.00021	234.3	50.96
	Constant	3.92775	0.02956		

Source: Estimated by authors
TBE is Tobacco expenditure variable

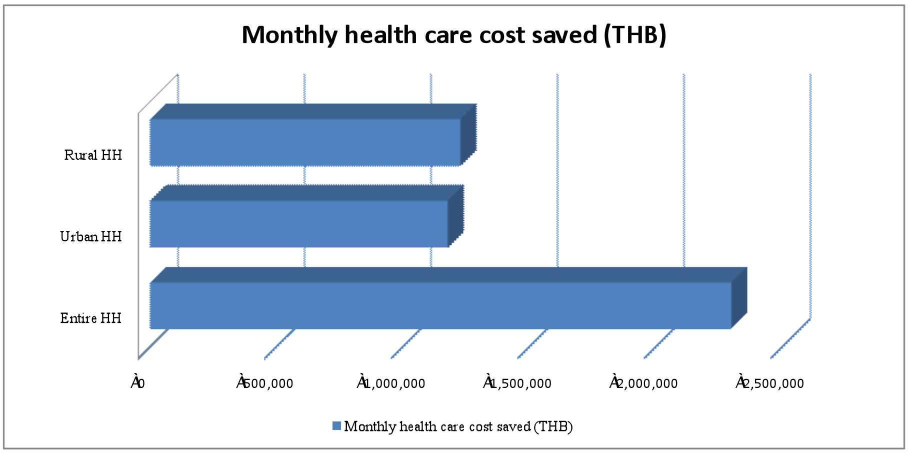

Figure 1: Health Care Cost Saved from Reduction in Tobacco Spending

6. Summary and Concluding Remarks

In economic principle, given budget constraint, higher smoking spending causes a reduction in expenditure items substituted whereas increase in expenditure categories complemented with tobacco spending. Smoking causes “direct cost” to household in term of reductions in necessary expenditure categories, particularly education of household members. It also causes a decline in labor productivity of smokers. The indirect cost of smoking is health deterioration, expressing in term of rising in household medical care cost. In Thailand, panel data household surveyed by the National Statistic Office (NSO) during 2006-2007 was indicated that household smoking expenditure was rather minimal as compared to total expenditure (only 1 per cent). It also showed that their health care expenditure was slightly outlay which was roughly 2 per cent of total. Although the smoking spending proportion is small the efforts to cut smoking expenditure would be deserved in the fashion that not only it is important to alleviate poverty, especially in poorer rural areas, but it also has been critical in improving health.

There are two main conclusions from our research associated with the fractional logit model as well as the application of the exposure to environmental tobacco smoke (ETS) on health. One is that the more household smoking expenditure, the higher spending in those complementary items such as the health care as well as the food and beverages categories. The change in household education expenditure, however, is not negatively associated with smoking spending at all. These finding is likely dissimilar to research result of China case study (Wang, 2009). The second conclusion is that the changes in health care cost associated with tobacco consumption spending are positively relationship and statistically significant. The marginal effect of health care cost associated with tobacco spending of urban households is greater than those of rural households, however, the health care cost saved of those rural household probably higher than because most Thai households live in rural area. The anti-smoking policies should be emphasis on households in rural areas as a priori policy recommendation because it not only helps people to reduce tobacco consumption spending but also save their health care cost. Additional policy recommendation will be focused on educating young people associated with smoking harmful since they persistently consume tobacco as well as high volume amount.

Acknowledgement

We are appreciated to Miss Patcharada Chuchit and Mr. Kamphol Phonthiem as the well-perform research assistants

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Awareness toward environmental problem solving of students at Sirindhorn college of public health, Yala, Thailand.

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Abstracts

Awareness toward environmental problem solving of students at Sirindhorn college of public health, Yala was descriptive study. The objectives of this study were to study the level of awareness toward environmental problem solving of students and the factors effected to awareness toward environmental problem solving of students at Sirindhorn College of Public Health, Yala. The samples were 206 students random by multistage sampling technique. Questionnaire was used to collect the data. The descriptive statistics were generated for frequencies, percentages, means, and standard deviation (S.D.). The effected between factors was performed by stepwise multiple regression analysis.

The results of this study have found that 4 of 16 independent variables effected to awareness complies the value on the environment, technical pharmacy student and emergency medical technician student and student that have domicile in the northeast at p-value .001 and all of this independent variables can predicted awareness at 53.2 % (R^2=.532) , therefore the prediction equation was

Y = 1.181+.759 (the value on the environment) +.190 (technical pharmacy student) -.252 (emergency medical technician student) - .125 (domiciled in the northeast).

Conclusion and recommendation: Most of respondents were high level of knowledge, the value to environment, and awareness toward environmental problem solving. However, it should continually encourage students, especially in the value to environment that was highest factor effected to awareness. Besides, should change viewpoint of technical pharmacy and emergency medical technician students and students from northeast part of Thailand that have negative effected to awareness of this study.

Keyword: awareness, environment, Sirindhorn College of Public Health, Yala, Thailand.

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1. Backgrounds and Significances

Environmental problem is the major problem that effected to human being worldwide. It can be separate environmental problem in to two types are the degradation of natural resources and environmental pollution. The main problems that related to health problems are water pollution, air pollution, noise pollution, chemical discharge, global warming, and solid waste problem.
Sirindhorn college of public health, Yala is college that have the activities about environmental solving continuously but it not achieve to the objectives. Therefore, the researcher was interested in studying awareness toward environmental problem solving of students at Sirindhorn college of public health, Yala. The results of this study can be used for encourage awareness of students in environmental problem solving activities.

2. The objectives

The objectives of this study were:

2.1 To study the level of awareness toward environmental problem solving of students at Sirindhorn College of Public Health, Yala.

2.2 To study the factors effected and predicted to awareness toward environmental problem solving of students, Sirindhorn College of Public Health, Yala

3. Research Methodology

The study of awareness toward environmental problem solving of students at Sirindhorn college of public health, Yala was descriptive survey.

3.1 Population:

The population were 418 students from Sirindhorn college of public health, Yala.

3.2 Samples:

The samples were 206 students, multi-stage sampling technique was performed by systemic random sampling and simple random sampling. Questionnaire was used to collect the data during December, 2010.

3.3 Instrumentation:

The questionnaire was used for data collection and was divided into five parts:

Part 1: general information	6 questions
Part 2: sources of environmental information	11 questions
Part 3: knowledge about environmental problem	12 questions
Part 4: giving value to environment	10 questions
Part 5: awareness toward environmental problem solving	6 questions

3.4 Criteria for evaluation:

The questions of part 2: sources of environmental information were rating scale of five levels. The respondents were selected the sources and able to score as following as:

Everyday	Score = 4
4-5 day/week	Score = 3
1-3 day/week	Score = 2
1-3 day/month	Score = 1
Never	Score = 0

The level of perception of environmental information from the source divided in to three levels including high, moderate, and low level.

High level of information perception	2.68-4.00
Moderate level of information perception	1.34-2.67
Low level of information perception	0-1.33

The questions of part 3: knowledge about environmental problem were rating scale of two levels. The respondents were able to score as following as:

Correct	Score = 1
Non Correct, Unknown	Score = 0

The level of knowledge divided in to three levels including high, moderate, and low level.

High level	$\overline{X}$ + 0.5S.D.
Moderate level	$\overline{X}$ ± 0.5 S.D.
Low level	$\overline{X}$ - 0.5 S.D

The questions of part 4: the value on the environment and **The questions of part 5**: awareness toward environmental problem solving were rating scale of five levels. The respondents were able to score as following as:

Strong Agreement	Score = 5
Agreement	Score = 4
Moderate Agreement	Score = 3
Less Agreement	Score = 2
Non Agreement	Score = 1

The level of giving value divided in to three levels including high, moderate, and low level.

High level	3.68-5.00
Moderate level	2.34-3.67
Low level	1.00-2.33

3.5 Data Analysis:

1. Descriptive statistics were generated for frequencies and percentages to describe the distributions of general information of respondents.
2. Descriptive statistics were generated for means and standard deviation (S.D.) to describe the environmental information perception, knowledge about environmental problem, and the value on environment
3. Stepwise multiple regression analysis were generated for identified the factors effected and predicted to awareness toward environmental problem solving of students at Sirindhorn college of public health, Yala. Independence variables of the nominal and ordinal scales including sex, religion, program of study, year of study, domicile, and participation in environmental activities were create dummy variables under the condition of multiple regression analysis.

4. Finding Results:

4.1 General information:

The results of this study have shown that most respondents were female (78.2%), Buddish religion (63.6%), bachelor degree student (30.1%), first year student (59.7%), students that have domicile on the southern, exclude three provinces in southern most of Thailand (36.9%), and participate in environmental activities (85.9%).

4.2 Sources of environmental information:

The results of this study have shown that internet was highest source of environmental information of students was moderate level (2.64) , the next source was television also was moderate level (2.34), while journal was the lowest source of low level (0.81). The level of perception of environmental information was moderate level (62.1%).

4.3 Knowledge about environmental problem:

The results of this study have indicated that all respondents knew that the increasing of temperature related to the dissolved of iceberg was highest (99.5%), the next was increasing of population effected to solid waste problem (99.0%), while CO_2 can replace O_2 in red blood cells due to low O_2 in blood was lowest (15.0%). The level of knowledge about environmental problem was high level (45.1%) as shown in Table 1.

Table 1: Knowledge about environmental problem

Level	n=206	Percentage
High level (>9.88)	93	45.1
Moderate level (9.86-9.88)	59	28.6
Low level (<9.86)	54	26.2
Total	**206**	**100.0**

Min. = 7 Max. = 12 Mean = 9.24 S.D.= 1.275

4.4 The value on the environment

The results of this study have shown that most respondents giving value on the environment was high level (4.37 from 5.00). If cooperate, the environmental problem will be decrease was the highest (4.68), the next was environmental problems were result form human activities (4.63), and the lowest was agree with PPP (4.01). The level of the value on the environment was high level (96.6%) as shown in Table 2.

Table 2: The level of giving value to environment

Level	n=206	Percentage
High level (3.68-5.00)	199	96.6
Moderate level (2.34-3.67)	7	3.4
Total	**206**	**100.0**

4.5 Awareness toward environmental problem solving:

The results of this study have shown that most respondents awareness toward environmental problem solving was high level (4.45 from 5.00). The environmental problem solving should start at ourselves was the highest (4.77), the next was we should solve the environmental problems for the next generation (4.57), and the lowest was participation in environmental problem solving at the college every time (4.26). The level of awareness toward environmental problem solving was high level (93.2%) as shown in Table 3.

Table 3: Awareness to environmental problem solving

Level	n=206	Percentage
High level (3.68-5.00)	192	93.2
Moderate level (2.34-3.67)	14	6.8
Total	**206**	**100.0**

4.6 Results of Hypothesis Testing:

4.6.1 Testing of factors effected to awareness toward environmental problem solving

1. The results of this study was performed by stepwise multiple regression analysis have shown that four factors including giving value on the environment, technical pharmacy student and emergency medical technician student and students that have domicile in the northeast of Thailand statistically significant effected to awareness toward environmental problem solving of respondents at p- value .001 as shown in table 4.

Table 4: Stepwise multiple regression analysis

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.204	1	18.204	184.966	.000(a)
	Residual	20.077	204	.098		
	Total	38.281	205			
2	Regression	19.096	2	9.548	101.026	.000(b)
	Residual	19.185	203	.095		
	Total	38.281	205			
3	Regression	19.763	3	6.588	71.863	.000(c)
	Residual	18.517	202	.092		
	Total	38.281	205			
4	Regression	20.371	4	5.093	57.155	.000(d)
	Residual	17.910	201	.089		
	Total	38.281	205			

a Predictors: (Constant), MEANC (the value on the environment)
b Predictors: (Constant), MEANC, CUR2 (technical pharmacy student)
c Predictors: (Constant), MEANC, CUR2, CUR4 (emergency medical technician student)
d Predictors: (Constant), MEANC, CUR2, CUR4, L3 (students that have domicile in the northeast of Thailand)
e Dependent Variable: MEAND (awareness toward environmental problem solving)

2. General information including sex, religion, students of community health, traditional medicine, dental health program, participation in environmental activities, sources of environmental information, and knowledge about environmental problems were not effected to awareness toward environmental problem solving of respondents.

4.6.2 The prediction equation:

1. From this study found that the coefficient of determination: R^2 = .532 that can be predict the equation as 53.2 percent with error 46.8 percent as shown in table 5: model 4

Table 5: The coefficient of determination

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.690(a)	.476	.473	.31371
2	.706(b)	.499	.494	.30742
3	.719(c)	.516	.509	.30277
4	**.729(d)**	**.532**	**.523**	**.29850**

2. The results of this study indicated that the prediction equation was shown in table 6: model 4

Table 6: The prediction equation:

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.055	.251		4.209	.000
	MEANC	.778	.057	.690	13.600	.000
2	(Constant)	.960	.248		3.876	.000
	MEANC	.796	.056	.705	14.119	.000
	CUR2	.255	.083	.153	3.072	.002
3	(Constant)	1.077	.248		4.347	.000
	MEANC	.773	.056	.685	13.771	.000
	CUR2	.233	.082	.140	2.842	.005
	CUR4	-.216	.080	-.134	-2.699	.008
4	**(Constant)**	**1.181**	**.247**		**4.772**	**.000**
	MEANC	**.759**	**.056**	**.672**	**13.641**	**.000**
	CUR2	**.190**	**.083**	**.115**	**2.303**	**.022**
	CUR4	**-.252**	**.080**	**-.156**	**-3.146**	**.002**
	L3	**-.125**	**.048**	**-.130**	**-2.611**	**.010**

From model 4 can be generate equation:

$$\boxed{Y = 1.181 + .759(MEANC) + .190\ (CUR2) -.252\ (CUR4) - .125\ (L3)}$$

Y = awareness toward environmental problem solving
MEANC = the value on the environment
CUR2 = technical pharmacy student
CUR4 = emergency medical technician student
L3 = students that have domicile in the northeast of Thailand

Therefore, if respondents increase the value on the environment 1 point due to increase the awareness toward environmental problem solving .759 point (highest effected factor), if respondents were technical pharmacy student due to increase the awareness .109 point. If respondents were emergency medical technician student or respondents from northeast of Thailand will be negative effected to awareness.

5. Conclusions and Recommendations:

1. The results of this study have shown that the level of awareness to environmental problem solving of students at Sirindhorn college of public health, Yala was high level: level of participation, knowledge, the value and awareness toward environmental problem solving also high level. However, should encourage the value on the environment, especially on emergency medical technician student and students from northeast of Thailand.
2. Continuous the environmental problem solving in the college with cooperate by all students and personnel.

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Applied γ-ray preirradiated fabrics grafting with acrylic acid to heavy metal removal

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The topic of the submission: Environmental Sustainability & Human Consumption: Waste

Applied γ-ray preirradiated fabrics grafting with acrylic acid to heavy metal removal

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Abstract

In this research, the synthesis of carboxyl adsorber was carried out by applying acrylicacid grafting onto polypropylene (PP) fabrics with the gamma-ray (γ-ray) preirradiation. The grafting conditions, such as which kind of fabrics used, acrylic acid concentration, gamma-ray dose rate and dose, grafting time, grafting temperature were conducted to obtain the optimum carboxyl adsorber manufacturing conditions. Furthermore, the effectiveness of carboxyl adsorber for removal heavy metal ions using various operating conditions such as reaction time, pH and metal/carboxyl adsorber molar ratio was also evaluated in this research. Lastly, the appropriate desorption agents were selected to discuss the effectiveness of heavy metal ions desorption and durability of re-adsorption works. Moreover, synthetic wastewater and electroplating wastewater were used to evaluate the feasibility of the prepared adsorption materials.

Keywords: gamma-ray, fabrics, grafting, carboxyl adsorber, heavy metal removal

1. Introduction

The electroplating industry and the semiconductor industry have advanced and prospered in recent years. As a result, the release of wastewater containing heavy metals produced in the manufacturing process has increased gradually year after year. According to the statistical data (2007) of the Industrial Development Bureau of the Ministry of Economic Affairs, the wastewater produced by the electroplating plants throughout the country reached 415,700 CMD. In order to handle such an enormous quantity of wastewater containing heavy metals, the development of economical and environmentally friendly materials to remove the heavy metals in wastewater for isolating and recycling has become an important subject worth further investigations. The traditional methods for the treatment of waste water containing heavy metals include chemical sedimentation, ion exchange, absorption, reverse osmosis, and diaphragm filtration (Bailey et al, 1999). Among these methods, the addition of a base plus coagulation and sedimentation is the most commonly used method. By the addition of an alkaline solution, the metal ion is allowed to react with hydroxide to form the fairly insoluble metal oxide compound, followed by coagulation and sedimentation, to isolate the solid from the liquid for the removal of heavy metals. However, due to the dense urban environment with limited land resources in Taiwan, the traditional sedimentation method involving the addition of chemical reagents has become less and less appropriate for dealing with the enormous quantity of wastewater produced due to the need of a large sedimentation area. Moreover, the disposal and treatment of sludge generated by such method posses another challenge to overcome. Without proper treatment, the heavy metals may be released from the acidic soil leading to a secondary environmental hazard (McDonald et al., 2006). The reverse osmosis method requires a higher operational cost and thus is difficult to be used extensively. From the perspectives described above, the objective of the present study was focused on the invention of the material capable of absorbing heavy metals based on the economical, environmental and efficiency-related considerations.

The present study utilized the capability of gamma-ray (γ-ray) preirradiation in modifying the surface properties of materials to activate the polypropylene (PP) fabrics surfaces, which was followed by a grafting procedure. The effects of different kinds of fabrics used, acrylic acid concentration, gamma-ray dose rate and dose, grafting time, grafting temperature were conducted to obtain the optimum carboxyl adsorber manufacturing conditions. Furthermore, the effectiveness of carboxyl adsorber for removal heavy metal ions using various operating conditions such as reaction time, pH and metal/carboxyl adsorber molar ratio was also evaluated in this research. During the study, the water loss rate was used to determine the modification effects under various plasma parameters. The grafting yield and COOH quantitative method was used to evaluate the grafting effects under different grafting parameters. The absorption models under a range of absorption environment were investigated to simulate the application for the heavy metal absorption of wastewater produced in actual plants.

2. Materials and Method

The present study exploited the activation and modification properties of gamma-ray (γ-ray) preirradiation combined with the grafting technology to develop the ion exchanger capable of absorbing the heavy metal ions in wastewater in order to remove them from the wastewater. The experimental procedure, materials, equipment and methodology are illustrated below.

2.1. Investigation of the activation of polymer after γ-ray preirradiation treatment

Polypropylene (PP) fabrics was used as the substrate under various γ-ray irradiation treatment parameters, the γ-ray irradiation rate was 400 Gy/hr and the γ-ray irradiation dose was 20-60 kGy. The water loss rate was based to determine the activation effects of substrates for selecting the optimal γ-ray irradiation treatment parameters.

2.2. Investigation of the properties of polymer after grafting treatment

The substrate afterγ-ray irradiation treatment was subject to grafting treatment under different monomer concentrations (2M, 4M, 6M), grafting times (1hr, 3hr, 5hr), and grafting temperatures (70°C, 80°C, 90°C). Various equipments were used for the chemical analysis, the weight method was used to calculate the grafting yields, and the titration method was used to analyze the COOH functional group for the determination of grafting effects in order to identify the optimal grafting parameters.

2.3. Study of the absorption of heavy metal ions by prepared ion exchangers

The ion exchangers with the optimal grafting effects prepared according to the two points described above were used in the experiments of heaving metal absorption. The heavy metals to be absorbed were changed to observe the absorption behaviors under various absorption environments. Moreover, liquid and solid phase analyses were conducted to study the absorption results and properties.

3. Results and Discussion

3.1. Investigation of the optimal parameters for the γ-ray irradiation modification of PP fiber surface – water balance test

In general, when the surface tension of liquid is lower than that of substrate, the liquid spreads to the surface of substrate. As the energy of the substrate surface varied, the degree of water spread also varied. An increasing water loss rate indicated a shorter time for water to be lost on the substrate surface, and a greater degree of water spread required for a large heating area. This phenomenon illustrated the effect on hydrophilicity byγ-ray irradiation modification. Therefore, the comparison of water loss rates using this experimental method could reveal the effects on hydrophilicity after the treatment. Under various modification durations, the water loss rates were 3.3%/min and 8.3%/min for unmodified (original) PP fiber and modified (the γ-ray irradiation modification) PP fiber, respectively. Owing to the γ-ray irradiation (activation) reaction, the water loss rate increased, indicating the increasing hydrophilicity of the fiber's surface.

3.2. Investigation of the conditions for the acrylic acid grafting of γ-ray irradiation modified PP – grafting yield determination

The present study selected acrylic acid with a COOH functional group as the grafting monomer for the grafting reaction to prepare the ion exchangers with the effect of absorbing heavy metal ions. The effects of the factors, including grafting temperature, acrylic acid monomer concentration and grafting time on the grafting results during the process were investigated. Figure 1 illustrates the results using FTIR-ATR to analyze the functional groups on the surface of PP fibers before and after theγ-ray irradiation treatment. From the Figure it was found that it was difference between the functional groups on the surface of the ion exchanger after grafting of the γ-ray preirradiation PP fibers. It was found that the characteristic peak of C=O of COOH in acrylic acid fell at 1720 cm^{-1} (Kondo et al., 2006).

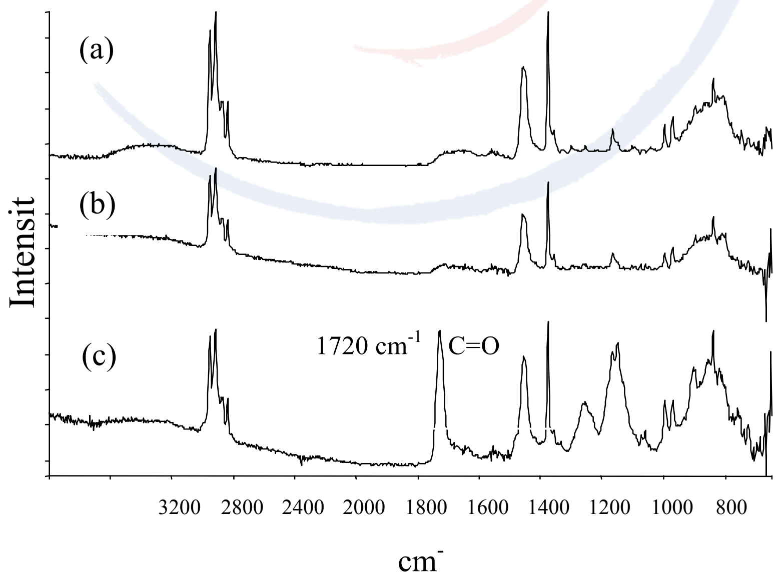

Figure 1 FTIR absorption spectra of PP fibers under various treatments (a: PP fiber only; b:γ-ray preirradiation PP fiber; c: γ-ray preirradiation PP fiber and followed by grafting treatment)

Figure 2 revealed that the grafting yields altered at grafting temperature of 80°C and 90°C, with the grafting yield of average 1.68% and 3.39%, respectively. It was believed that, under elevated temperature, the peroxy groups or the initiators on the substrate surface were easily decomposed thermally to form free radicals leading to a higher grafting probability with a higher grafting yield. Another cause for the increased grafting yield at elevated temperature was that the mobility of the acrylic acid monomer in the solution was enhanced owing to the increase of temperature. As a result, the probability of the monomer to come into contact with the free radicals was raised giving rise to a higher grafting yield (Xu et al., 2002).

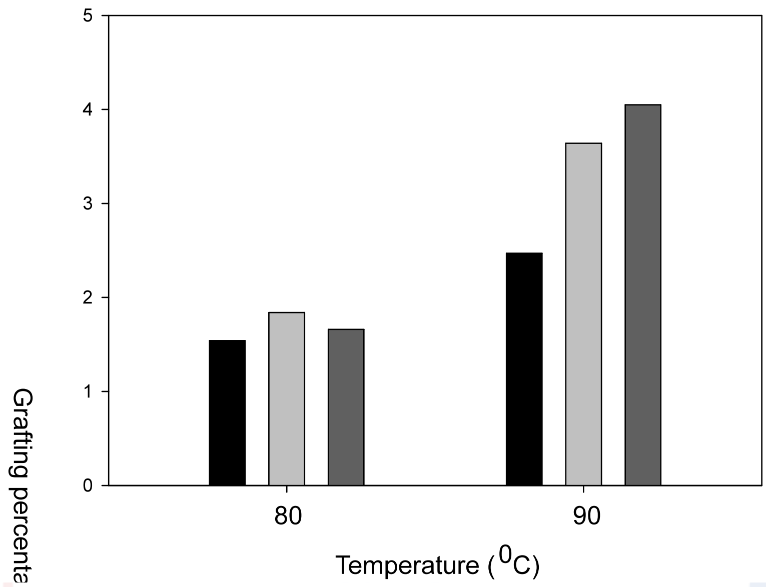

Figure 2 The grafting yields of PP afterγ-ray irradiation treatment and grafting under various temperature

3.3. Investigation of the adsorption of heavy metal ions by the modified material

The present study placed prepared material followed by washing and drying prior to the subsequent heavy metal absorption experiment. It was found that the absorption of Cu^{2+} was 4.5 mg-Cu/g-polymer. The copper removal rate was 26.7%.

4. Conclusion

The present study used PP fibers as the substrate and γ-ray irradiation treatment for modifying the surface properties in order to increase the hydrophilicity of the PP fibers. Afterwards, an ion exchanger capable of absorbing heavy metals was prepared by acrylic acid grafting. Moreover, the ion exchange properties of the COOH functional group were explored to investigate the absorption behavior of heavy metal ions. The potential of the application of theγ-ray irradiation surface modification combined with an ion exchanger developed by grafting technology was evaluated for wastewater treatment. The results are summarized as follows,

After the surface modification and activation of the PP fibers byγ-ray irradiation treatment, hydrophilicity could be improved to be favorable for acrylic acid grafting. At a grafting temperature of 90°C, the grafting yield could reach 3.39% under such conditions. The use of γ-ray irradiation to modify PP fibers could improve the grafting yield and successfully prepared the ion exchanger to absorb heavy metals. This technology is unique due to its convenience, quickness, low energy consumption, and environmental friendliness. The absorption behavior was believed to be a physical absorption reaction useful for the subsequent desorption and recycling of heavy metals. The developed technology displays a great potential for wastewater treatment, but thus requires further advanced studies.

Acknowledgement

The authors would like to thank the National Science Council, R.O.C. (NSC 99-2221-E-166 -005) for the financial support of this research.

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Problem Solving of Mountain Waterworks System during a Decade in Bankangsuan, Tambon Koh Saba, Amphoe Thepha, Changwat Songkhla, Thailand

Paiboon Chaosuansreecharoen[1]

The objectives of this research were to study (1) the problem-solving factors of mountain waterworks system, (2) the leaderships of problem-solving in mountain waterworks system, and (3) the problem-solving processes of mountain waterworks system. This study was long-term study during 1999-2010.

The findings:

1. The enabling factors of success related to the problem-solving of mountain waterworks system of this community including: (1) Natural resources: the prosperous forest resources created the sustainable water resource to produce mountain waterworks system in this community. In addition, the prosperous forest was able to sustain the results of social and cultural changes, (2) Human resource: Sixty five of workforce was working age (14-60 year olds). This age group was useful for development, (3) Social organization: there were several organizations that were involved in this project including governmental organizations, state enterprises, private stores, saving group, and Bureau of the Royal Household, (4) Contact: people in this community contacted and communicated to other communities, and (5) Experiences: the people in this community gained experiences by observing real situation and field trip from other communities.

2. The key leader of problem-solving in mountain waterworks system of this community was abbot. He played several leadership styles depending on circumstances at the time and factors. The leadership styles included autocratic leader, democratic leader, and servant leader, for example, listening, foresight, community building, displaying authenticity, and sharing leadership.

3. The processes of problem-solving in mountain waterworks system management of this community included (1) the few leader to make decisions, (2) diversity of participants in mountain waterworks system management such as participants as memberships, participants as meeting members, participants as workers, participants as coordinators, participants as voters, participants as supporters or protestors. Peoples in this community worked closely with the leader of mountain waterworks system management to protect the project, to keep the benefits of the community.

Keywords: Problem Solving; Mountain Waterworks System, Thailand

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Introduction

Bankangsuan is one of villages of the southern provinces (Songkhla Province) of Thailand. It located in Ko Saba (Tambon administrative organizations; TAO), Thepha District (Amphoe), Songkhla Province (Changwat). Bankangsuan is 12 kilometer (km) far from Thepha District and it is approximately 60 km far from Hat Yai District, the biggest city in Songkha Province. It is 72 km far from Songkhla Province. In the north of the village is Gulf of Thailand and Sakom subdistrict. In the south of the village is Thepha and Wang Yai subdistric. In the east is Gulf of Thailand and Thepha subdistrict and in the west is Wang Yai and Sakom subdistrict. Bankangsuan is one of Thailand's violence-ridden southern border provinces. It was not initially affected by the recent outbreak of Pattani Separatism, which began in 2004. However, bombs planted in 2005 and 2007 created fear the insurgence might spread into Songkhla province as well. The districts Thepha bordering Pattani is under martial law since 2005. The village's geography is plateaus, forests and mountains sloping in the central and plain and lowland toward Gulf of Thailand in the north. Songkhla has a wet climate due to the double influence of the northeast monsoon blowing from China in winter and the southwest monsoon from the Indian Ocean which brings in moisture all year round. Even so, Songkhla receives less rain than the western coast of the Southern region on which rain is dumped when the southwest monsoon hits the Tenasserim range.

Picture 1 Location of Songkhla Province

Source: http://www.worldcountries.biz/thailand--country/

The previous main occupation in Bankangsuan was rice cultivation. Subsequently, villagers have change to plant rubber in the foothills. There is sometimes temporary flooding in this area because the rain water runs off from mountains and the hill valleys. The population of Bankangsuan was 900 in 2010. Approximately 20% of population was children (aged below 14 years old) and 15% was elderly (aged above 60 years old). Thus, approximately 35% of population was dependent group. Approximately 65% of population was working group and studying age (aged 14-59 years old). A variety of ethic groups live in Bankangsuan together such as Thai, Chinese descent, Malay descent, and immigrant Burma workers. Most of populations are Buddhists.

Rivers, springs, swamp and streams act as the natural water resources quality filtration system to Bankangsuan village. In addition, there are two reservoirs and 2 weirs developed by government. There are eight water resources to provide untreated water. In the past, villagers dug sallow well for water supply in their households. Subsequently, drilled well was installed by Department of Health, Ministry of Public Health to supply underground water to the village. However, the underground water was shortage to supply all households. Thus, the villager had to find alternative resource of water supply. In 1999, mountain waterworks system was constructed by villagers. Abbot was the leader to bring mountain waterworks system as the water supply in this village. All workers who constructed system were the villagers. The first total budget was 250,000 Baht. At present, mountain waterworks system is the main water supply in Bankangsuan village. This study was long-term study during 1999-2010. The objectives of this study were to study (1) the problem-solving factors of mountain waterworks system, (2) the leaderships of problem-solving in mountain waterworks system, and (3) the problem-solving processes of mountain waterworks system.

Methodology

This study was conducted during 1999-2010. The primary data were obtained from key informants who were involved in mountain waterworks system management of this community such as abbot (head of temple) and villagers (water users). The primary data were collected by in-depth interview, observation, photograph recording, VDO recording, voice recording, and field visits. The secondary data were collected from the documents of Tambon Administrative Organization of Koh Saba including water supply, water demand, and accounts of incomes and expenses of waterworks system. The micro data were analyzed by domain analysis and taxonomy. The macro data were analyzed by situation analysis following the theory framework.

Results and Discussions

The findings of this study indicated that there were five enabling factors to the success in problem solving of mountain waterworks system in Bankangsuan, Tambon Koh Saba, Amphoe Thepha, Changwat Songkhla, Thailand. These factors included natural resources self-reliance, human resources, social organization, contact, and experiences. The details are as following:

1. Natural resources self-reliance: As all people know that the forest is the source of water for all people. The forest provides for underground water storage, making the ground moist as a benefit for all people. The result of cutting forest is the destruction of the water source. The forest was also the source of mountain waterworks system in Bankangsuan village. "Wongdo" was called by Bankangsuan's villagers for forest to provide source of water. In the past, Wongdo was the tropical rain forest which was fertile forest. As this type of forest was a water source surrounded by large trees that were characteristically cool and dense. Wongdo functions like a sponge, absorbing water during the rainy season and with a long period of seepage into stream during the rest of the dry season. Subsequently, there were many cases of illegal forestry concessions in Bankangsuan village such as for trade, for community expansion to make a living, for having inherited land from their ancestors and for expansion for good breeds of rubber tree plantation and fruit plantation (Picture 2). Therefore, the forest which provided water source was decreased. At the same time, water shortages experienced by mountain waterworks system, upland and lowland irrigations.

Picture 2 Illegal forestry concessions in Bankangsuan Village

Efforts to exert more control over local resources began only after the richly forested areas around the village had been destroyed by logging and shifting cultivators and the villagers began to experience severe water shortages for mountain waterworks system. Therefore, the villagers have considered the causes of the problems and tried to rehabilitate, maintain and protect the water source forests that have been destroyed. Abbot was the important person to protect the forest in this village. He used different strategies to preserve the forest. Firstly, he sent the report to Royal Forest Department about illegal forestry concessions. The Royal Forest Department regulated and controlled the illegal forestry concessions in Bankangsuan village because the forest of this village was declared as a conserved national park. It was forbidden to cut down any trees in the protected village forest. This was to protect it as a water source for production and for use and consumption by the village.

Secondly, abbot and villagers used cultural, tradition and belief strategies to preserve their forest such as tree ordination ceremony (buat ton mai). Tree ordination ceremonies were performed by abbot and villagers in order to raise the awareness of the rate of environmental destruction in Bankangsuan village and to build a spiritual commitment among local people to conserving the forests and watersheds. There are numerous descriptions, for instance, of religious or spiritual significance being attached to certain plants or animals, which are thereby protected. Picture 3-4 were the case of Bankangsuan village in March 2001, when abbot and villagers entered a national park to wrap monks' robes around all the large trees in a rainforest threatened by illegal forest forestry concessions. Most tree ordinations were aimed at local areas, and villagers, through their participation in these ceremonies, signify their acceptance of this adaptation of a Buddhist ritual to sanctify the forest and thereby protected it. The regulations the monks established limit villagers' use of the forest, forbidding the cutting of any trees or killing of any wildlife within forest.

Picture 3 Abbot and villagers worshiped to one of many trees that was destroyed (cutting food and water pipe of its trunk)

Picture 4 Monks and villagers worshiped during tree ordination ceremony (buat ton mai)

Third, abbot taught a simple lifestyle, using minimal resources, having just enough to eat and being at one with nature that would leave the forest, soil and water, surrounding the village, abundant and fertile. Vast humid forests bring rain. Water rain was absorbed by the forest and slowly released for the community to use all year, forming streams and creeks that flow unhindered into rivers. Thus, the villagers have looked after these kinds of forests as water sources within a community preserve. Natural resources self-reliance in this case was based on law enforcement, psychological self-reliance and social-cultural self-reliance. Social controls have also been developed in this community explicitly to regulate resource use and to ensure that the environment was managed sustainably. Moreover, natural resources self-reliance supported mountain waterworks system in Bankangsuan village.

2. Human resources: Sixty five of villagers in Bankangsuan village were working age (14-60 year olds). This productive age group was useful for social and economical development**.** For mountain waterworks system managements, this working group was free labor because they helped to manage the system. In the past, there was sometimes shortage of water for mountain waterworks system during summer periods. Abbot and community leaders discussed this problem. Finally, they decided to build the reservoir on the top of mountain. This reservoir would be useful to keep abundant water during the rainy season. Water in the reservoir would provide water supply to mountain waterworks during the rest of the dry season. Adult men were a main labor to construct this reservoir. It took almost one year to finish reservoir construction because adult labors were able to build reservoir after they finished their works in rubber cutting or plantation. After reservoir was built to keep water, there was no problem of water shortage for mountain waterworks system during dry season. In present, the mountain waterworks system had been managed by new generation of working group of the community. There is more productive age group in the community, therefore, it would be more development in quality of life of people in that community.

Picture 5 Adult men was relaxing during reservoir construction

3. Social organization: there were several organizations that were involved in mountain waterworks system management including governmental organizations, state enterprises, private stores, saving group, and Bureau of the Royal Household. The governmental organizations included Ko Saba Tambon Administrative Organizations and Royal Irrigation

Department that provided budget for mountain waterworks system construction. The state enterprises included Khokpho electrical power plant and stores of supplier and material for construction equipment. Khokpho electrical power plant supported electric for running mountain waterworks system while stores supported supplier and material for construction. The saving group was association running by villagers that was formed in this village before mountain waterworks system. The saving group had supported budget to mountain waterworks system at the initial stage. Bureau of the Royal Household increased potential of mountain waterworks system by constructing big tank to keep numerous of water. Big and tall water tank increased powerful water current that was distribute to villagers' household in low and upland. In case of mountain waterworks system in Bankangsuan village, it is one example of people's participation in rural development. Over the past two decades, many governments, development agencies and non-governmental organizations have recognized that the "top-down" approach characteristic of traditional development strategies has largely failed to reach and benefit community. For example, underground water system run by Department of Health, Ministry of Public Health. This system did not suit with community situation. The basic fault in the underground water system was that the community was not consulted in development planning and had no active role in development activities. Therefore, the system was abandon. For mountain waterworks system in Bankangsuan, local community formulated their own plans and activities and supports were supplied from several external agents, such as governmental organizations and state enterprises.

4. Contact: Bankangsuan village was the open community**.** The villagers have contacted with external agency by trading, sharing knowledge, cultural exchange, and communication. For mountain waterworks system in Bankangsuan village, abbot and villagers learnt mountain waterworks system from other villages where gained experience in success of mountain waterworks system management. Bankangsuan villagers and villager leaders involved in mountain waterworks system management in this project was to provide a forum for blending local knowledge with externally supplied technical information and to mobilize local villagers together with outsiders in a process that enables them to adapt technical standards for planning and monitoring mountain waterworks system to meet local needs. Thus, in the case of Bankangsuan village, the sharing knowledge from experienced community reduced uncertainty about technical information of mountain waterworks management.

5. Experiences: For mountain waterworks system, Bankangsuan villagers and village leaders gained experiences by observing real situation and field trip from other communities. Therefore, this blending of external knowledge, mobilized through the village committees, with externally supplied technical information considerably relaxed the rigor with which technical information was usually applied in the planning process in order to define type and location for mountain waterworks system intervention that villagers found acceptable.

The key leader of problem-solving in mountain waterworks system of this community was abbot. He played several leadership styles depending on circumstances at the time and factors. The leadership styles included autocratic leader, democratic leader, and servant leader, for example, listening, foresight, community building, displaying authenticity, and sharing leadership. For autocratic leader, abbot controlled over all of the villagers or followers. He was in complete control and no one was permitted to make any suggestions or offer any opinions, no matter how it may benefit the group. In case of mountain waterworks system required strong leadership. For example, abbot controlled every process of mountain waterworks system at the initial stage. He built his project with personal attention to each and every detail. Under democratic leadership, the villagers had a more participatory role in the decision making process of mountain waterworks system. Abbot retained final say over all decisions but allows villagers and village leader to share insight and ideas via committees. For example, abbot asked all group members for ideas and input and asked all groups to work with their strengths and provide input on how to divide the work in mountain waterworks system management. For servant leader, abbot had a responsibility towards society and those who are disadvantaged. He wanted to help villagers best do this by leading them.

Conclusions

The processes of problem-solving in mountain waterworks system management of this community included (1) the few leader to make decisions, (2) diversity of participants in mountain waterworks system management such as participants as memberships, participants as meeting members, participants as workers, participants as coordinators, participants as voters, participants as supporters or protestors. Peoples in this community worked closely with the leader of mountain waterworks system management to protect the project, to keep the benefits of the community.

The enabling factors of success related to the problem-solving of mountain waterworks system of this community including: (1) Natural resources: the prosperous forest resources created the sustainable water resource to produce mountain waterworks system in this community. In addition, the prosperous forest was able to sustain the results of social and cultural changes, (2) Human resource: Sixty five of workforce was working age (14-60 year olds). This age group was useful for development, (3) Social organization: there were several organizations that were involved in this project including governmental organizations, state enterprises, private stores, saving group, and Bureau of the Royal Household, (4) Contact: people in this community contacted and communicated to other communities, and (5) Experiences: the people in this community gained experiences by observing real situation and field trip from other communities.

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Title:

Establishing the Holistic Sustainability Evaluation Framework for Asia-Pacific Regions by Exploring Local Practices in China

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Categories:

Environmental Sustainability & Environmental Management: Land Use & Misuse

Establishing the Holistic Sustainability Evaluation Framework for Asia-Pacific Regions by Exploring Local Practices in China

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Abstract

Traditional reductionist methods of analysis, which breakdown and isolate the component parts will bring the risk of fragmented decision making with potential unforeseen consequences. The Holistic Sustainability Evaluation Framework for Asia-Pacific Regions developed in previous research discusses the overlapping worldviews of the east and west to provide better understanding on systems theory to be applied on sustainability evaluation methods based on the indigenous approaches of China. The conceptual process utilizes the eastern thinking model into the organisation of sustainable development evaluation framework, which can be adopted by policy-makers, designers, and stakeholders in Asia-Pacific. The construction of a theoretical framework toward an indigenous environmental philosophy can be applied to current sustainable urban development issues in China and Asia-Pacific. However, its applicability in different cultural regions and local practice still needs to be tested. This paper is to further establish the qualitative criteria and quantitative indicators for evaluation from case studies on urban developments at different spatial scales of selected Chinese cities. The future work is to validate this framework by testing an external case in China.

Keywords: Indigenous approach; Sustainability; Holistic Sustainability Evaluation Framework for Asia-Pacific Regions; Chinese cities

1 Introduction

Chinese traditions offer conceptual resources for ecological thinking by placing economics within a wider socio-ecological fabric, emphasising soft technologies, challenging meta-economic assumptions, and encouraging systemic wisdom(Goossaert & Keith, 2006). The Chinese worldview derived from Chinese philosophical traditions of Confucianism, Taoism, Buddhism, neo-Confucianism which are based on ideals of harmony, human perfectibility and systemic theory within natural systems and processes. In imperial times, institutional religions are various organic mixtures of Buddhism and Taoism within a Confucian framework (Jenkins, 2002). However, many of the urban theories and sustainability evaluation methods applied to Chinese cities now have been appropriated from western models of urban development. Since the concept of sustainability is value-based, and values can vary over time and between cultures (PCE 2002). The sustainable development evaluation needs to be tailored-to-fit the environmental, social and economic conditions in an individual region(Roberts, 2006). This has provided motivation for this research to find out how the traditional philosophy and western models were underpinning the urban practices in Chinese cities, and to establish the sustainability evaluation methodologies that are based on indigenous philosophies and thinking and the local practices in China.

2 The Process for Building an Sustainability Evaluating Framework

Various authors explored the establishment of integrated models for evaluating sustainable development (Brandon & Lombardi, 2005) (Plessis, 2009) (Iuliis & Brandon, 2010) (RESCUE, 2005).

Lombardi's model for evaluating sustainable development laid a foundation for this area in terms of the context of SD at policy, values, management, implementing, and the time horizon etc. It concludes three key layers of evaluation framework at the existing approaches to evaluation, the indicators at all levels aggregated together, and assessment methods with a directory and link to framework. Several issues are supposed to be concerned in constructing proposed framework, including dimension, space, functions, accessibility, environmental compatibility, historical/cultural significance, feasibility, visual appeal, flexibility, adaptability, institutional sustainability, interest and concern.The time horizon is still being by M. De Iuliis(Iuliis & Brandon, 2010). However, it does not clarify how the traditional theory was developed into a proposed framework. Unlike the layers of framework, indicators and assessment methods in Lombardi's framework, the properties of the system in Plessis's process represent the similar essence as the eastern philosophy. The system structure stresses not only the entities that make up the system, but also the linkages between them, the cross-scale structure, linkages and interactions. The behaviour of the system and the system attributes use the words such as 'flows', 'dynamics', 'adaptability', 'transformability', 'self-organisation' etc. The potential of the system is another important behaviour besides the flows. In terms of the concept of urban sustainability, Plessis described it as an ecological worldview, a function of relationship, interplay between change and persistence, reflective process, and a new view of urban sustainability. The city as complex and adaptive systems is also charactered by holarchical and panarchical structured noosystem, as well as symbolic construction. These statements represent the spirit of eastern philosophy.

Plessis's process is purely a theoretical exploration to define a world view by analysis of ecology and society articles with keywords 'social-ecological systems' and 'complex adaptive systems', and a second round of quantitative analysis of themes used in papers studying SES and CAS by coding conceptual framing, method used, research design, research objectives, case studies, aspects studied and how the system and its properties are defined and studied. The method could be applied in the literature review on the existing sustainability evaluation methods and traditional philosophies.

The case studies in Lombardi's process aim at the application to check the completeness, duplication, consistency and internal logic of the model. The cases in older edition focus on the identification of relevant evaluation criteria, stakeholders' views and quantitative indicators synthesis, whereas the new edition adds another case to highlight interrelations and links in decision-making, which is one of the key features in holistic theories. The case studies in RESCUE framework are employed for the mutual purposes of developing a set of evaluation method as well as finding out the best local practices. It developed an analytical sustainability framework for finding good practice of brown field development in Europe. Quality goals are made and a set of qualitative and quantitative indicators was derived to benchmark whether or not objectives were met (RESCUE 2005). The applicability checks of indicators, strengths, weaknesses and gaps analysis, good/best practice analysis and transferability analysis are designed to find out the best practice for brown field development in Europe.

3 The Tentative Sustainability Evaluation Framework

The framework developed in previous research is embedded with the character of "ordinal loops" of traditional diagram 'Yin-Yang' that is suitable for sustainability evaluation framework for Chinese cities (Dong, Lehmann, & Mackee, 2010)(Fig 1).

The framework tries to integrate the hierarchical contents of modalities and the dynamic changes between the human and environment interfaces (Table 1). A list of Environment and Human Index is designed to assign the framework value which represents the dynamic relationship between environment and human (Table 1).

Table 1 Environment and Human Index

		Environ-ment Index(EI)	Human Index(HI)			Environ-ment Index(EI)	Human Index(HI)
TQ2.1	++++++++	8	0	TQ4.1	--------	0	8

TQ2.2	+++++++-	7	1	TQ4.2	-------+	1	7
TQ2.3	++++++--	6	2	TQ4.3	------++	2	6
TQ2.4	+++++---	5	3	TQ4.4	-----+++	3	5
TQ3.1	++++----	4	4	TQ1.1	----++++	4	4
TQ3.2	+++-----	3	5	TQ1.2	---+++++	5	3
TQ3.3	++------	2	6	TQ1.3	--++++++	6	2
TQ3.4	+-------	1	7	TQ1.4	+++++++	7	1

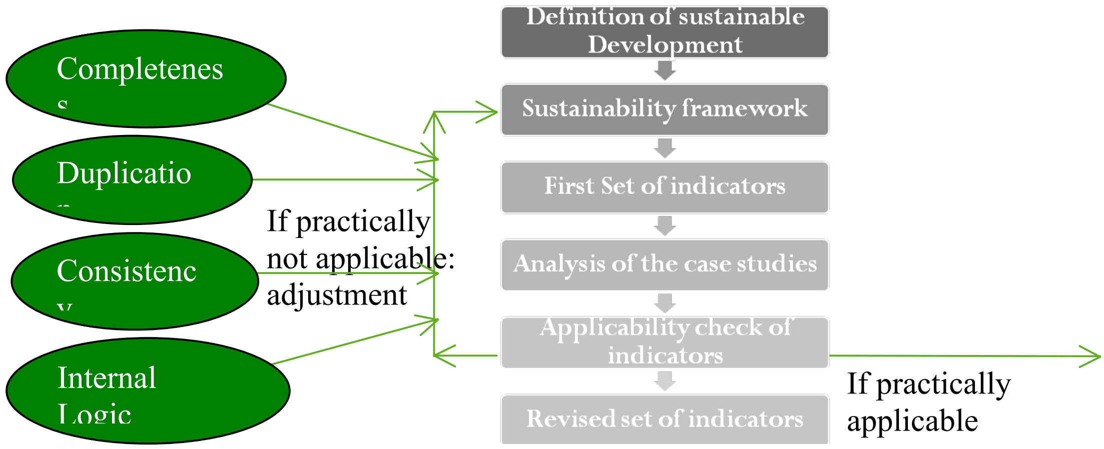
4 Analysis and Modelling

The construction of a tentative theoretical framework toward an indigenous environmental philosophy can be applied to current sustainable urban development issues in China and Asia-Pacific. However, its applicability in different cultural regions and local practice still needs to be tested. This paper is to further establish the qualitative criteria and quantitative indicators for evaluation from case studies on urban developments at different spatial scales of selected Chinese cities.

In analysis, qualitative methods are used as indicated in this research. Quality goals are made and a set of qualitative indicators was derived to benchmark whether or not objectives were met (RESCUE 2005). Case studies are used as the main research strategy. Cross-case analysis is the chief method for the purpose of deepening understanding of the generic processes or explanation that occur across individual cases(Miles & Huberman, 1994; Yin, 2009). The cases are carefully selected to ensure variety and opportunities to learn (Stake 2000). Data are gathered through semi-structured interviews. Besides the interview transcriptions, the resources to derive narratives also include formal government documents, on-line government document and journals.

For each urban project there are three participants interviewed for the case studies. The project managers are sourced from planning bureaus when governments are the proponents of the projects. They are sourced from the real estate/investment companies when the private sector is responsible for the project. The designers are sourced from architecture and urban planning research institutions when the public sector is the responsible for the projects. They are sourced from the architect/consultant companies when the private sector is responsible for the design and planning process. Participants are required to provide their time to participate in a semi-structured interview. They are asked to give their views and insights into the project that they were involved. They are not asked to divulge any corporate secrets or any material that would jeopardise their employment. The interviewer is trying to understand the decision-making in regard to the sustainability issues of the project.

The research methods in qualitative coding are the basic steps in working with transcribed records of interviews, or secondary sources obtained from qualitative data archives. Nvivo is particularly appropriate for analysis of free flowing texts(Gibbs & Flick, 2007).



Analysing words

Key-words-in-context (KWIC) as one strategy for word analysis are created by finding all the places in a text where a particular word or phrase appears and printing it out in the context of some number of words before and after it. This process produces a concordance. Except KWIC, other methods, such as word counts, structural analysis and semantic Networks Cognitive maps all remove words from the contexts in which they occur so that nuance may occur(Denzin & Lincoln, 2008).

Coding

Coding forces the judgements about the meanings of contiguous blocks of text. Coding could identify themes, build codebooks, mark texts, construct models by relationships among codes, and test the models against empirical data. Coding identifies a corpus of text, and then selects the units of analysis within the text. Finding themes and building theory may require fewer cases than comparing across groups and testing hypotheses or models. Coding assigns codes to contiguous units of text and they act as values assigned to fixed non-overlapping units of analysis which could be nominal, ordinal, or ration scale values in content analysis.

Building codebooks

In the analysis of all interview transcriptions, 89 KWIC are conducted. 16 Theory Questions (TQ) and 36 Interview Questions (IQ) are coded. Codebooks are organised lists of codes, in way of hierarchies as following table (Table 2).

Table 2 Codebooks

TQ 1.1 Could this project connect different city districts and provide	KWIC 1.1Bicycle	TQ 1.3 How does this project consider the balance of the land use and increase	KWIC 1.3 Business Office
	KWIC 1.1Metro		KWIC 1.3 Compatibility
	KWIC 1.1Parking		KWIC 1.3 Land Use
	KWIC 1.1Public transport		KWIC 1.3 Mix of Land Use
	KWIC 1.1Transportation Studies		KWIC 1.3 Residential
	IQ 1.1aTraffic concept in		IQ 1.3a Secondary and third uses

access for all means of transport	adopted transport context	the mix of uses	of buildings and building plots
	IQ 1.1bPublic transport		
	IQ 1.1cDiversified transport systems		
TQ 1.2 How do you manage to achieve high quality planning in urban form and land uses	KWIC 1.2 Development Process	TQ 1.4 How does this project designed to control urban growth and curb urban sprawl	KWIC 1.4 Compact
	KWIC 1.2 Industry		KWIC 1.4 Density
	KWIC 1.2 Land Management		KWIC 1.4 Diversified Cultures
	KWIC 1.2 Network society		KWIC 1.4 Development Degree OR Reserve Land
	KWIC 1.2 Relationship to Superior Planning		KWIC 1.4 Derelict OR Declined OR Single OR Monotony
	KWIC 1.2 Relocation Housing		KWIC 1.4 FAR OR Development Intensity
	KWIC 1.2 Underground Space		IQ 1.4b Redevelopment
	IQ 1.2a Regional economic and spatial development strategy		IQ 1.4a Vacant suburb infill or Urban agriculture
	IQ 1.2b Socio-economic and commercial demand		KWIC 1.4 Sprawl OR Evacuate OR Move out OR Sea reclamation OR Expand
	IQ 1.2c Regional land management pool		
	IQ 1.2d Integrated urban development strategy		

TQ 2.1 Are climate responsive strategies been adopted	KWIC 2.1 Climate adaptation OR Sun shading OR Sunlight OR Ventilation	TQ 2.2 How do you consider the energy and resources efficiency on the site	KWIC 2.2 Energy Saving
	KWIC 2.1 Heat engineering OR Heat preservation		KWIC 2.2 Material Recycling
	KWIC 2.1 Orientation OR Distance		KWIC 2.2 Renewal
	KWIC 2.1 Sunshine or sunlight		IQ 2.2a Renewable energy production
	KWIC 2.1 Ventilation		
TQ 2.3 How do you design to minimise environment pollution and recycle resources	KWIC 2.3 Dust	TQ 2.4 Are landscape and spatial fragmentation avoided How do you think the continuity and permeability of the site	KWIC 2.4 Earth up
	KWIC 2.3 Flood control		KWIC 2.4 Accessibility
	KWIC 2.3 Garbage		KWIC 2.4 Continuity Permeability
	KWIC 2.3 Groundwater OR Drainage OR Waste Water		KWIC 2.4 Fragmented or scattered or blocked or closed
	KWIC 2.3 Pollution		KWIC 2.4 Greenery OR Forest OR Vegetation
	KWIC 2.3 Unpurified water		KWIC 2.4 Landscape OR Square
	KWIC 2.3 Fire Control		KWIC 2.4 Permeable or open
	KWIC 2.3 Garbage OR Pollution OR Dust	TQ 2.5 How do you guarantee the development will not damage wildlife habitat, and maintain bio-diversity	KWIC 2.5 Habitat OR Biodiversity OR Biotope
	KWIC 2.3 Rainwater OR Grey water OR Water Percolation Road Surface		IQ 2.5a Compatibility studies of the natural site conditions
	KWIC 2.3 Resource Recycling OR Material OR Ecological		IQ 2.5b Valuable biotopes changes
	IQ 2.3a Surface water and groundwater monitoring		
	IQ 2.3b Complaints about the air and dust		
	IQ 2.3d Separated management of rainwater and waste water		
	IQ 2.3e Noise control		
	IQ 2.3f Waste, reuse, recycling, landfill		

TQ 3.1 How do the needs of human cognition being considered	KWIC 3.1 Interface Cognition Sense of Safety	TQ 3.2 Does the development encourage diversified and vivid environmental behaviour	KWIC 3.2 Liveability
	KWIC 3.1 Sense of belonging		IQ 3.2a Outdoor activities
	IQ 3.1a Complaints on site redevelopment		
	IQ 3.1a Human engineering		
	IQ 3.1b Public participation, dissatisfactions, conflicts	TQ 3.4 What has been implemented for social acceptance and social equity	KWIC 3.4 Planning suggestion
	IQ 3.1b Sense of community		KWIC 3.4 Acceptance OR Conflicts OR Equity
TQ 3.3 How do you improve cost effectiveness and technical feasibility	KWIC 3.3 Operation OR Deployment Property assessment		KWIC 3.4 Complain OR Criticize OR Suggestions
	KWIC 3.3 Real right OR Property right		KWIC 3.4 Education or Medical treatment
	KWIC 3.3 Compensation		KWIC 3.4 Historical Problems
	KWIC 3.3 Flexibility		KWIC 3.4 Public participation
	KWIC 3.3 Realization of Transformation OR Planning		KWIC 3.4 Reason of conflict OR Coordination
	KWIC 3.3 Relocation to original place		IQ 3.4b Initiatives for or against the project
	IQ 3.3b Employment off the site, economic multiplier effects		IQ 3.4c Long-term jobs on the site

TQ 4.1 How does the design and plan define the cultural and regional identity	KWIC 4.1 Creative Industry	TQ 4.3 Are citizen's personal values affected by the development considered	KWIC 4.3 Project Orientation
	KWIC 4.1 Cultural transition		KWIC 4.3 Orientation High Standard Money Worship
	KWIC 4.1 Culture OR Regional OR Humanity OR Local		KWIC 4.3 High Standard Money Worship
	KWIC 4.1 Diversified Cultures		IQ 4.3a Compatibility studies with the anthropogenic conditions
	KWIC 4.1 History OR Heritage		
	IQ 4.1a Natural and historical heritage		
	IQ 4.1b Local elements in design		
TQ 4.2 Does the institution system support the development	KWIC 4.2 Analysis	TQ 4.4 How do you consider the aesthetic matters	KWIC 4.4 Form
	KWIC 4.2 Bottom-up Opinion		KWIC 4.4 Sense of Scale
	KWIC 4.2 Decision-making		KWIC 4.4 Façades
	KWIC 4.2 Experts OR Competition		KWIC 4.4 Ceremony OR Visual OR Good looking
	KWIC 4.2 GIS Aided Decision-making Hydrology Geology Model Presentation Visualization		KWIC 4.4 Colour Guidance Façades along streets Continuous Interface
	KWIC 4.2 Phasing		KWIC 4.4 Harmony
	KWIC 4.2 Research OR Impact Evaluation		KWIC 4.4 Tone Size Originality Concept
	KWIC 4.2 Underground OR Service life of buildings		IQ 4.4a Equilibrium of image or volume
	IQ 4.2a Step by step-realization, flexibility		IQ 4.4b Original concept
	IQ 4.2b Decision support institution system		
	IQ 4.2c the decision support tools		

	IQ 4.2e Are there studies realized treating the above issues		
	IQ 4.2f Different expert opinions		

Cluster analysis

Cluster analysis is used to visualize patterns by grouping nodes that are coded similarly by nodes. The diagrams provide a graphical representation of sources or nodes to make it easy to see similarities and differences. Sources or nodes in the cluster analysis diagram that appear close together are more similar than those that are far apart. When setting the number of cluster to be 16, the branching diagram could show the 16 new groups of codes, to be in comparison with the groups of 16 TQs (Figure 3).

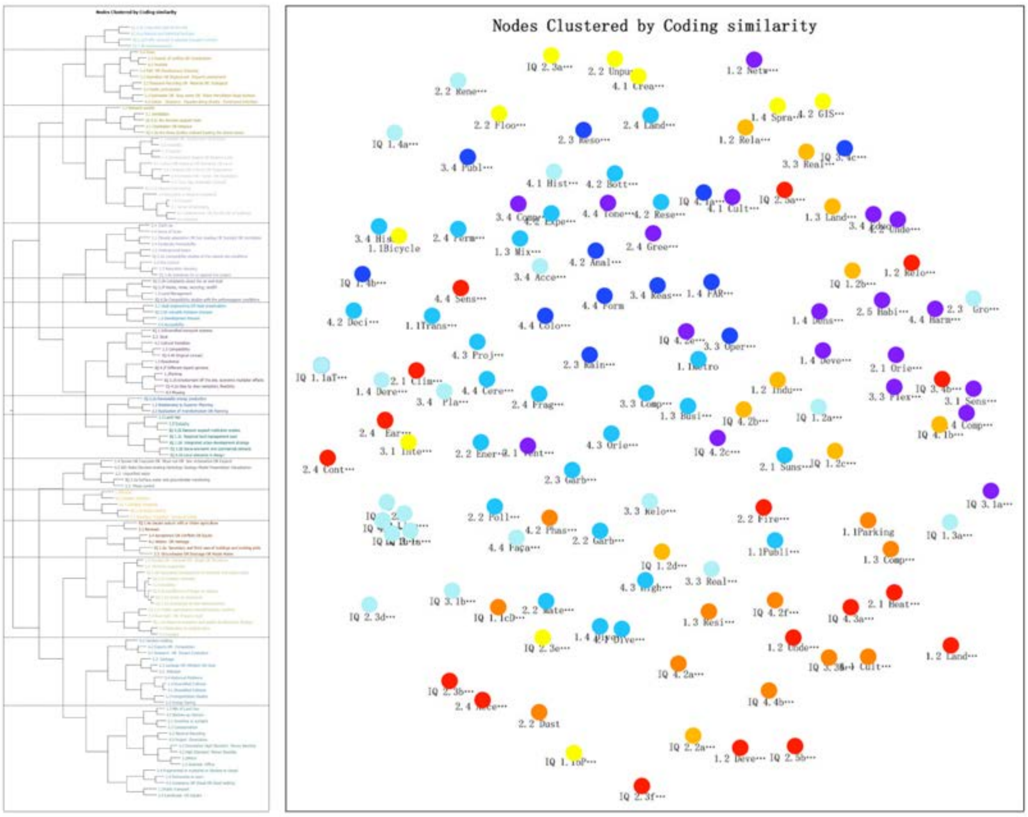
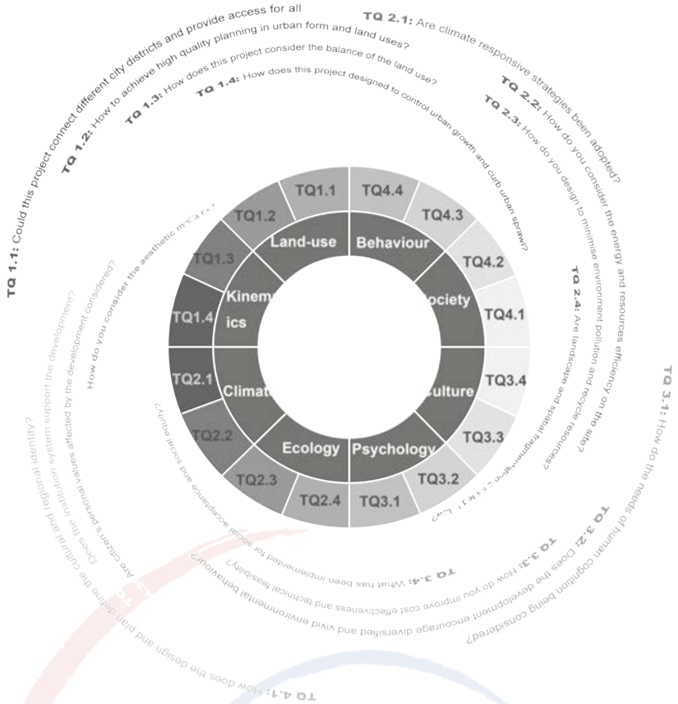


Figure 3 Branching diagram and 2D cluster map

A pattern of a spiral shape is identified in the cluster map. This implies that each group has gradual change in content to the next one. This could well explain the cyclical, wavelike, and continually changing relationship.

The pattern of a spiral shape is conceptualized into the following diagram (Figure 4).



Building conceptual models

Once a set of themes are identified, the next step is to identify how things are lined to each other in a theoretical model. Models are sets of abstract constructs and the relationships among them. They could be conceptual maps and flow charts. The relationships between the nodes are recorded by the coding query. The more references there are in the cross table, means that they are more related. Their relationship could be positive or negative. The Matrix Coding Query of the 16 Theory Questions (TQ) is shown in the table 3.

Table 3 No of Coding References in Matrix Coding Query

TQ 1.1	209															80
TQ 1.2	35	145														70
TQ 1.3	34	131	520													60
TQ 1.4	31	42	86	201												50
TQ 2.1	23	11	34	10	246											40
TQ 2.2	5	0	16	8	20	72										30
TQ 2.3	11	13	14	19	6	32	285									20
TQ 2.4	45	29	48	29	36	5	13	449								10
TQ 2.5	1	1	3	5	4	1	14	53	29							8
TQ 3.1	4	2	9	1	4	0	7	40	1	26						4
TQ 3.2	1	4	20	6	2	0	1	20	0	4	25					0
TQ 3.3	7	20	56	18	6	0	13	18	0	2	1	125				
TQ 3.4	9	22	30	24	9	1	23	35	5	15	4	30	228			
TQ 4.1	7	39	33	14	22	4	20	72	11	3	8	23	55	340		
TQ 4.2	39	56	74	25	27	10	28	31	8	15	8	35	77	56	419	

TQ 4.3	0	10	20	8	0	0	0	2	2	1	0	3	19	13	14	97
TQ 4.4	19	19	53	25	32	15	33	63	3	11	4	11	29	83	45	14
	TQ 1.1	TQ 1.2	TQ 1.3	TQ 1.4	TQ 2.1	TQ 2.2	TQ 2.3	TQ 2.4	TQ 2.5	TQ 3.1	TQ 3.2	TQ 3.3	TQ 3.4	TQ 4.1	TQ 4.2	TQ 4.3

The table shows that most of the TQs are related to each other. So the matrix coding query of 125 coding is conducted to identify the existence of relationships among the codes. Using the query outcome, an integrated model is built here, and the connectors show the related items within the model (Figure 5).

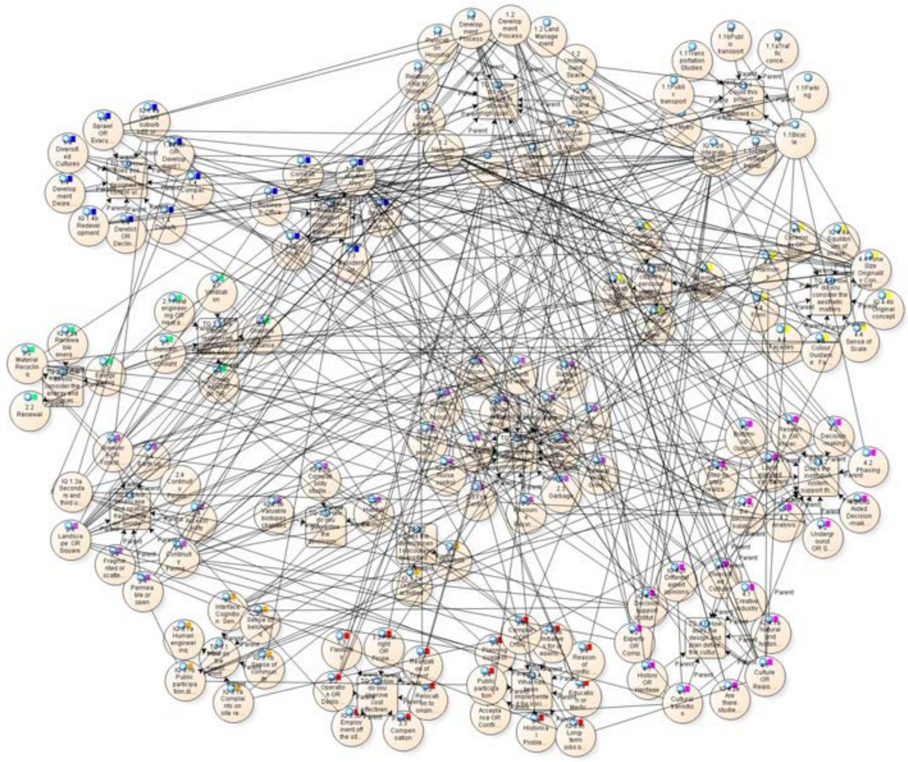


Figure 5 Connections in the model

The next step will need to interpret each relationship, whether they are positive or negative to each other in terms of sustainability. That will show the dynamic and interdependent attribute of the system.

7 Conclusion

A conceptualized pattern of a spiral shape is identified in the analysis which could explain the cyclical, wavelike, and continually changing relationship. The world consists of human activity and natural phenomenon in mutual interactions changing overtime. This is represented in both the Yin-Yang diagram of Taoism and also the integral environment system(Markovie, 2006). Taoism believes that there are 'natural laws' which are summarized as opposition, interdependence, inter-transformation, and dynamic between Yin and Yang. Yin and yang are not inherently paradoxical since they can change into each other. This is the other law of interdependence and inter-transformation. The last law is that the qualities of yin and yang counter and complement in oscillating flux. Taiji (Supreme Ultimate) is the expression of their unity, opposition and energy. So the dynamic balance explains the gradients on a scale of complete yin and yang (Bramble, 2003). It avoids reductionism views which explain the whole only in terms of parts, focuses on organisational principle and understanding of systems, dynamics and tensions.

This paper also noted that the construction of a theoretical framework toward an indigenous environmental philosophy can be applied to current sustainable urban development issues in China and Asia-Pacific. The conceptual process utilize the eastern thinking model into the organisation of sustainable development evaluation framework; Generating systemic recommendations by the systemic framework and combinational analysis method. However, its applicability in different cultural regions and local practice still needs to be tested. The future work is to refine the framework and validate by case studies on urban developments at different spatial scales of selected Chinese cities.

The paper forms part of the first author's higher research degree thesis.

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TITLE

Energy Access to Rural Areas: Exploring Decentralized Renewable Energy Systems for the Indian State of Bihar

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THE TOPIC OF THE SUBMISSION

Economic sustainability and Environmental Challenges

Energy Access to Rural Areas: Exploring Decentralized Renewable Energy Systems for the Indian State of Bihar[1]

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Abstract

This paper sets forth a series of institutional and governance options to meet the energy needs of rural India, taking the case example of the Indian state of Bihar. Resource analysis, governance-policy analysis, and case study of two renewable energy service companies highlights the significant opportunity for establishment of decentralized renewable energy system (DRE) for the state. The proposed options take a co-benefits approach and integrates the basic sustainability issues of economic security, stakeholder involvement, infrastructure development and energy security. Specifically, the paper suggests a rural electricity infrastructure development plan; develops a small scale industry model for DRE implementation; integrates business principles in the existing renewable policy; develops governance structures for promoting private participation and micro-grids, including the role of the regulatory authorities. The paper concludes by reiterating the importance of DRE for sustainability.

Keywords: Energy Access; rural population; India; stakeholder concerns; integrative strategies

[1] The author would like to gratefully acknowledge Greenpeace International for the financial support provided for this research. The study on the Indian state of Bihar is part of a report commissioned by the Greenpeace International, India Office.

INTRODUCTION

India is among the top five CO^2 emitting nations in the world (EIA, 2008). As one of the fastest growing economy with a large population, it faces multiple challenges of contributing to global climate change mitigation along with achieving domestic goals of poverty reduction, environment protection and maintaining high economic growth (IPCC, 2007; UNDP, 2010; Parikh and Parikh, 2004).

Search for cost effective mitigation strategies concerns both developed as well as developing nations (McKibbin and Wincoxen, 2002; Gurtoo and Antony, 2009). Developing countries have a low economic capacity of bearing the cost of mitigation like cost recovery, increased sensitivity to natural factors (McKibbin and Wincoxen, 2002). Furthermore, more critical domestic economic imperatives of growth and poverty reduction will be compromised by aggressive climate change mitigation efforts as huge investments in physical and human capital is needed for these efforts (Pandey, 2002; Dubash, 2009; Parikh and Parikh, 2004; Chanakya and Alwis, 2002). Climate change is predicted to negatively impact livelihood and food security if action is not taken on that front (IPCC, 2007).

Hence, balancing ecological sustainability and the socio-economic imperatives by integration of livelihood security and food security to mitigation efforts, becomes important. Moreover, stakeholder involvement is critical as it supports varying degrees of citizen empowerment and contributes to a more effective and efficient implementation process (Stivers, 1990; Zhong and Mol, 2008; Shukla et al., 2008; Akimoto et al., 2008).

In this paper we highlight some of the low carbon options that are feasible to implement in India, using the case study of the Indian state of Bihar. Based on the resource and governance analysis of the state, and case studies of some successful rural entrepreneurship initiatives, the paper suggests some domestic developmental policy options where India can play a substantive role in GHG emissions reduction without harming its developmental agenda.

The next section reviews literature on international support and on the domestic development concerns of rural India. The review highlights the possible strategies and is used to develop the research questions. The next section highlights the methodology used and is followed by identification of the salient observations from the case study, using the framework by Balachandra (2010). The last sections put forth the policy options and conclude the paper.

LITERATURE REVIEW

This section reviews the rural sector from the climate change perspective and the international strategies and schemes existing. The United Nations Intergovernmental Panel for Climate Change (IPCC) assessment reports of 2007 discusses these issues as significant.

Poverty and government intervention Incidence of rural poverty has been on a steadily decline since 1960s (Ghose 1989; Ravallion and Datt 1995; Ninan 1994). Factors explaining this change are several. One, positive impact of the intervention of technical systems and government employment programs has been recognized recently (Udayaadithya and Gurtoo, 2010; Datt and

Ravallion, 1998; Fan et al., 1999). Two, studies argue for declining poverty due to increase in the share of the work force employed in nonagricultural activities (Mukherjee 1996; Sen 1997; Sundaram and Tendulkar, 2003; Ravallion and Datt 1995). The burst of poverty-oriented government programs in the 1970s, to improve rural assets, create employment and increase people's access to agriculture inputs, had a trickle down benefits for the poor (Sen 1997; Scherr and Hazel, 1994; Visaria and Basant 1994;). It created rural non farm jobs and increased wages.

Natural resources utilization and depletion Rural households in developing countries depend on local common pool resources like forests and grazing lands to a significant degree (UNDP, 2002, IPCC, 2007). Similarly, there is high dependence on construction wood, driven by demand both for houses and for agricultural implements. However, on the other side, desertification and degradation of natural resources is a significant concern (Sarin and Khanna, 1991; IPCC, 2007; GOI, 2007). Estimates show that out of India's total landmass (328 million ha), more than half (about 175 million ha) is undergoing some form of degradation, and therefore needs preventive and rehabilitation measures to enhance and maintain agricultural productivity (GOI, 2007; Narayana and Rambabu, 1982; Sharma and Sinha, 1993). The impact of climate change aggravates this phenomenon of deterioration (Narayana and Rambabu, 1982; Agrawal, 2001).

Technology and infrastructure Higher rate of technology adoption and infrastructure development significantly correlates with reduced rural poverty (Fan et al., 1999; Scherr and Hazel, 1994). For example, increase of irrigation facilities, from 34 percent in 1970s to almost 90 percent by end of 1990s, contributed to agricultural productivity growth and also poverty reduction through the generation of nonagricultural employment opportunities (Pandey, 2002; Fan et al., 1999). Similarly, the rapid adoption of high yield seeds together with improved irrigation increased agricultural production and productivity growth sharply during the 1970s and 1980s (Scherr and Hazel, 1994).

International policies and schemes

As a broad approach, climate change mitigation proposals are classified into two categories, namely, technology-led initiatives, and government-led policies and measures. Several low carbon society (LCS) studies undertaken in developed countries push for integration of these two measures and related policies (Matisoff 2010; Kameyama 2007; Shimada et al., 2007). These integrated roadmaps include new technology innovations, sustainable development, carbon initiatives, as well as structural changes in various aspects of economy (Fujino et al 2008; Strachen et al. 2008; Barker et al. 2008; Groenenberg et al. 2004; Baumert and Goldberg 2006; Michaelowa et al. 2005). Fujino et al (2008) and Shukla (2010) further argue that these roadmaps as well as broad policy targets have to balance the specific future vision of a particular society.

Reflected in the idea of the Nationally Appropriate Mitigation Actions (NAMAs), government-led domestic policies and measures that link climate benefits with non-climate domestic goals like energy saving and security, reduced local pollution levels, and sustainable development, are especially proposed for developing countries. Examples of current proposals which transfer resources to developing countries are the financial support through Copenhagen Green Climate Fund (UNFCCC, 2009; Gomi et al., 2009) and the Clean Development Mechanism (CDM) initiatives (Baumert and Goldberg 2006; Gupta and Bhandari 1999). For instance, the Copenhagen Green Climate Fund provides financial support to developing countries for forest conservation, adaptation, technology development and transfer, and capacity building.

Discussion: Way forward

The literature review of international strategies and local concerns point towards several significant issues. One, improved rural infrastructure not only reduces rural poverty through improved agricultural productivity but also through improved wages and non-farm employment due to infrastructure development. The role of government expenditure, therefore, for infrastructure and asset development in agriculture as well as non agriculture sector, is evidently critical. Two, while there are many proposals for international transfer of resources to support developing countries, there is limited attention on internal transfer of domestic resources and local community initiatives, to support climate change mitigation efforts. Acknowledgement of climate change impacts and adaptation as a local phenomenon is recent and therefore the current focus is to put the local community initiatives as the central representation in carbon mitigation solutions (Shukla, 2010; Gomi et al., 2009). Three, linkages between ecology and livelihood security are significant in the rural area. Balancing use and regeneration therefore needs critical attention. Hence, a common threat emergent from the literature emphasizes collaborative action between the two, namely, local and international initiatives of technology and resource support. Following research questions are put forth:

a) How can the two strategy initiatives – international and technology led, and local government and policy led – interact with the local needs such that sustainable local initiatives can emerge?
b) What is the nature of policy support that can promote these sustainable local initiatives?

METHODOLOGY

The conceptual components of an integrated approach, as suggested by Balachandra (2010) in his paper on energy access, are used to evaluate the potential collaborative capacities of local regions for successful mitigation, Figure 1 illustrates the conceptual framework.

Primary and secondary data is analyzed using the above framework. A three-fold methodology is used, namely, secondary data analysis of the existing energy and resource scenario, existing governance and policy scenario and interview based case field study of two localized power generation projects in the state.

The secondary data for the energy and resource scenario of the state was taken from various sources, including The report of the Bureau of Statistics and Economics, Bihar, 2007; RHS Bulletin, March 2008, M/O Health & F.W., GOI; Road map for development of power sector in Bihar, Government of India, July 2007; www.biharstat.com/industries/18/ industrial growth; Centre for Monitoring Indian Economy Pvt. Ltd., 2010; www.biharonline.gov.in; Report: an overview of Renewable Energy Potential of India, 2006, Global Energy Network Institute

(GENI), http://www.geni.org/globalenergy/ energy trends/library/an overview of renewable energy potential of India.pdf; and IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, 2008 (http://www.ipcc-wg3.de/publications/special-reports).

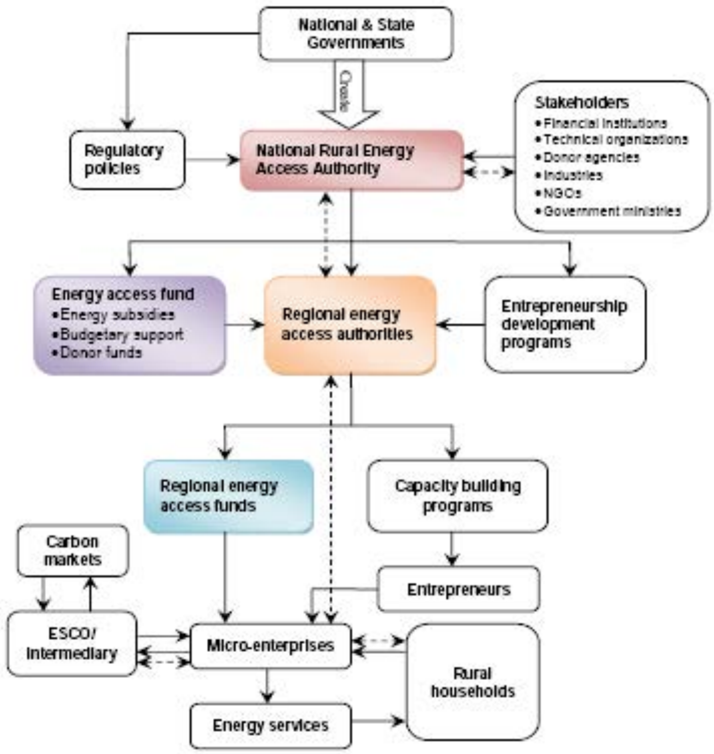

Figure 1: Integrated Energy Access Framework[2]

For the case studies of the two local DRE companies, field visits were carried out in the Indian state of Bihar, over a period of two months, taking 2 localized generation projects spread over 3 districts. Case interviews on field were semi structured and involved three groups of actors, namely, the generator/owners, government officials who were involved with energy access, and the customers. Data was collected during July-September 2010.

[2] **Source:** Balachandra, P. (2010), Modern energy access to all in rural areas, discussion paper no.2010-08, John F Kennedy School of Government, Harvard University, Cambridge, MA.

RESULTS

Resource and Energy Analysis

The state of Bihar, with an area of 94,163 sq. km. and a population of 82.9 million, consists of about 45,098 villages, holding 89% of the population.The census of India 2001 estimates about 42% of the state population at below the poverty line, with rural, non-farm, informal economy playing a significant role in providing employment income for them. Overall physical infrastructure of the state needs substantial increase and improvement. For example, as per RHS bulletin, 2008, the state has only 366 rural dispensaries, 70 referral government hospitals, 8 medical colleges to cater to 45 thousand villages and only about 10% of this population has access to all immunisation systems.

Census 2001 states almost 95% of the rural house-holds are still dependent on kerosene as a source for lighting (compared to 40% in urban). According to Rural Electrification Corporation Ltd. Report 2004, transmission wires have still not reached 50% of the inhabited villages and Bihar's power system has a peak of about 1,500 MW under the constrained demand scenario. Against this peak demand, the availability is about 950 MW, leading to wide-scale rationing of power to all the categories of consumers. The annual per capita consumption in Bihar is currently at 95 units, against a national average of 717 units (CEA General Review, 2009). Table 1 and Figure 2 indicate the possibility of acute power and energy shortage in the coming years.

Table 1: Power scenario at the end of the 11th Five Year Plan

	Particulars	Amount
Peak	Peak demand	3067
	Peak (MW)	1534
	Peak deficit (-)/Surplus(+)	-2073
	Peak deficit/Surplus (%)	-57.50
Energy	Energy requirement (MU)	19905
	Energy availability (MU)	11755
	Energy deficit(-)/Surplus (+)	-8150
	Energy deficit/surplus (%)	-40.90

Source: *Road map for development of power sector in Bihar, Government of India, July 2007*

Bihar has a vast stretch of fertile plain, drained by the river Ganga and its tributaries Gandak, Bagmati and Koshi. Additionally the state is located in a non costal region and near the Tropic of Cancer, with an average annual temperature range of 14-28 degrees Celsius and an average annual rainfall of 1205 millimeters (www.mapsofindia.com). This gives the state several natural strategic advantages in terms of location and range of temperature, for crops like sugarcane, rice ands other wasteland produces, and high solar energy potential. Planning Commission reports about 65 lakh tonne of rice production in the state where about 22 lakh tonne can generate nearly 200 MW power. So far 13 gasifier systems have been installed in rice mills and other industries in Bihar during the last two years for captive power requirement. Furthermore, MITCON, Pune

(1999) indicated about 85 MW exportable surplus energy could be generated from the 7 major sugar mills in Bihar. The sugar and husk based examples indicate the significant renewable energy potential and the need for an integrated approach towards energy planning.

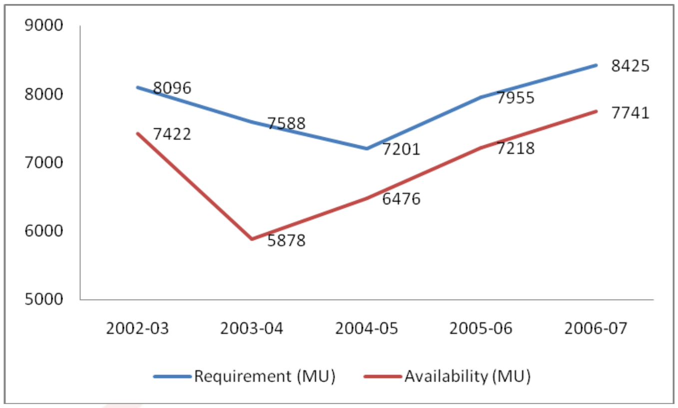

Figure 2: Power supply position (requirement and availability)[3]

Case Study: Renewable Energy Service Companies

Case Study 1: Husk Power Systems Owned privately by three people, Husk Power Systems provides electricity to about 40000 households/1 lakh people across 125 villages in Bihar, using rice husk as the main raw material to produce electricity. The company has 35 plants currently in operation and 25 under installation. Most of the plants are 32kW installed capacity (aggregating to a total installed capacity of 2 MW) and each plant uses about 330 kgs(300-350 kgs/day or 50-60 kgs/hr) of rice husk to generate power for six hours a day. The cost of producing 32kW of electricity per month is INR 22,000, which includes cost of raw material, salaries and maintenance, and the proprietors hope to recover their investment costs within 3 years. Each plant employs about four to five people to run and maintain the plant. Husk power systems has put in their own distribution lines and each line has a fuse to ensure no one draws more power than informally agreed upon. This also avoids power theft. The ash residue from the power plants is given to producers of incense sticks.

The husk power system operates on several innovative ideas and mechanisms as part of their business model. At a broad level, firstly, the system uses a natural waste material found in abundance in the local areas, making this model scalable. Secondly, the proprietors own the entire system from generation to revenue collection, as there is virtually no government or other agency support. Thirdly, they have integrated the system with other positive externalities like carbon mitigation by encouraging customers to use energy-efficient CFL bulbs, by selling the ash residue to incense stick manufacturing and the risk husk char to solar panel manufacturers.

[3] **Source:** *Lahiri, D (2011), Energy situation in the state of Bihar: technical analysis, In A. Gurtoo, A (2011), Providing energy access to rural Bihar: An analysis and policy options. A report. Greenpeace, India.*

Specifically, the model maximizes energy use and minimizes distribution /system losses by keeping an optimal mix of plant wattage and distance served. The husk power plants are small in size (maximum 32kW) and serve a maximum distance of two to three kilometers. The internal human resource effectiveness is managed by employing people who are well trained. Moreover, the system creates a sense of equality by working professionally in a place seeped in socio-economic barriers.

Case Study 2: Saran Renewable Energy Saran Renewable Energy Limited (SRE) is a build and operate model of decentralized electricity system operating in 3 villages. It provides electricity to about 250 households and about 50 pump sets with the help of a biomass gasification plant of about 120 kW capacity. The plant largely runs on Dhaincha (*Sesbania grandiflora*), with some use of wood chips. Dhaincha is a fast-growing, local weed-like plant. The plant taste is bitter and cannot be used as fodder. It typically grows on considerable empty lands in and around the Saran district. About 1.25 kg of Dhaincha is used to produce one unit of electricity at INR 8 per unit cost. Typically the plant operates for 6-7 hours per day in the evenings.

SRE operates despite several constraints and barriers. One, and the biggest barrier, is the reliable supply of raw material. SRE purchases Dhaincha at competitive prices, i.e., one acre of grown Dhaincha for Rs. 10,000 or more. This creates income for farmers. However the farmers have not come forward actively to grow this weed, despite clear economic benefits. Secondly, companies face lack of significant financial support from the relevant local government agencies, or the commercial banks. The banks do not consider the electricity industry /power sector in the state as a safe investment.

One of the bigger achievements of this power system has been the successful management of the local dynamics. SRE integrated the existing diesel power providers into its system, as distribution franchisees. This also incorporated the already existing micro-grids into his business system. Saran now supplies to about 80% of the electricity users in the Garkha Block of villages, with about 75% of the earlier diesel power generators managing the distribution end of the business. However, trust between all main stakeholders, the farmers and the proprietors, remains elusive creating the biggest bottleneck for the system to get cost effective.

Discussion The entrepreneurial systems on biomass operates on several innovative ideas and mechanisms as part of their business model, namely, use of abundant raw material, integration of the power system with other positive externalities like carbon mitigation, and utilization of ash, minimization of distribution /system losses by keeping an optimal mix of plant wattage and distance served and creating local employment. Moreover, the system creates a sense of equality by working professionally in a place seeped in socio-economic barriers. Barriers of smooth functioning are reliable supply of raw material and lack of significant support from the relevant local government agencies,

The case studies show a pattern of growth and constraints. One, the case studies demonstrate lack of institutional and government support for growth. Two, lack of private sector investments in potentially profitable options like the biomass projects reflect potential policy gaps. Three, the lack of socio-political support, an example: for procurement and production of raw material production despite economic incentives, indicate severe support deficit from the local government as well as specialized agencies. These issues and impediments create a need to analyze the existing policy and governance structures.

Governance Analysis

Using the framework provided by Balachandra (2010), and technology and governance analysis is shown in Table 2. The three system inputs, namely, economic, infrastructural and environmental / global climate change are analysed to understand the governance involvement, and stakeholder involvement, and reveals that gaps and potential options. Meeting the energey needs of rural Bihar, requires skills and training, local involvement, better greener technologies, structures and incentives for participation of corporate as well as local populations. These inputs and requirements are expected to deal effectively with possible climate change impacts like increased mean temperature and extreme weather, increased emissions and lead to positive impacts of energy security, employment opportunities and food and livelihood security. Using these inputs and requirements, the system interventions and strategies are discussed below.

PROPOSED STRATEGIES

Effective climate change mitigation interventions require strategies that remove the socio-economic and institutional barriers while developing low carbon societies (Shukla 2010, and IPCC 2007). The elements of policy, governance and capacities suggested in this section are based on the principles of inclusiveness, increasing state's investment capacity, generating developmental benefits and minimizing the environmental damage. They answer the question on how can the three strategy initiatives – technology led, carbon market led and local government policy led – interact with the local needs such that sustainable local initiatives can emerge, and what is the nature of policy change that can promote these sustainable local initiatives.

In the state of Bihar, renewable energy systems, both large scale and decentralized systems, in collaboration and cooperation with private investment, is a sustainable and clean energy source which can circumvent all the practical problems faced by the state as summarized in Table 2. The state of Bihar, with its abundant natural resources in the form of rice husk, sugarcane, and weed from wetlands like Daincha, wide-spread solar radiation, and ample water for small-scale hydro can easily be a leader in renewable energy production.

Governance and Support

Planning: The institutional structures of planning, governance and implementation in India suffer from ineffective inter-sectoral coordination (Bhandari 2008). The energy sector is looked after by several ministries that work almost independently like Rural Electrification Corporation (REC), Bihar Renewable Energy Development Authority (BREDA), and the Department of Energy. The policy setting has to start with developing an integrated approach to electricity planning and setting specific targets for the same. Specifically the following integrative steps need to be undertaken.

Table 2.Governance analysis: barriers and facilitators

Stakeholder category	Stakeholder group	Major interests or concerns	Potential synergy with climate actions	Main barriers and facilitators
Government	State government and regional agencies like BREDA and REC	State economic growth, generating funds through market, increased economic and industrial capacity, public infrastructure, industry, agriculture, governance, environmental pollution.	Low carbon infrastructure, industry, agriculture	Low creditworthiness hence low investment; weak participation of local groups; poor coordination between agencies. High political will; Abundant natural resource and high renewable potential. Market orientation towards encouraging entrepreneurs; access to technologies
Business/Industry	Entrepreneurs (large, medium and small business) and other financial institutions	High return on investment, availability of raw material and ease of supply chain, low government interference and administrative barriers, expansion of consumer base,	Low carbon technology related business opportunities	Rigid government rules and regulations; Limited policies to promote low carbon technologies; poor access to knowledge by the government agencies of low carbon innovations ; Inadequate government support for innovation; lack of access to latest technologies High National and State Government willingness to promote entrepreneurs in renewable technologies.
Civil society	Urban economy, rural economy, donor agencies	Economic opportunities, reliable energy access, industrialization and development	Small scale renewable energy; Water/ waste recycling; Participation in low carbon urban infrastructure supply and maintenance	Weak institutional and market support; weak participation of local groups; poor bargaining power, low awareness on climate change threats; lack of knowledge about technologies High political will; Abundant natural resource and high renewable potential. Market orientation towards encouraging entrepreneurs

Yield stability of rice under high temperature

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ABSTRACT

Yield stability of rice under high temperature was conducted in pot experiment. The experiment design by split plot in CRD with different cultivation environment included 1) normally cultivation; under ambient temperature, 2) cultivation under high temperature (~2 ºC over the ambient). The Suphanburi 1 rice variety was planted in pot experiment by using Kamphaeng Saen soil series (Typic Haplustalfs). Pots of rice plants were remain under ambient air temperature throughout the growing season for normally cultivation. Rice plants of high temperature treatment were stored inside controllable temperature chamber (~2 ºC over the ambient temperature) from panicle initiation stage to harvesting for cultivation. Rice plant growth and yield were observed throughout growing season.

Filled grain weight under high temperature was ~43% lower than rice cultivation under ambient temperature. Unfilled grain under high temperature condition was ~40% higher than normal condition. Rice yield under high temperature and ambient temperature was significantly different ($p \leq 0.05$). The result concluded high temperature decrease rice grain yield in this experiment. In order consider stability of total rice grain yield for world population, more field experiment under various rice varieties and various location of rice cultivation are needed.

Keyword: rice growth, rice yield, rising temperature,

1. Introduction

Rice cultivation needs suitable climate condition and optimum environment for rice growth. In Thailand, almost half of agricultural area is rice cultivation area. Rice is normally cultivating 1-2 crops per year in order to meet consumption demand and export. Increasing of greenhouse gases such CO_2 CH_4 and N_2O that absorbs radiation may lead to an increase global surface temperature and may have impact on rice production. Number of research reported effects of high temperature and increasing of CO_2 concentration on rice production (Matsui et al., 1997, Luo et al., 1998, Cheng et al., 2008). High temperature effects on rice growth and rice yield by decreased rice panicle number (Cheng et al., 2008) high unfilled grain (Keawklom et al., 2009) and lead to low rice yield (Luo et al., 1998, Thanacharoenchanaphas, 2008).

This study investigates pot experiment in green house in order to simulate of high temperature situation on rice growth and yield. The objective of this study was to determine effects of high temperature during growing period on rice growth and yield.

2. Materials and method

2.1 Green house for rice cultivation and temperature control equipments

Controlled temperature green house was used in this experiment. The green house was square in shape of base and its roof was semicircle in shape. It was 2 m. x 2.5 m. x 2.5 m. (W x L x H), open front, its frame construct of steel and cover by plastic sheet 0.5 mm. thick. Air conditioner was installed inside the green house. Temperature inside green house was controlled approximately 2ºC over ambient temperature by automatically circuitry. Temperature inside green house was continuously record by data logger throughout the growing season.

2.2 Pot experiment

The pot experiment was conduct at Kasetsart University Kampheang Sean Campus Nakornpathom province in central of Thailand. The photoperiod insensitive rice cultivar Suphanburi 1 was used. Rice plant was transplanting on November 3, 2010 in pot with six replicates of two treatments included 1) normally cultivation; under ambient temperature, 2) cultivation under high temperature (~2 ºC over the ambient). The pots were flooded on 7 days after planting and the water level in each field was controlled (5-10 cm) throughout the growing period. The final drainage was applied for all treatment at 15 days before harvesting. No chemical fertilizer was used in this experiment but the pesticide was used once for worn eradication during vegetation period. The soil was Kampeang Sean (Kps) soil series and the soil was classified as Typic Haplustalfs. Soil texture was classified as clay with a percentage composition of sand: silt: clay of 22: 24: 54. Table 1 descripts soil properties of Kampeang Sean soil series before growing season.

For ambient temperature condition of rice growing, the pot of rice plant was store under ambient temperature since transplanting throughout growing season. While rice plant cultivated under high temperature treatment was store under ambient temperature since transplanting to initial panicle growth stage. Then rice pots were move into green house during the initial panicle growth stage to harvesting.

Table 1 Soil properties of Kampeang Sean (Kps) soil series before growing season

Soil parameters	Soil properties
pH	7.06
Organic matter (%)	1.80
Organic carbon (%)	1.04
Phosphorus (mg P/kg)	97.71
Potassium (mg K/kg)	61.70
Bulk density (g/cm^3)	1.31
Total carbon	1.53
Total nitrogen	0.06
C/N ratio	17.30

3. Results and discussions
3.1 Rice growth and rice yield

Rice growth data was observed throughout growing period. Plant height, number of plant per pot, and number of rice ear per pot were shown in Table 2. Plant height, number of plant per pot between two treatments was not different. However, number of plant per pot and rice ear per pot of rice cultivated under high temperature was ~10% lower than normal condition.

Table 2 Rice plant growth

Treatments	Plant height (cm.)	Plant/pot	Rice ear/pot
Control	88.80a	21.30a	14.66a
High temperature	88.50a	19.26a	13.17a
F-Test	ns	ns	ns
CV. (%)	3.43	19.74	22.29

Values in a column followed by a common letter are not significantly different at the 5% level by DMRT. ns: not significantly different

Rice grain yield was recorded after harvested. Rice grain weight per ear, filled grain per ear, and filled grain weight under high temperature were lower compared to normal condition. In addition, unfilled grain of rice cultivated under high temperature was higher than normal condition and was significantly different ($p \leq 0.05$). This result consists with the result of Peng et al. (1995), which was reported that rice grain yield cultivated under high temperature (at 38 °C) was decreased compared to rice cultivation at 35 °C and 32 °C. Rice yield was decreased up to 9.5% when temperature increase 4 C and rice yield decline up to 10% for every 1 C of increasing temperature.

In case of high temperature treatment, we store pots of rice plant in the green house at panicle initial growth stage. Filled grain yield per ear under high temperature was 43% lower than that cultivated under ambient temperature. High temperature damage grain yields because high temperature may effects rice growth at panicle initial and flowering (Yan et al., 2008). Rice growth rate, flowering potential, and filled grain activity of rice plant was destroy by high temperature (Wang et al., 2009).

Table 3 Rice yield

Treatments	Filled grain/ear (seed)	Unfilled grain/ear (seed)	Filled grain weight/ear (gram)	Filled grain weight/1000 seeds (gram)
Control	77.04a	18.35a	2.10a	25.74a
High temperature	44.28b	46.75b	1.05b	23.90b
F-Test	**	**	**	*
CV. (%)	12.44	26.02	13.51	3.45

Values in a column followed by a common letter are not significantly different at the 5% level by DMRT. **: significantly different, ns: not significantly different

3.2 Soil properties after harvested

Soil properties of Kampheang Sean soil after harvested shown in Table 4. Higher organic matter, organic carbon, potassium, and phosphorus remained in soil was observed from soil under high temperature treatment than that normal condition. However, soil organic carbon and soil organic matter from both treatments were not much different (2 and 4%, respectively). Phosphorus and potassium under high temperature treatment was ~15 and 25% higher than normal condition, respectively. High temperature may leads to high activity of decomposition in soil (Akkarathanakul, 1986, Yingjajaval, 1993). Soil pH after harvested period was increasing compared to soil pH before growing period (7.06). However, comparisons of soil pH between two treatments were not different.

Table 4 Soil properties after harvested

Soil properties	Control	High temperature
pH	7.54	7.56
Potassium (mg/kg)	66.58	76.65
Phosphorus (mg/kg)	48.64	50.67
Total Carbon (%)	0.97	0.97
Total Nitrogen (%)	0.08	0.07
C/N ratio	11.29	13.26
Organic Carbon (%)	0.90	0.92
Organic Matter (%)	1.55	1.58
Bulk density (g/cm^3)	1.12	1.14

4. Conclusion

Pot experiment in green house to simulate of high temperature situation on rice growth and yield in this study concluded that high temperature decrease rice grain yield. Filled grain weight under high temperature was ~43% lower than rice cultivation under ambient temperature. Unfilled grain under high temperature condition was ~40% higher than normal condition. Rice yield under high temperature and ambient temperature was significantly different ($p \leq 0.05$). In order consider stability of total rice grain yield for world population, more field experiment under various rice varieties and various location of rice cultivation are needed.

5. Acknowledgements

We extend great thanks to Kasetsart University for financial supported. Thank you to the laboratory of soil and plant analysis, Faculty of Agriculture Kampeang Sean, Kasetsart University Kampheang Sean Campus. Thank you to Miss Wilaiporn Promraksa for her kindly assist for field data collection. Thank you to Mr. Nheng Sukheewong and Mr. Somkiet Krabthong for their helpful suggestions of rice cultivation during growing period.

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Study of Dynamic Characteristic of PM_{10} Concentration During Street Sweeping

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Abstract. The paper presents an evaluation on street sweeping by PM_{10} measurements from active traffic streets. A modified regenerative-air vacuum sweeper (RAVS) was used in this study. Compares the changes of measured parameters by subtracting the "after" values from the "before" values for each measurement episode (before and after sweeping). During the monitoring period, the PM_{10} concentration increased instantly by up to 40% after the road was swept by a street sweeper. The average emission potential increase measured on all roads is 15%. Approximately 1.5 hours after the initial sweeping, the emission potential from road and returned to pre-treated levels. The results of sweeping experiment indicate that the direct of PM_{10} emissions are short no more 2 hours and the efficient of reduce can be kept up to 3~4 hours. It appears that the application of street sweeping is possibly feasible to control the ambient PM_{10}. Finally, correlated with dust and silt loading, a correlation is proposed to estimate the PM_{10} concentrations, which is valid in appropriate conditions suggested by the work. It is feasible to predict the increase of PM_{10} concentrations by the regenerative-air vacuum sweeper used in this work. Effects of traffic volume and wind velocity on the increase of PM_{10} concentrations are also discussed in the paper.

Keywords: street sweeping, dust, silt, PM_{10}.

1. Introduction

One of the most serious environmental problems in Taiwan is air quality, with the major air pollution source being automobile exhaust emissions. There has been growing public concern about air quality in Taiwan's urban areas, especially focused on particulate matter (PM) produced from paved roads and as well as construction activities. The Taiwan's government has implemented some strategies to improve its air quality. One of strategies is the street sweeping and washing to control ambient PM_{10}. Street sweeper took place recently on the wood pavement and attracted crowds of persons to view its very novel apparatus. The cart was drawn by two horses, and attended by a driver, and as it proceeded caused the rotary motion of the wheels to raise the loose soil from the surface of the wood, and deposit it in a vehicle attached being equal to the of forty men, and it operation being of a same time, which under the old process, formed three distinct operations (Ibid, 1844). Street sweepers are often suggested for reducing the emissions from paved roads, so in a few past years, the street sweeping has become a feasible method for removing dust from roads in Taiwan.

According to several recent studies, for example, Street sweeping may be a valuable best management practice (BMP) for the control in U.S.A **[1]**. Fitz and Bumiller **[2]** estimated that good sweepers could reduce PM_{10} generation from paved roads by over 30%. Duncan et al. **[3]** also found out dust emission from paved street can be controlled and reduced by approximately one-third by street cleaning. However, some of studies actually registered increases in PM_{10} levels or emissions after sweeping procedures, and actually injected it back into the atmosphere. For example, Gertler et al. **[4]** indicated the street sweeping was found to increase the PM_{10} re-entrainment rate of the remaining road dust.

A number of street sweeper problems are the debris maybe swept back-ward by the brush especially increased the concentrations of PM_{10}. Furthermore the emission algorithm correlates the overall PM_{10} emission factor to total road surface dust and silt loading, traffic volume, wind speed and humidity. For this reason, the major objectives of this investigation were to: (1) Evaluate the contribution rations of PM_{10} after street sweeping; (2) Quantify the time of re-entrainment (Tr) after street sweeping; and (3) Find the effect factors of street sweeping on ambient PM_{10} emissions.

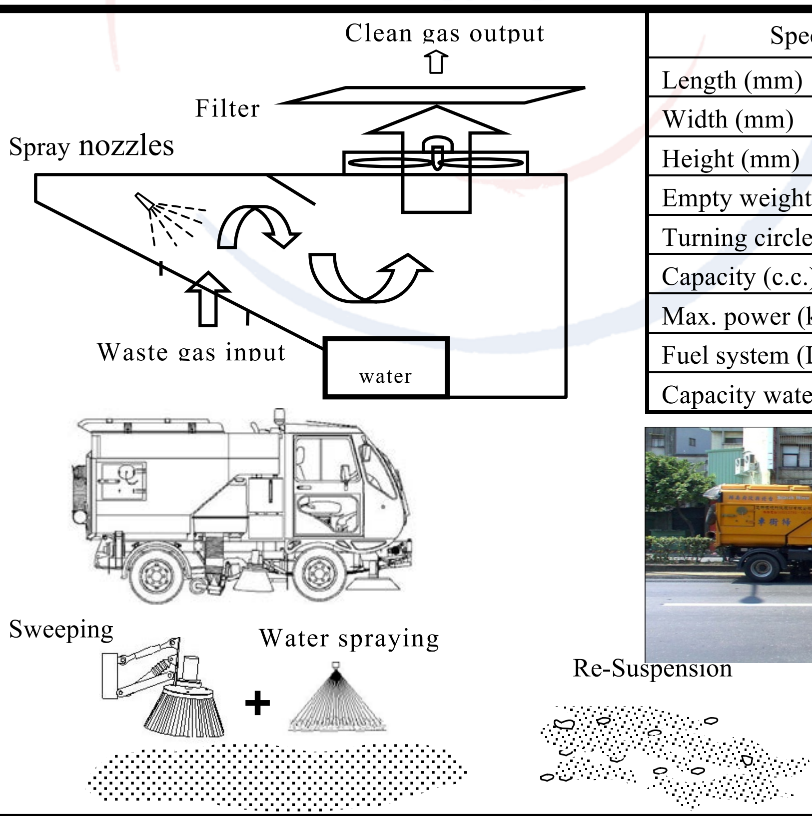
2. Method and Measurement

2.1. Street sweeper

The regenerative air vacuum sweeper (RAVS) with 55 kw engine power, upgraded in this study to improve its sweeping performance, was used in the work. This sweeper uses a regenerative air system for dust pickup as shown in **Fig. 1**. A gutter broom moves the street dirt from the curb toward the center of the sweeper. To suppress dust, the RAVS has two water spray nozzles at the front of sweeper, three at each end of the pickup head, three at each gutter broom, and four inside the hopper which functions as a wet scrubber. The total water spray rate is about 75L/hr. A blower forces air through a slot in the pickup head, which rides on top of and seals the head to the street surface. The dirt is then vacuumed up and carried to the hopper through a vacuum hose. In the hopper, paper and leaves are removed from the air stream by a screen. Large particles are removed by a centrifugal separator. The vented air then goes through a fabric filter mounted in the upper sweeper, The air is then recirculated after it is cleaned by the wet scrubber and filter.

2.2. β-attenuation particle monitors

β-attenuation particle monitors (β-gauge) is one of techniques for aerosol mass measurement, which could be most appropriately described as a shore-term batch process. It also can determine the mass of collected aerosol samples in intervals convenient for many applications. The beta gauge method of mass determination depends upon the near exponential decrease in the number of beta particles transmitted through a thin sample as the areal density is increased. The beta particles are emitted as a continuum energy distribution by a radioisotope source and their intensity is measured with suitable electron counter. The method has the advantage of instrumental simplicity an ease of automation for large-scale applications. The dynamic range of sensitivity is well matched to the mass range normally of interest in aerosol monitoring in which thin membrane filters are the substrates. Its monitoring method was followed by Taiwan NIEA 206.10C (based on US EPA 40CFR Part 53, 1994[5]).



Specification	
Length (mm)	4,230
Width (mm)	1,650
Height (mm)	2,320
Empty weight (kg)	3,500
Turning circle (m)	8.5
Capacity (c.c.)	2,776
Max. power (kw/rpm)	55
Fuel system (L)	60
Capacity water tank (L)	420

2.3.Dust and silt loadings

Dust and silt loading are a measure of the mass of particles less than 75 μm per unit area of road surface. The sampling method of dust or silt collection was referred to the method AP-42 (1998), by which the vacuumed area of road surface is 10 m^2 (0.5 m × 20m). Dust (<297μ m) and silt (<75 μm) were determined by measuring the proportion of loose dry surface dust that passes 48 mesh and 200 mesh respectively, using the ASTM-C136 method. The silt loading is rapidly replaced after sweeping to an equilibrium level dependent on factors such as vehicle speed and traffic volume.

3. Results and discussion

3.1. Dynamic of PM_{10} concentration during street sweeping

In this study with intense sweeping of road surface have been performed in order to evaluate the increased of PM_{10} concentration. Compares the changes of measured parameters by subtracting the "after" values from the "before" values for each measurement episode (before and after sweeping). Continuous measurements were averaged in hourly concentrations and evaluated during the 5 hours after treatment. **Fig.2** shows a typical dynamic data of PM_{10} concentrations during street sweeping. During the monitoring period, the PM_{10} concentration increased instantly by up to 40% after the road was swept by a street sweeper. The average emission potential increase measured on all roads is 15%. The increase of PM_{10} after street sweeping is likely due to the scrubbing action of the brush in the street sweeping machine. The brush release parts of the load but the suction sweeper is not capable of removing this material from the road surface. This has important implications because whilst street sweeping is effective in removing gross pollutions, it may have an adverse impact on pollution wash-off by releasing the finer materials making them readily available for wash-off by the next storm event. Similar observations have been suggested by other researchers, where the authors did not find a detectable reduction in road dust emission potential immediately after street sweeping. It is unclear if routine street sweeping reduces emissions of PM from a paved road over longer periods of time. A number of sweeping problems are identified. The debris may be swept backwards by the brush. This is called "backward sweeping". Insufficient brush-debris contact may arise if the combination of the brush operating parameters is not adequate. (e.g. Kuhns et al., 2003, Chang, 2005**[6,7]**).

3.2. Time of re-entrainment (T_r)

Street sweeping practices may actually increase PM_{10} emissions by scrubbing action of the brush in the street sweeping machine; especially like the re-suspended road dust is an important contributor to ambient particulate matter. In this study, the measurements began immediately after passage of street sweeper at approximately 8:00. **Fig.3** shows the increase of PM_{10} concentration from 9 roads during the first hour after street sweeping, as measured by three monitors. Corresponding with high levels of visible dust that were immediately stirred up by street sweeper, the monitors recorded the highest PM_{10} concentration after 20 minutes.

Approximately 1.5 hours after the initial sweeping, the emission potential from road and returned to pre-treated levels. The results of sweeping experiment indicate that the direct of PM_{10} emissions are short no more 2 hours and the efficient of reduce can be kept up to 3~4 hours. It appears that the application of street sweeping is possibly feasible to control the ambient PM_{10}.

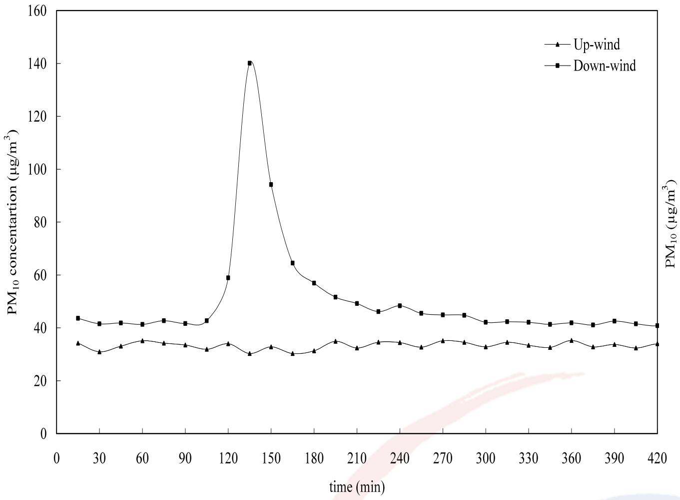


Fig.2 Typical dynamic variability of PM_{10} during sweeping

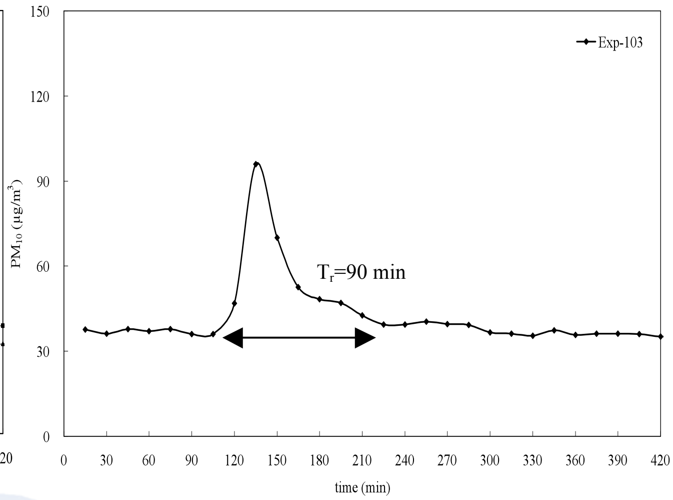


Fig.3 T_r of PM_{10} during sweeping

3.3. Effects on PM_{10} Concentration

(1) Traffic Volume

Based on the equivalent fugitive particle emission rate, the traffic volumetric rate is defined as follows[6]: pcu/min =4×(number of trunk per min.)+1×(number of car per min.)+0.2×(number of motorcycle per min.)

For the range of 42-138 pcu/min with vehicles traveling at a velocity of 30-50 km/hr, Fig.4 shows the traffic volume effect on the PM_{10} concentration. It appears that there is no significant relation between the PM_{10} concentrations and traffic volume during street sweeping. Intrinsically, the dust or silt load is not dependent on the traffic volume. However, some field investigations have shown that the fugitive dust emission rate depends on the road surface texture, road surface moisture, average vehicle speed, average vehicle weight, and average number of wheels per vehicle [5]. Therefore, an increase in traffic volume will increase the ambient PM both before and after sweeping.

(2) Wind Speed

Most particulate matter arises from open dust sources that entrain particles into the atmosphere by the force of the wind with or without machinery acting on exposed materials. Thus, the fugitive dust re-suspension rate has a high degree of temporary and spatial variability because of the sporadic nature of the wind on the fugitive particle emission potential. Although the fugitive dust re-suspension rate has been found to increase with increasing wind velocity, a comparison of the re-suspension rate indicates that the wind velocity effect is not different with and without sweeping. It seems that the same wind velocity effect occurs on the re-suspension rate either with or without sweeping application. As a consequence, the PM_{10} concentration is not a function of the wind velocity, as shown in **Fig.4**.

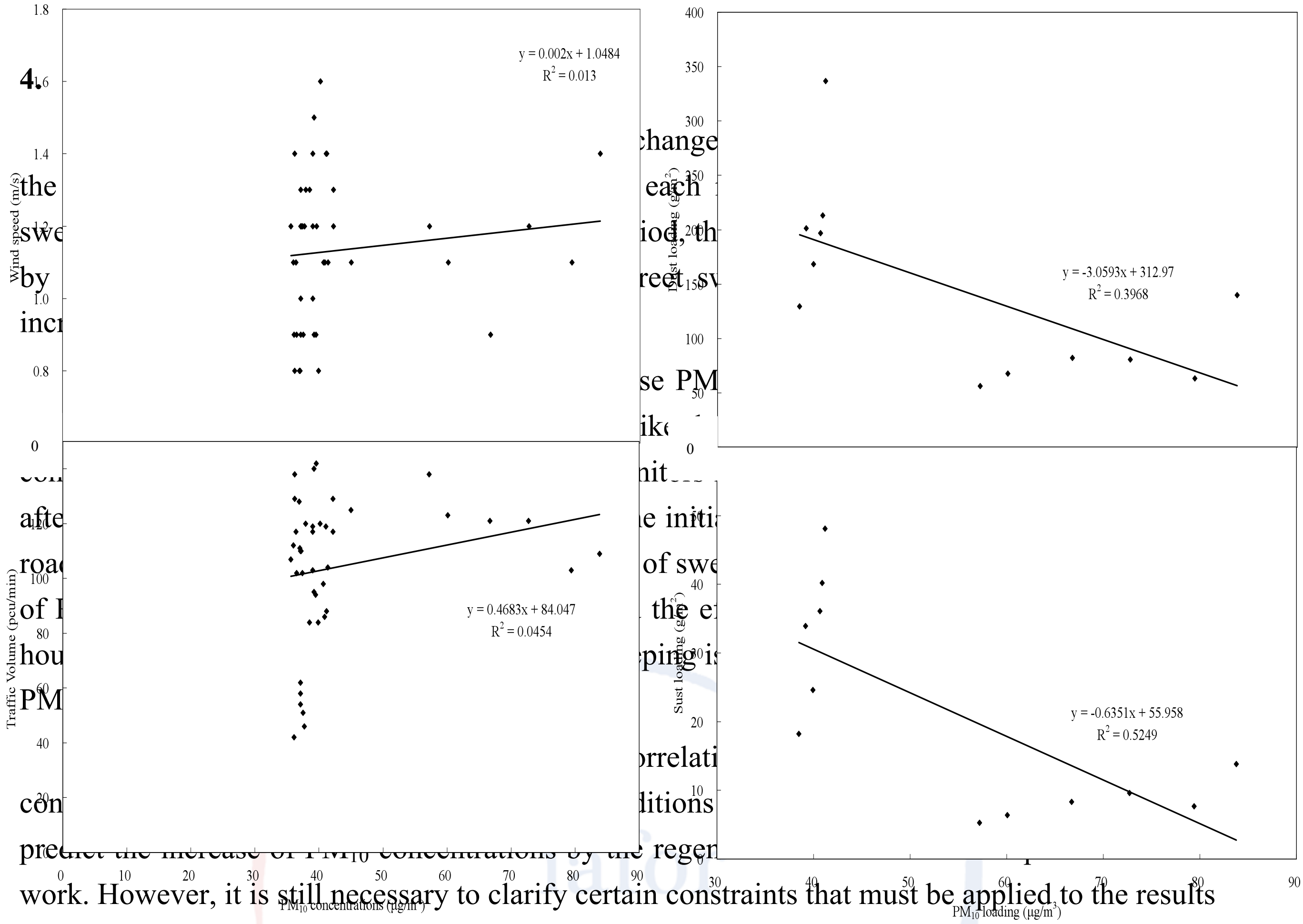
(3) Dust & Silt Loading on Paved Road

As in the cases for most predictive models, the use of silt content of road surface material is strongly recommended for estimation of re-suspension rate of fugitive dust. In fact, the re-suspension rate would increase with the increase in silt content. That is to say the more silt content on the road surface, the greater the fugitive dust re-suspension potential. The silt load (g/m^2) on the road surface was systematically measured in the range of 5.3-48.1 g/m^2 for this work. The effect of silt load effect on PM_{10} concentrations is shown in **Fig.5**. It shows that PM_{10} loading seems to significantly depend on the silt load. It will increase poorly as the silt load increases to the higher silt load.

PM_{10} concentration (μg/m^2)

Fig.4 Effect of wind speed and traffic volume on PM_{10} concentrations

Fig.5 Effect of Dust & Silt loading on PM_{10} concentrations



work. However, it is still necessary to clarify certain constraints that must be applied to the results obtained from this work, such as the need for more information to verify the results for other conditions.

5. Acknowledgements

The authors are grateful to the National Science Council, ROC, for the financial support of this work (Grant no. NSC-99-2218-E-228-003).

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Optimum air change rate for night ventilation in order to achieve energy saving in Yemeni office building.

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Abstract

In Yemen important steps have to be done to develop some initiatives in order to promote design strategies for energy efficiency in office building in different climates types of the country. This paper discusses the reducing of cooling demand in office buildings by using natural night ventilation in the two main cities of Yemen Sana'a and Aden. Both cities have different climate and many simulations were done using energy plus program- Design Builder in order to achieve the reduction of cooling demand during summer. Parameters such as shading and glass ratio were considered. These variations of design parameters shows that high energy savings can be achieved by basic design strategies including night ventilation and orientation of windows with respect to solar heat gain.

This paper shows the feasibility of reaching the necessary night ventilation through windows for an efficient cooling in office buildings. By using night ventilation energy saving will be achieved in office building in both cities Sana'a and Aden. The simulation results show the relation between the cooling demand and air change rates.

Keywords: Night ventilation, Air change rate, Reduce cooling demand, Office building.

- Introduction

Building sector in Yemen has many problems in term of energy efficiency. There are needs to do more investigations in building sector in order to reduce the amount of energy consumption. The problem will be clear with the overview of energy situation in Yemen. There is schedule cutoff electricity due to huge shortage of it. There is no building energy standard in Yemen even with increasing of energy consumption in building sector. Office buildings are part of this sector which is consuming significant amount of energy in cooling devices. Most of office buildings in Yemen are located in Sana'a and Aden cities. Both cities have different climates and different altitude from the sea level. Sana'a is 2300 meter above the sea and its climate shows no need to use air condition units. Due to absence of energy efficiency strategies, the buildings consume more energy. Recently many HVAC devices are installed in Sana'a city due to the need for cooling in summer time.

The climate of Aden city is totally different which is located in hot climate with high cooling demand due to high outdoor temperature. The problem of office building in Aden city is that, the buildings do not interact with the surrounding climate in term of energy efficiency.

There are many new office buildings which are built recently without any proper design to solve the problem of increasing the cooling demand. One of these problems is using high glass ratio in building façade. There are needs to provide the office building with different strategies to minimize the energy consumption especially reduce the cooling demand.

Night ventilation is an essential factor to decrease the cooling demand when outdoor temperature is lower than indoor temperature. The key point is examining the effect of different air change rates on the cooling demand for both different climates of Sana'a and Aden. The natural night ventilation will remove the heat absorbed during day time. The office building is unoccupied during the night which could be utilized to apply night ventilation strategy.

- Sana'a city

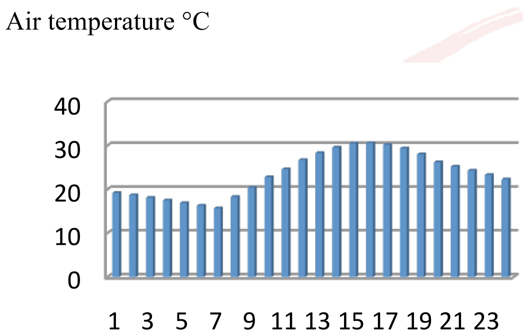

Figure (1) Outdoor Temperature summer day 21 July

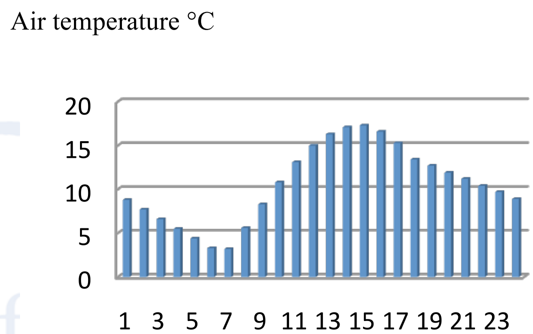

Figure (2) Outdoor Temperature winter day 21 December

The climate of Sana'a is cold in winter and mild in summer with average temperature between 12 °C and 30 °C in summer. The average temperature in winter is between 0 °C and 20 °C. The climate of Sana'a city has high difference in temperature between day and night and it could reach up to 20 °C. This difference in temperature could be used to provide cold air in building during summer at night and removes the heat absorbed by the building construction. The humidity average is between 35% and 55 %. The Figure (1) shows that summer temperature could reach up to 12 °C at night which is very low compared to day temperature which reaches to 30 °C. In winter is very cold at night and its temperature reaches up to 0 °C and on the other hand the day temperature could reach up to 20 °C Figure (2). The problem should be solved from the design stage because it seems that there is no attention to the increasing of cooling demand. There are other parameters that affect the cooling demand such as increasing of glass ratio in modern offices. The façade with high glass ratio without any shading leads to increase in the cooling demand. The designer should encourage the ventilation through the building space by proper design and give more attention to building façade in term of energy efficiency.

Figure (3) Office building in Sana'a city

Figure (4) Office building in Sana'a city

- Aden city

Climate of Aden city is very hot during summer and the average outdoor temperature is between 22 °C and 38 °C and it could reach more than 40 °C. The figure (5, 6) shows the outdoor temperature in summer and winter. The temperature difference could reach up to 12 °C between day and night which could be utilized through night ventilation in order to reduce cooling demand. The climate of Aden city has little rain fall during all the year. The average of precipitation is from 2-5 mm. The sunshine hours reach to 300 hours per month during summer and the minimum sunshine hours could be found in February which is about 200 hour per month. Aden has high percentage of humidity which reaches up to 75% all over the year.

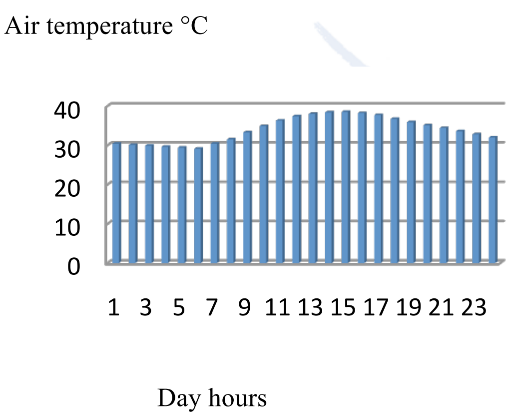

Figure (5) Outdoor Temperature summer day 21 July

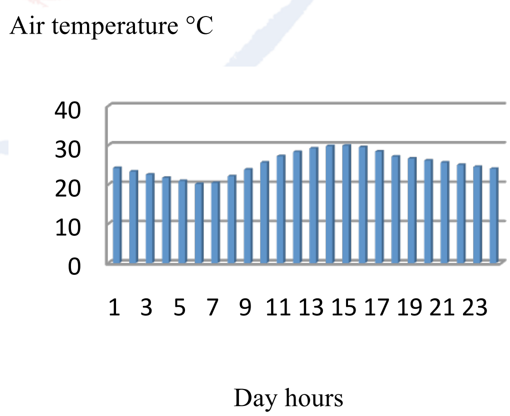

Figure (6) Outdoor Temperature winter day 21 December

- Simulation program

Figure (7) Office model in Design Builder

The simulation model shown above is built in Design Builder program for both climates of Sana'a and Aden. The model for both climates is the same dimension and all other parameters such as shading, glass ratio and glass type. The weather data file for Aden and Sana'a cities are used with epw format. The design builder program is validated in ASHRAE 140 and is using the energy plus program calculation. The four main orientations are simulated for both climates in order to analyze the effect of different air change rates in different orientations. The simulation model walls and roof are adiabatic in order to study the thermal behavior of the whole building and at the same time reduce the time need to run the simulation. The model describes as the following:

Location Sana'a and Aden cities- Yemen	
Area of the model office = 12 m^2	Volume of the zone = 36 m^3
Height of the zone = 3 m	Working hours = 8 – 18 h
U value of external walls = 1.6 $w/m^2.k$	Thickness of wall = 0.3 m
U value of internal walls = 2.0 $w/m^2.k$	Thickness of wall = 0.2 m
U value of external glass = 2.0 $w/m^2.k$ (solar protection glass)	

Table (1) Model description

Internal gain and ventilation	
Person in each zone = 2	Person gain = 150 W
Computer in each zone = 2	Computer gain = 140 W
Lighting Density = 13 w/m^2	Cooling temperature set point = 26 °C
Air change rate occupied = 1/h	Air change rate unoccupied = 0.3 /h
Infiltration rate = 0.3 /h	Night ventilation = 22 – 6 h

Table (2) Model internal gains and ventilation

The simulation model progress starts with 10 different air change rates from 1 ac/h to 10 ac/h in both climates and different orientations North, South, East and west. The result will show the cooling demand for every orientation and air change rate.

Simulation Result

- Night ventilation – Sana'a

Night ventilation in climate of Sana'a city should be utilized due to the characteristic of this climate. It is shown that the outdoor temperature of this climate has high difference between day and night which will be studied in this part by testing different air change rates during night time in order to see the effect on the cooling demand. The type of the ventilation in the model is single sided ventilation.

Cooling demand

kWh/m^2.a

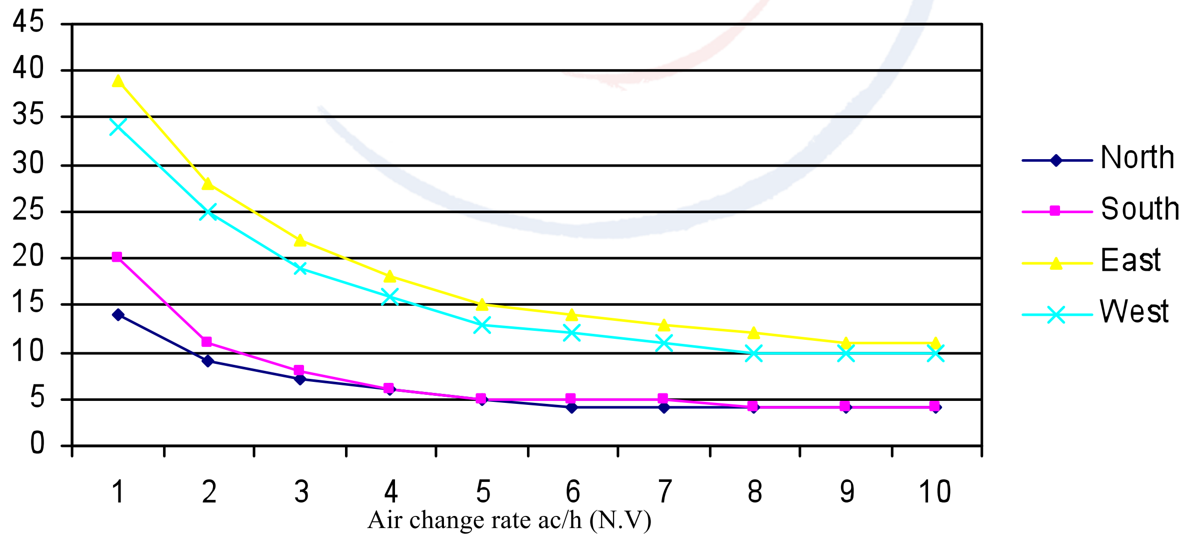

Figure (8) Relation between cooling demand and air change rate- Sana'a

The figure (8) shows the relation between different air change rates and cooling demand. Different air change rates were tested in simulation model and the result shows that there is reduction in cooling demand with increasing of the air change rate. The graph shows that between 1 ac/h and 5 ac/h there is a very high potential to reduce cooling demand (reduction very high). Between 5 ac/h and 10 ac/h the reduction are not very high. The result shows the effect of different air change rates with different orientations. The result shows the possibility to utilize night ventilation in climate of Sana'a. The reduction in cooling demand is due to low outdoor temperature during night and it's possible to have this reduction in the four main directions. It is clear from the graph that there is no significant reduction in cooling demand between 5 ac/h to 10 ac/h in south and north direction. There is reduction in cooling demand in East and West direction between 5-10 air change rates but still not high compared to air change rate from 1 ac/h to 5 ac/h. The reduction in cooling demand is a significant amount from 38 kWh/m^2.a and reducing to 12 kWh/m^2.a in east direction. In West direction is reduced from 33 kWh/m^2.a to10 kWh/m^2.a. In South direction is from 20 kWh/m^2.a reducing to 8 kWh/m^2.a. In North direction is from 13 kWh/m^2.a reducing to 8 kWh/m^2.a.

To achieve the previous air change rate in simulation model, fan was used to provide certain amount of air change rate inside the model in case there is no sufficient air flow. The optimum air change rate will be defined by the relation between cooling demand, cooling power, fan power and electricity. Increasing the air change rate will increase the fan power and the energy use, on the other hand reducing the cooling demand and power. The result shows that 5 ach/h is the optimum air change rate. The figure (9) shows the cooling demand and the electricity used by fan with 5 ach/h.

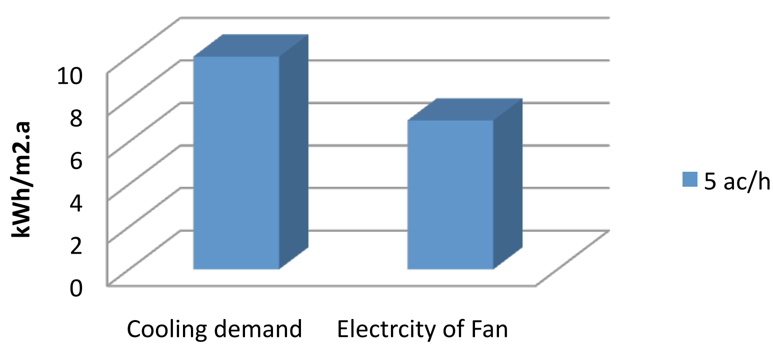

Figure (9) Cooling demand an fan electricity (5 ac/h)

The cooling power is reduced from 43 W/m^2 with 1 ac/h to 30 W/m^2 with 5 ac/h which shown in figure (10)

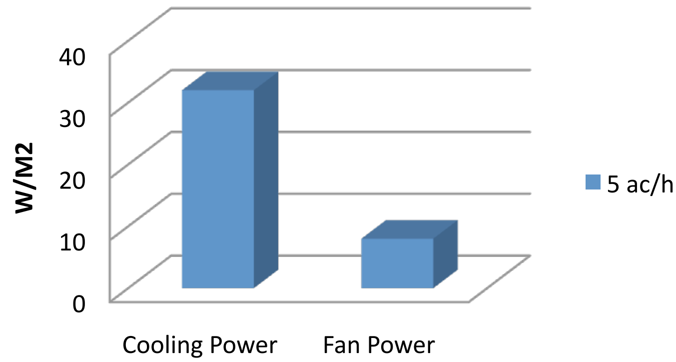

Figure (10) Cooling power and fan power (5 ac/h)

- Night ventilation - Aden

The effect of night ventilation will be examined in the simulation model and tested in the climate of Aden city to determine the energy saving potential in office building located in Aden city. Different air change rates will be tested it in the simulation. The figure (11) shows the relation between different air change rates (1 - 10 ac/h) and cooling demand for different orientations in Aden office building. The cooling demand reduced from about 200 to 175 kWh/m^2.a for West, East directions and 160 to 140 kWh/m^2.a for North, South directions as shown in the graph. Ventilation depends on the air pressure, wind speed and direction and the temperature difference between indoor and outdoor. The window opening ratio controls the amount of air flow crossing the building. Proper design for office building is very important to have more air flow through the building space. In case there is no sufficient air flow to reaches certain air change rate required so mechanical device such as fan will be used.

Cooling demand

kWh/m^2.a

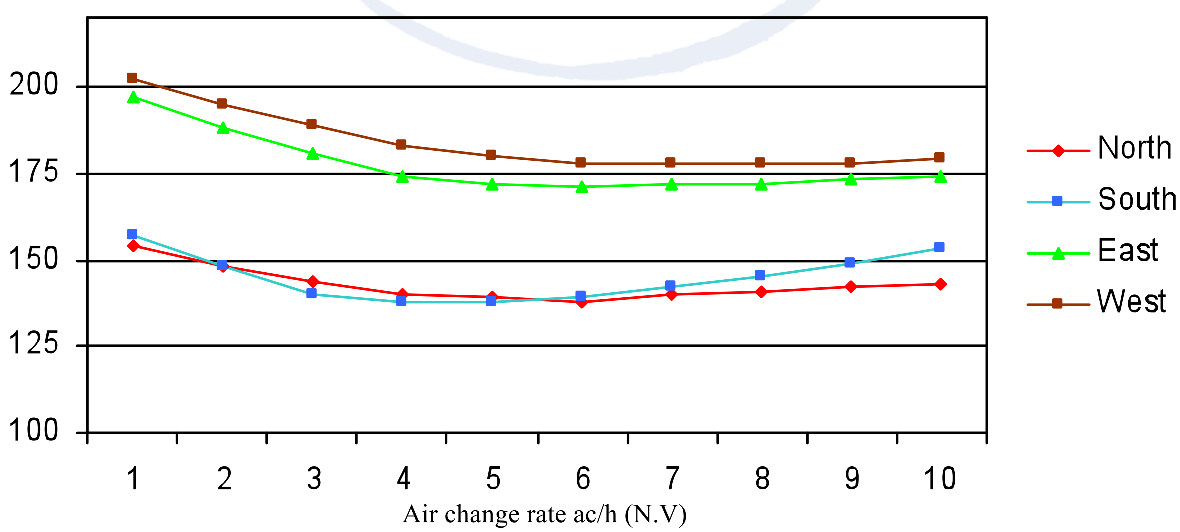

Figure (11) Relation between cooling demand and air change rate- Aden

The significant amount of reducing the cooling demand in hot climate such as Aden city by using night ventilation was shown in the graph above. The effect of different orientations is clear in the above graph and shows more cooling demand in West and East orientation compared to North and south orientation. The graph shows that cooling demand is influenced by different air change rate during night until certain air change rate and after that there is no significant influence. The reduction in cooling demand could reach up to 15% in different orientation with different air change rate. The above result shows the significant reduction in cooling demands occurs when increasing the air change rate till 5 ac/h rate. The windows opening could be controlled by the simulation program to increase the air change rate in the office space. The windows could be opened with different percentage from 0% (closed) to 100 % (full open) or only 30 % or 50 % (half open). The air change rate increases rapidly with increasing the percentage of the windows opening during the night when apply the night ventilation. The advantage of the simulation program that calculates the air change rate with considering the air flow caused when window is open.

- Conclusion

The result of the simulation model of Sana'a and Aden cities shows that there is high potential to reduce the cooling demand by applying night ventilation. The air change rates during night time play an important role to reduce the cooling demand. The improvement of night ventilation in office building will reduce the energy consumption especially in cooling units. The effect in cooling demand will be cleared when apply 5 ac/h which could reduce the cooling demand in Sana'a and Aden cities. The effect of reducing the cooling demand due to different air change rates in Sana'a city is more than Aden city.

The outdoor temperature difference between day and night plays an important role in Sana'a city. The building designer should encourage and utilize night ventilation in office building of Yemen.

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Lauric Oils Synthesis in a Semi-Batch Reactor using Tungstated Zirconia as a Solid Acid Catalyst

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1. Abstract

A most important desirable product in the oleochemical industry is lauric oils because it is very considerable fraction for the cosmetics and pharmaceuticals manufacture. Fat splitting of coconut oil is a conventional process to produce lauric oils. It requires high temperature and high pressure (a major drawback) to increase the water-oil miscibility. Tungstated zirconia (WZ) catalyzed hydrolysis of coconut oil in a semi-batch reactor in the temperature range of 110-170°C at atmospheric pressure was studied to minimize the drawback of fat splitting. The pioneer semi-batch configuration is including a continuous water feed (vapor phase), coconut oil (liquid phase), and WZ (solid phase). The catalytic activity of WZ catalyzed hydrolysis of coconut oil is depended on the operating condition as WZ loading, water feed flow rate, and reaction temperature. The activation energy of WZ catalyzed hydrolysis of coconut oil was also investigated in this temperature range. It was found that the WZ loading positively impacted to FFAs yield. On the other hand, the lower catalytic activity was obtained which dealing the increase of water feed flow rate due to the partial catalyst deactivation by hydration of strong Brfnsted acid sites. The influence of reaction temperature on WZ catalyzed hydrolysis of coconut oils involves the reaction kinetic and phase miscibility. As expected, the highest reaction rate of coconut oil was carries out at the highest temperature (170°C). It can be concluded that the using WZ catalyzed hydrolysis of coconut in this configuration is a superior process to produce lauric oils.

2. Introduction

Lauric oil is a mixture of free fatty acids obtained from coconut and palm oils. Lauric acid is a form of saturated fatty acid. This acid is also known as a medium chain fatty acid (C12:0). It occurs naturally in coconuts as a powdery white substance. This acid is often used to make pharmaceuticals and cosmetics. This acid can also be taken orally, usually in the form of coconut oil [1]. Coconut oil is a major source to produce lauric acid in the commercial scale so-called fat splitting. Triglycerides (TG), mainly component in fats can be split into glycerol (GL) and free fatty acids (FFAs), the resulting mixture containing three molecules of fatty acid for each molecule of glycerol. Hydrolysis is the process of splitting a substance whereby water is taken up. It is clearly that the hydrolysis of oils accompanied by mass transfer due to the solubility of water in oils. As can be seen in the literatures, hydrolysis of oils performs at a high temperature increase the solubility of water in oil (decrease the induction period) [2]. Actually, the higher temperature leads a higher solubility of water in oil and a higher reaction rate. Therefore, the commercially fat splitting process requires high temperature and high pressure to obtain the short reaction time. The Colgate-Emery process, a non-catalytic fat splitting process, is the most of efficient of the current methods of fat hydrolysis [3]. FFAs product can corrosive to this splitting tower under high pressure (5000 kPa) and high temperature (250-260°C) operation. A high investment cost of corrosion-resistant material such as stainless steel 316 or inconel alloy combined with high operating cost is required which is a major drawback. The used of solid acid catalyzed hydrolysis of TGs in a batch reactor can be minimized this drawback. Yow and Liew [4] has reported an investigation of the kinetics of hydrolysis of palm oil catalyzed by a macroporous cation-exchanged resin at 155°C. Satyarthi et al. [5] also reported the solid Fe-Zn double-metal cyanide catalyzed hydrolysis of vegetable oil and animal fat in the temperature range of 160-210°C. However, it still required the autogeneous pressure to carry out in a liquid phase reaction. Our previous work purposed a 3-phase reaction system configuration for solid acid catalyzed hydrolysis of tricaprylin as a model compound for TGs under atmospheric pressure (110-150°C) [6]. It was found that this configuration is appropriate to minimize a deactivation of Brfnsted acid site of tunstated zirconia catalyst (WZ) by hydration of water. Consequently, it should be used for the synthesis of lauric acid and the other FFAs from WZ catalyzed hydrolysis of coconut oil. This study aims to investigate the effect of process parameters, including catalyst loading, water feed flow rate, and reaction temperature on the production of lauric oil as a mixture of FFAs in a coconut oil.

3. Experimental

The coconut oil having 12.8% FFA was obtained from Sangsook Industry Company Limited. The fatty acid composition consisting of 74.7% saturated FFAs and the other properties were present in Table 1 [7].

The 3-phase reaction system configuration, a semi-batch reactor, consisted of an oil-bath heated, three-neck 50 mL round bottom flask wrapped with heating tape on the top. Water was continuously fed into semi-batch reactor using a syringe pump. Unreacted water was vent through an ice bath connected to a tap water cooled reflux condenser. The procedure to start the reaction was provided in the previous study [6]. The amount of total FFAs production in this study was analyzed by following ASTM D 5555.

Table 1. Properties of coconut oil feedstock.

Properties	Composition
Fatty acid composition (%)	
(i) Caprylic acid (C8:0)	3.35
(ii) Capric acid (C10:0)	3.21
(iii) Lauric acid (C12:0)	32.72
(iv) Myristic acid (C14:0)	18.38
(v) Palmitic acid (C16:0)	13.13
(vi) Steric acid (C18:0)	3.60
(vii) Oleic acid (C18:1)	12.88
(viii) Linoleic acid (C18:2)	4.35
Density at 15°C, kg/m^3	920.6
Free fatty acid content (as lauric acid) %wt.	12.8
Kinematic viscosity at 40°C, mm^2/s	28.05
Water content, % wt.	0.22

[a] Other fatty acids (arahidic and lignoceric acid) is less than 1 %wt.

4. Results and Discussion

4.1 Effect of catalyst (WZ) loading on hydrolysis of coconut oil.

According that the amount of catalyst is one of the important parameters affecting on the catalytic reactivity. Thus, in this study, the amount of WZ loading of 0-30% wt. based on coconut oil was used to catalyze hydrolysis of coconut oil in this 3-phase reaction system configuration as shown in Figure 1. The reaction without catalyst showed that an autocatalytic for hydrolysis of coconut oil with 11.8% TG conversion was occurred, which was not found in the previous study [6]. The autocatalysis for hydrolysis of coconut oil is more likely due to the amount of FFAs content in a coconut oil (12.8% wt.). The presence of FFAs might lead to increase the miscibility of water-oil system and act as a homogeneous acid catalyst [8]. It was clearly that increasing of WZ loading increased the rate of hydrolysis of coconut oil. At 10% wt. of WZ loading, 30% TG conversion was achieved in 60 min, whereas the same TG conversion was obtained in about 10 min for 20% wt. of WZ loading. However, by looking at the initial stages of reaction, an identical of TG conversion curve was obtained for 20 and 30% wt. of WZ loading. This phenomenon is more likely due to the existing of mass transfer limitation on the reaction rate. Actually, the catalytic activity should increase proportionately with the catalyst loading in the lacking of any mass transfer limitation as tested by Madon and Boudart [9]. At high WZ loading may result in non-homogeneity of the slurry in a reaction mixture as corresponding to the report by Satyarthi et al. [5].

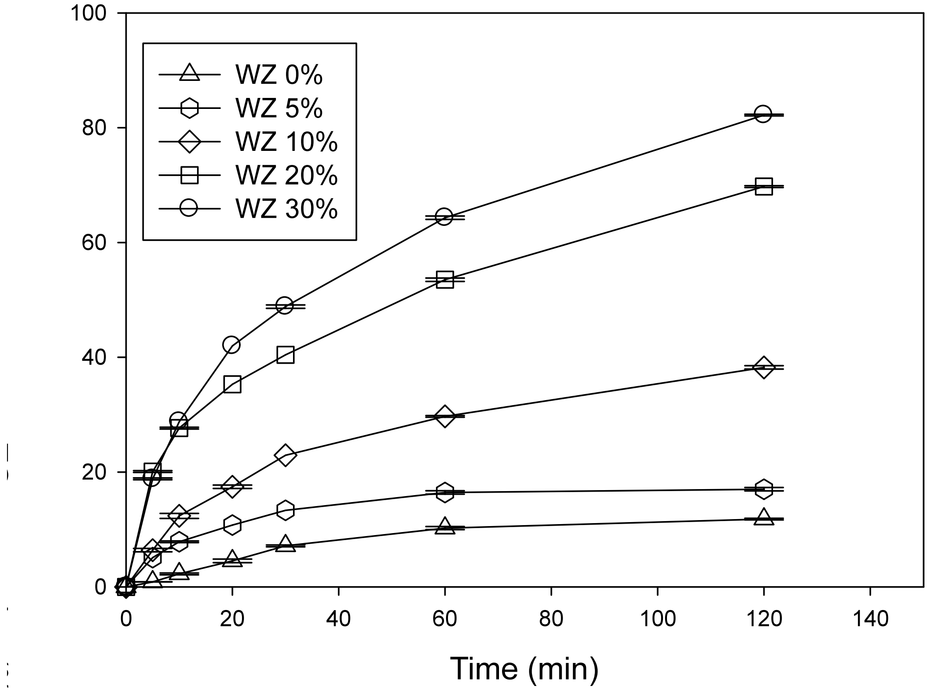

Figure 1. Effect of WZ loading on % TG conversion for WZ catalyzed hydrolysis of coconut oil at 130°C with water feed flow rate of 50 μL/min in the semi-batch reactor.

4.2 Effect of water feed flow rate on hydrolysis of coconut oil.

Water feed flow rate could be a key parameter to control the hydrolysis rate. This may be due to the water is not only being a reactant but also causing of acid catalyst deactivation by hydration [8, 10, 11]. Thus, the influence of water concentration on the catalytic activity as presented in the term of water feed flow rate was examined. The hydrolysis of coconut oil was tested with water feed flow rate of 1, 10, 50, 100, and, 200 μL/min in the 3-phase reaction system. The cold trap was used to maintain the concentration of water in a reaction mixture by a balancing of dissolved and vaporized water as described in previous study [6]. As shown in Figure 2, the highest TG conversion for WZ catalyzed hydrolysis of coconut oil (47%) was carried out using water feed flow rate of 10 μL/min which is in agreement to the previous result [6]. This is more likely due to a similar effect of water on the surface characteristic of WZ catalyst. WZ has a distribution of weak and strong acid sites from both of Brfnsted and Lewis acid sites. Adsorption of water on WZ surface has two counteracting effect which decrease Brfnsted acid sites strength and form of new Brfnsted acid site from Lewis acid site [12]. In addition, the concentration of water in a reaction mixture can result in the hydrolysis reaction rate. Our previous work also reported the negative reaction order of water in hydrolysis of TCp [13]. The hydrolysis rate decreased with increasing of water concentration which is corresponding to the reaction profiles of using high water feed flow rate.

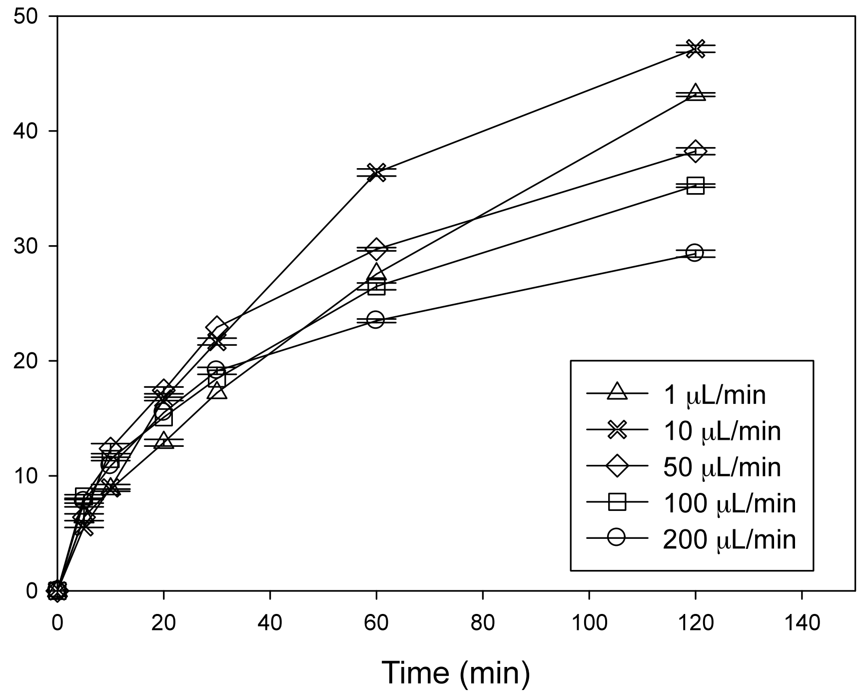

Figure 2. Effect of water feed flow rate on % TG conversion for WZ catalyzed hydrolysis of coconut oil at 130°C (10% wt. of WZ loading) in the semi-batch reactor.

4.3 Effect of reaction temperature on hydrolysis of coconut oil.

This study aims to reduce the reaction temperature of the conventional hydrolysis. The effect of reaction temperature on the rate of hydrolysis of coconut oil was studied in the temperature range of 110-170°C with the presence of 10% wt. of WZ catalyst and water feed flow rate of 50 μL/min under atmospheric pressure. As known, Hydrolysis at high reaction temperature was utilized in order to obtain a high reaction rate because a high temperature can lead to better water-oil miscibility and improved a reaction kinetics. As presented in Figure 3, reaction temperature impacted positively the TG conversion of WZ catalyzed hydrolysis of coconut oil. TG conversion increased with reaction temperature from 110 to 170°C resulting in high lauric oil production yield. However, at high temperature, there is a negatively influence on the FFAs production selectivity by the reverse esterification of FFAs as present in Satyarthi et al work [5]. In addition, the deactivation of WZ catalyst on hydrolysis of tricaprylin was also observed at high reaction temperature (150°C) illustrated in a previous report [6]. However, the Arrhenius plot of WZ catalyzed hydrolysis of coconut oil at 110-170°C (data not shown) was a the straight line. It was indicated that the deactivation of WZ on hydrolysis of coconut can be negligible. The calculated apparent activation energy value (Ea) was 43.1 kJ/mol which in good agreement with the self-catalyzed (by FFAs) hydrolysis of coconut oil as report by Patil et al [14].

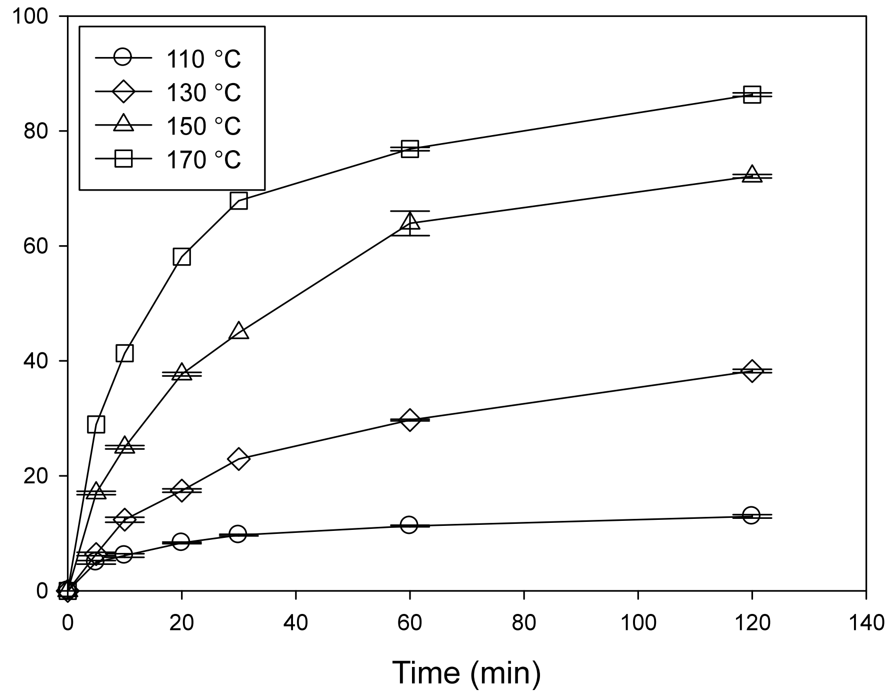

Figure 3. Effect of reaction temperature on % TG conversion for WZ catalyzed hydrolysis of coconut oil with water feed flow rate of 50 μL/min and 10 % wt. of WZ loading in the semi-batch reactor.

5. Conclusions

Luaric oil synthesis can be obtained from WZ catalyzed hydrolysis of coconut oil in the 3-phase reaction system configuration at water feed flow rate under the temperature of 110 to 170°C and 1 atm. The process parameters such as amount of catalyst loading and reaction temperature exhibited the positively effect on the hydrolysis of coconut oil rate. Water feed flow rate, on the other hand, increasing of water feed flow rate resulted in low catalytic activity of WZ due to the kinetic mechanism of WZ catalyzed hydrolysis (negative reaction order of water) and deactivation of WZ by hydration of strong Brfnsted acid sites.

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SINGLE-WALLED CARBON NANOHORNS SUPPORTED SULFONATED CATALYST FOR BIODIESEL PRODUCTION

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ABSTRACT

The increasing awareness of the depletion of fossil fuel resources and the environmental benefits of biodiesel fuel provide it more attractive in this recent time. There are several comprehensive studies of acid-catalyzed transesterification to produce fatty acids methyl esters (FAME) with higher conversion of triglycerides. Better supports for the solid acid catalyst are needed to increase the catalyst performance by gain more conversion and give a longer lifetime for the solid acid catalyst. Carbon support have several advantages such as a high specific surface area, suitable pore size, favorable surface functional groups, good corrosion resistance, and thermal stability. Many works have been done on the developing new carbon materials to meet these requirements. In this work, single-walled carbon nanohorns (SWCNHs) as a special member of the carbon nanotube family is a support for sulfonated single-wall carbon nanohorns. Due to SWCNHs outstanding properties as a catalyst support, they have a very large surface area, a mesoporous and also thermal stability. The SWCNHs were prepared by arc in water with nitrogen gas injection method. Moreover, the influences of diameter of cathode and anode ratio and nitrogen gas flow rate on the yield of SWCNHs are also determined in this work. Then, the sulfonated group was added by sulfonation of sulfuric acid so called SWCNHs-SO3H. SWCNHs-SO3H catalyzed transesterification of triglycerides was also performed.

Keyword: Single-walled carbon nanohorns

1. INTRODUCTION

These days, the development of synthesis method and applications of nanotube-family materials have been attracting hot attention because of their promising characteristics. Muti-walled carbon nanotubes [1] and single-walled carbon nanotubes are especially known as such materials. In addition, single-walled carbon nanohorns (SWCNHs) [2] also receive much interest for application to the use of catalyst-support in fuel cell, gas fuel absorption, solid lubricant, and so forth. Since SWCNHs was firstly reported by Iijima et al., who synthesized SWCNHs by laser ablation method [2], several methods to synthesize SWCNHs have been developed based on reaction systems using arc discharge. For example, arc discharge between graphite electrodes in liquid nitrogen can generate SWCNHs as a simple manner [3]. As the significant aspect of this method, its set-up can be built with extremely low cost, and thus this method is very helpful for people who want to obtain relatively high purity SWCNHs readily. Except the method using arc discharge in liquid nitrogen, torch arc in open air [4] and arc in gas with preheated electrodes [5] have been reported.

Since Sano et al. reported the synthesis of SWCNHs by the method with arc in liquid nitrogen, they have been investigated this system. In such activities, as they were motivated this system. In such activities, as they were motivated to use water instead of liquid nitrogen because water is much easy to use in terms of the cost and physical properties, 'arc-in-water with gas-injection' has been contrived [6]. In the first report about this system [6], the yield (weight-based ratio of production of as-grown SWCNHs to the consumption of graphite electrode) and the production rate were 2% and 3.4 g/h, respectively. Since then, we have been searching optimized condition to obtain SWCNHs with high yield to decrease the synthesis cost [7]. For the motivation to pursue the high yield of SWCNHs, this study was aimed at the influence of cathode/anode diameter ratio which has not yet been reported, and found that the yield of SWCNHs are affected by the nitrogen gas flow rate. Nevertheless, the present study reveals that the yield of SWCNHs can be significantly improved if the condition is optimized. In addition, the application of sulfonated single-wall carbon nanohorns (SWCNHs-SO_3H) for biodiesel production using SWCNHs synthesized with N_2 injection was discussed.

2. EXPERIMENTAL METHODS

Fig. 1 shows the structure of cathode used in this study. A graphite rod (diameter = 3.3 and 6.1 mm) were use as anode and a hollow graphite rod with large hole (diameter = 12.3 and 20 mm, diameter of the large hole = 8.1 and 11.9 mm respectively, depth of hole = 25 mm) were used as cathode. On the cathode, two holes to inject N_2 gas into the arc zone where drilled on the other side of the large hole. These electrodes were submerged in water while the arc discharge was generated by DC power supply. The gas flow rate of N_2 injection was varied to 5, 6, 8 and 10 L/min. When arc discharge was generated, the anode was raised up toward a static cathode to keep the inter-electrode gap during the anode is consumed by the arc discharge. With N_2 gas injection, carbon vapor was expected to be quenched rapidly in the fast N_2 flow until the carbon vapor was expelled out from the cathode hole. SWCNHs produced were conveyed to the water surface with gas bubble, and they floated there. The weights of the floating SWCNHs and the consumed anode were measured to determine the yield of SWCNHs. A transmission electron microscope (TEM; JEOL, JEM-1010) was used to characterize the morphology of SWCNHs. Raman spectroscopy (Raman Systems, R-3000) was also used to evaluate the crystallinity of the as-grown SWCNHs.

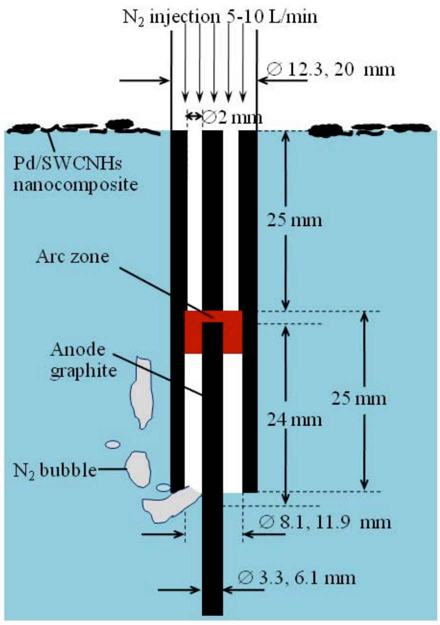

Figure 1 Structure of the hollow cathode and anode of arc-in-water with N_2 gas injection to produce SWCNHs.

3. RESULT AND DISCUSSION

3.1 Characterization of SWCNHs

Fig. 2 shows the typical TEM image of as grown SWCNHs obtained by arc-in-water with N_2 gas injection. It can be recognized that most of the SWCNHs are so-call bud-like structures, in which horns are relatively closed in each agglomerated particle. The purity of SWCNHs seemed to be 70-80% in the TEM observation at every synthesized condition. Here the most of impurity seemed amorphous carbon. Reportedly, ultimately high purity SWCNHs can show approximately 320 m^2 g^{-1} [8]. Base on such information, we consider that the specific surface area may be useful to evaluate the relative purity of SWCNHs in the products.

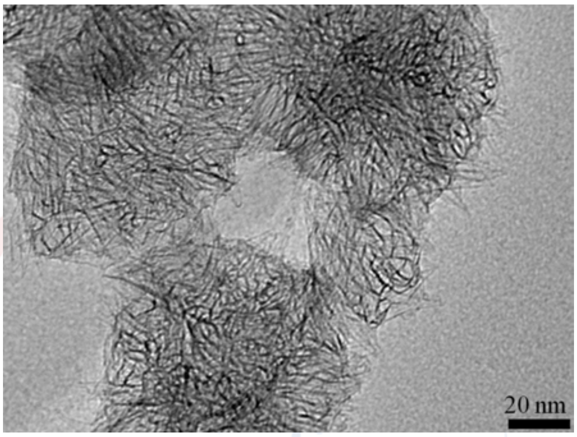

Figure 2 A typical TEM image of SWCNHs

A typical Raman spectrum obtained from the as-grown SWCNHs is shown in Fig. 3. In this spectrum, a graphitic peak (G-peak) at 1580 cm^{-1} and a disorder peak (D-peak) at 1353 cm^{-1} are seen, which show comparative intensities. Because amorphous carbon was observed as impurities in TEM observation, we consider that the purity of SWCNHs is high when the ratio of G/D is high.

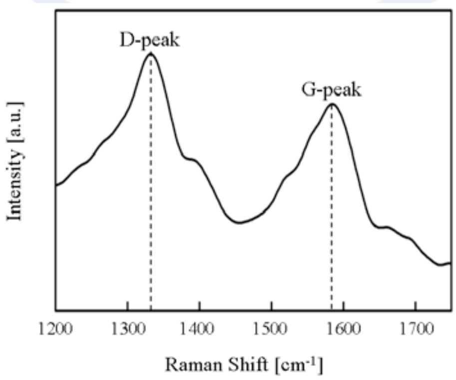

Figure 3 A typical Raman spectrum on as-grown SWCNHs

3.2 Influence of the cathode/anode diameter ratio on the yield of SWCNHs

Fig. 4 shows the influence of the cathode/anode diameter ratio on the weight-basis yield of as-grown SWCNHs. It is shown that the yield increases with the increasing of diameter of cathode and anode. The high values of the yield with increasing of anode diameter and cathode hole diameter can be simply explained by considering that the high amount of carbon vapour was generated when the cross section area of anode was increased. In this case when the cathode hole was larger the higher amount of carbon vapour can exist in the reaction zone in side cathode hole. Then, because of rate of reaction depend on the concentration of the reactant the high amount of carbon vapour can quench to form higher SWCNHs. From the result regarding the yield, we decided to employ the cathode/anode diameter ratio at 11.9 mm/6.1 mm in the investigation of influence of N_2 gas flow rate.

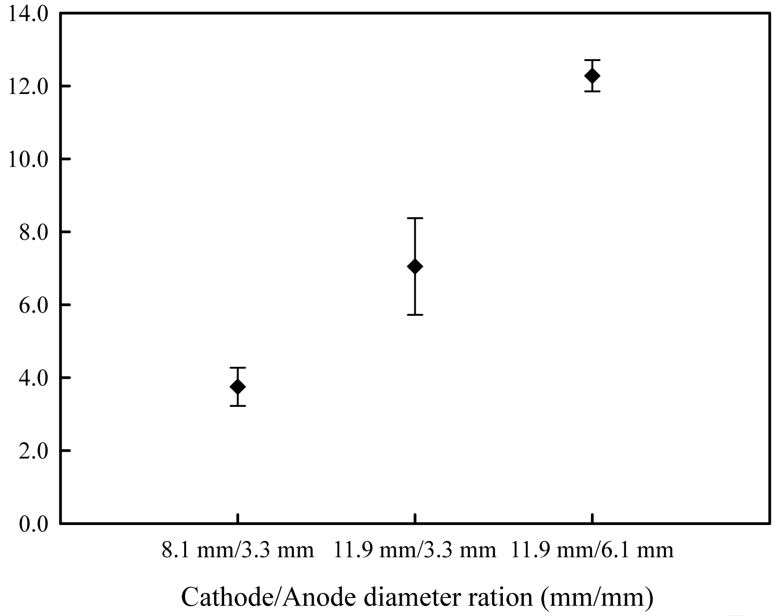

Figure 4 Influence of cathode/anode diameter ratio on the yield of SWCNHs (N_2 gas flow rate = 5 L/min)

3.3 Influence of N_2 gas flow rate on the yield of SWCNHs

Fig. 5 shows the influence of the gas flow rate on yield of the powdery products of SWCNHs, which is defined by the ratio of the weight of as-grown SWCNHs to the consumption weight of the anode. In arc-in-water with N_2 gas injection method, the cathode is not consumed. Here, there is the optimized gas flow rate for the high yield. One can observe here that the production rate increases with the gas flow rate in the relatively low gas flow rate range up to 10 L/min. This result indicates that this is an optimized gas flow rate for yield of SWCNHs. This rate can be explained by two effects in the reaction field. It is considered that the rapid quenching of carbon vapour is indispensable to produce the SWCNHs. Thus, the yield of SWCNHs becomes low when the gas flow rate is low because the quenching rate of carbon vapour that can not be high with the low flow rate. On the other hand, when the gas flow rate is sufficient for the rapid quenching, SWCNHs can be synthesized. It should reminded that the carbon vapour should be protected from water, which inhibits the formation of SWCNHs. Under the present conditions, the yield became approximately 12-18% at the optimized gas flow rate.

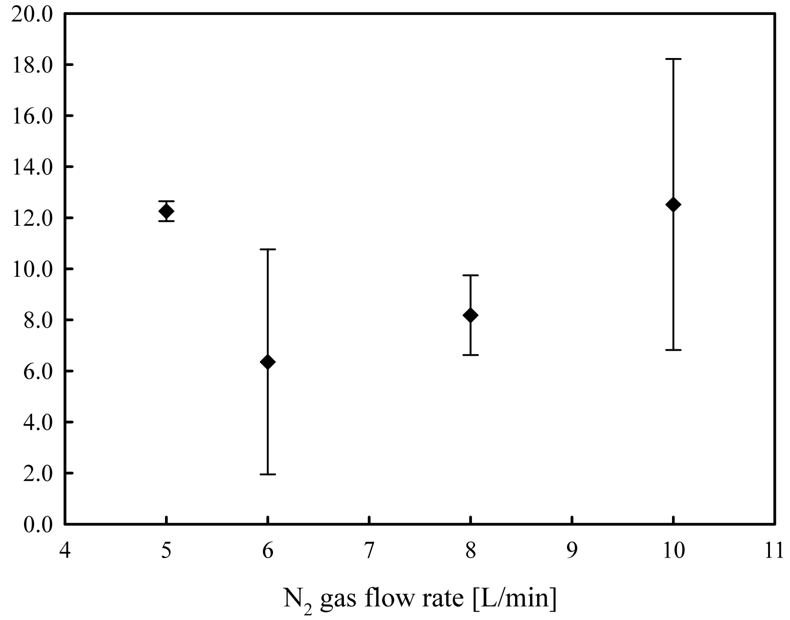

Figure 5 Influence of N_2 gas flow rate on the yield of SWCNHs (cathode/anode diameter ratio = 11.9 mm/6.1 mm)

3.4 The application of sulfonated single-walled carbon nanohorns as catalyst for biodiesel production

An ideal solid acid catalyst for the preparation for the preparation of biodiesel from a feedstock with considerable amounts of free fatty acids (FFAs) should have high stability and a high density of strong protonic acid sites in the presence of water (which is produced from the esterification of FFA by methanol). Unfortunately, the inorganic oxide solid acids such as Al_2O_3, zeolites and niobic acid have low density of strong protonic acid site and readily lose their activities in the presence of water. This is because the acid catalysis over these inorganic oxide solid acids occurs at acidic hydroxyl groups (-OH), which act as strong Br∅nsted acid sites, but the acid strength of these are reduced due to the hydration of –OH when water is present. Although strong acidic cation-exchangeable resins and Nafion have large amounts of sulfonic acid group ($-SO_3H$) Br∅nsted acid sites, and have been studied extensively as promising choice for the solid acids, they are expensive and their catalytic activities are still much lower than that of sulfuric acid.

For the transesterification, carbon-based solid acid catalysts have been used as promising catalysts. The catalyst can be either produced from the carbonization of sulfopolycyclic aromatic hydrocarbons (such as the sulfonate derivative produced by reaction of anthracene with concentrated H_2SO_4) or the sulfonation of the carbonized inorganic/organic compound. The former is simple and straightforward. Recently, carbon nanotubes [9] have become seen as an attractive material because of many unique properties originating from the small size, cylindrical structure, and high aspect ratio of length to diameter. SWCNHs consist of a single graphite sheet wrapped around to form a conical horn and between each horns, there have the mesopore structure [10] which is suitable for triglycerides molecule in feedstock for biodiesel production. The SWCNHs have a more cone structure and H_2SO_4 can be intercalated among the horn of the graphitic structure. It can be expected that SWCNHs could be used as an effective precursor to synthesize a solid acid.

The covalent functionalization of SWCNHs with sulfonic groups should provide stability, considerable solubility and strong surface acidity. However, the use of such catalysts to produce biodiesel has not yet been reported in current literatures. Thus, the application of sulfonated SWCNHs catalyst should be investigated in the biodiesel production.

4. CONCLUSION

SWCNHs were synthesized by the arc-in-water with N_2 gas injection. In the TEM observation, the purity of as-grown SWCNHs seemed to be 70-80%. It is found that the condition can be optimized the cathode/anode diameter ratio and N_2 gas flow rate at 11.9 mm/6.1 mm and 10 L/min respectively, so that the yield can be reach about 12-18%. It is should be reminded that this study have found a preferable condition to use the large diameter of cathode hole and the yield has become about nine times higher than the value firstly reported [6]. To discuss the application of the SWCNHs obtained by this method for biodiesel production, the sulfonated SWCNHs can be use to produce biodiesel.

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Accuracy Discharge Measurement for irrigation water distribution and conservation

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Accuracy Discharge Measurement for irrigation water distribution and conservation

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Abstract

An index velocity rating was developed for a SonTek/YSI Acoustic Doppler Current Profiler (ADCP) with a small mobile boat in the Wu-Shan-Tou Canal of the Chia-Nan Irrigation Association in Tainan, Taiwan. First, an experiment with a Price Current Meter was performed to obtain a reference data set. At the same time, the ADCP was utilized to obtain the velocities distribution across the canal. The validation of the ADCP used in the present work evaluated by comparing the measured velocities with the Price's data. As a result, the measured velocities of ADCP showed good agreements with the Price's data. The mean velocity of central line of canal is selected as the index velocity and measured by using the Price Current Meter. Finally, the experimental investigations of the index velocity rating of the Wu-Shan-Tou Canal are also presented. The procedure used in the evaluation included multiple measurements over a range of flows. This approach verified the validity of velocity measurement through the analysis of coefficients of determination and by the comparison of index velocities and mean velocities. The canal discharge estimation can be made by the measurements of index velocity and water level. By integrating the flow velocities across the flow areas, the computing discharge by the ADCP provided a reasonably accurate means of computing discharge by the index velocity. The application of the index velocity enhances the efficiency of discharge measurement in an ungagged station which strengthens the management of irrigation over large areas.

Keywords: Discharge measurement, ADCP, Index velocity

Introduction

Traditionally, the discharge is determined by a stage-discharge rating curve at a streamflow-gaging station. Once, the flow conditions make the use of stage-discharge rating curve impractical or impossible. These flow conditions include flow reversals, backwater effects, hysteresis effects, and channel-roughness changes (Morlock et. al. 2002). The hydraulic engineers deal with such flow conditions with a conventional measurement method to determine the discharge. The conventional discharge measurement uses a Price Current Meter to measure the mean velocity of each sub-section of a canal, the discharge of each sub-section equals to the mean velocity times the areas of each sub-section, and the total discharge is calculated by integrating the discharges of sub-sections. This involves extraneous expense and time-consuming in the discharge measurement. Therefore, it is difficult to regularly check the discharge along an irrigation canal, even can't control the discharge distribution efficiently over the whole irrigation canal. In order to resolve the problems, a new canal discharge measure procedure by appling the Acoustic Doppler Current Profiler (ADCP) with Index-velocity method was developed. Index-velocity method was developed and used by United States Geological Survey (USGS) for discharge monitoring or recording at streamflow-gaging stations where the application of the stage-discharge rating curve is impossible (Huang, 2004). The principle of the Index-velocity method is to develop a regression equation that relates the channel mean velocity to an Index-velocity. The development of an Index-velocity rating involves two steps. The first step is to collect data for discharge and Index velocity. The data collection needs to be conducted for a range of discharge. A set of data for channel mean velocity derived from measured discharge data and Index velocity will be obtained. The second step is to perform regression analysis for the data set. A regression equation is to be developed from the regression analysis. For collecting the mean velocity data, a flow velocity measurement instrument needs to be installed at fixed locations where the flow discharges are concerned. Apparently, the use of this velocity measurement instrument, such as H-ADCP, is cost-concerning because it usually takes thousands dollars to complete a station. However, the Index-velocity method is to be completed the discharge within a short time span. In order to concurrently fill the timing and cost efficient of discharge measurement, this study provides a new discharge measurement procedure by combining the ADCP, Index-velocity method and conventional current meter. The new procedure provided a quick measurement of discharge and it is thus more effective than the conventional method.

Discharge measurement and instrument setup

The field experiments were carried in an artificial concrete trapezium irrigation canal, the Wu-Shan-Tou Canal of the Chia-Nan Irrigation Association in Tainan, Taiwan. Fig.1 shows the canal cross section. The bottom width is 17m and the side slope is 1:1. An ADCP, developed by SonTek, was used to measure the three-dimensional velocity components, and the water level was measured by a water level gauge. The ADCP has three transducers mounted in the transducer head of the system. Each of these transducers has a different orientation and generates a narrow beam of sound that is projected through the water. Reflections from particles in the water column are used to determine the water velocity. Making velocity measurements with ADCP requires a small mobile boat for mounting the instrument, and by traversing the river cross section with the boat, as show in Fig.2. The mean velocity of each sub-section is measured by ADCP, and each sub-section area is the product of water depth and sub-section width. The total discharge of canal is calculated by using velocity-area method. Fig. 3 is the diagram of velocity-area method, and the formula of discharge computational can be express by the following:

$$Q = \sum U_i \Delta A \tag{1}$$

where:
Q = canal discharge
U_i = mean velocity of sub-section
$\Delta A = b_i \cdot h_i$ = the area of sub-section

Additionally, experiment was also conducted with a Price Current Meter to provide a reference data set for the comparison with the corresponding ADCP measurement. Fig. 4 shows the discharge measurement of the Price Current Meter. The velocity data measured by Price Current Meter and ADCP were used to compute the depth-averaged velocities and would be compared with the corresponding ones.

Index Velocity Rating

To determine an index velocity rating, canal mean velocity and ADCP measured velocities are required. The following steps outline the procedures we follow to collect mean velocity and stage data for developing an index velocity rating.

1. The channel is accurately surveyed and a stage-area rating is developed. Elevations for the cross-section points are in terms of stage referenced to the station datum.
2. The velocity distribution of each sub-section is measured by ADCP, and canal discharge is calculated by using Eq.(1).
3. The average water level during the discharge-measurement period is recorded.
4. The mean canal velocity is derived for each individual discharge measurement by dividing the measured discharge by the canal area computed from the stage-area rating.
5. In this study, the mean velocity of central line of canal is selected as the index velocity. For each discharge measurement, the index velocity is determined by using the Price Current Meter to measure the velocities at 0.2 0.6 and 0.8 of the water depth and to average the three velocities.
6. Each discharge measurement yields a computed mean channel velocity and an index velocity.
7. The index velocity rating procedure recommended by regression analysis.

Experimental results

Comparison between the depth-averaged velocities of Price Current Meter and ADCP across the canal is shown in Figure 5. The excellent agreement between velocity distributions of two instruments is marked. Both the measured flow velocity distributions become parabolic curves because of the wall boundary effects. The differences of measured discharges between Price Current Meter and ADCP are about 3%. In order to conduct the analysis of the Index-velocity method, a total set of nine discharge measurements are collected in the field. The measured stage, index velocity, and mean channel velocity are summarized in Table 1. The relationship between the mean velocity (x-axis) and the index velocity (y-axis) is plotted in Fig. 6. A linear relationship between the mean velocity and the index velocity can be clearly found. The relationship can be represented by a linear equation as follows:

$$V_m = aV_{CL} + b \tag{2}$$

where:

V_m = mean velocity of canal

V_{CL} = index velocity (the mean velocity of central line of canal)

a = coefficent

b = constant

A simple method for determining above coefficient and constant is linear regression. The linear index velocity rating equation determined from the dataset of Table 1 is shown below:

$$V_m = 0.8488V_{CL} - 0.0005 \tag{3}$$

Fig.7 shows the relationship between the computed mean velocity and index velocity by using linear regression. The r^2 value of 0.99 indicates that 99 percent of the variation in the mean velocity can be explained by the index velocity.

In order to verify the practicality of Index-velocity method, another four field experiments were taken. The canal discharges are estimated by the Index velocity method and the corresponding discharges are measured by ADCP. The results are summary in Table 2. The difference between Index velocity method estimated and ADCP measured discharges are less than 1.5%. It shows that, in an artificial fixed canal, the relationship between mean velocity and index velocity is good. The present results show that the Index-velocity method can be used to estimate discharge accurately. The present study proposes a convenient way by using a Price Current Meter to determine the index velocity. This provides the mobility for the field engineers to travel around the discharge station with only one Price Current Meter which reduces setup cost of a discharge station.

Conclusion

Mean velocity and Index-velocity data were collected and an Index-velocity rating was developed for a streamflow-gaging station in the Wu-Shan-Tou Canal of the Chia-Nan Irrigation Association in Tainan, Taiwan. The index velocity rating in this work is based on the ADCP measured mean velocity and the Price Current Meter measured index velocity at the central line of canal. The data for mean velocity and index velocity were best fit with a linear regression equation with a correlation coefficient of 0.99. Furthermore, another pairs of data were used to verify the practicality of Index-velocity method, the percent error between the discharge computed by the Index-velocity method and the discharge measured by ADCP was approximately ±1.0% ~ ±1.3%. The present results indicated the Index-velocity method estimating discharge accurately. The proposed Index-velocity rating can be used by irrigation engineers to travel around the discharge stations with one Price Current Meter which reduces setup cost of discharge stations.

Acknowledgements

The authors gratefully acknowledge the financial support from NSC Taiwan under the grant of 99-2625-M-020-001.

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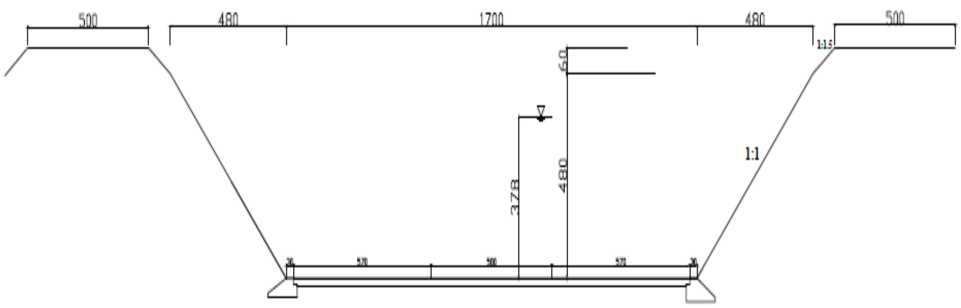

Fig. 1. The dimension of canal cross section

Fig. 2. Measurement of canal discharge by using ACDP

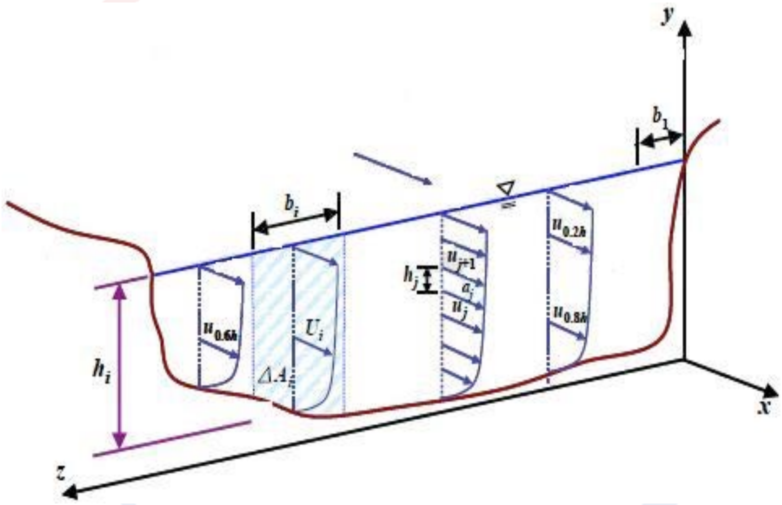

Fig. 3. The schematic diagram of velocity-area method

Fig. 4. Discharge measurement by Price Current Meter

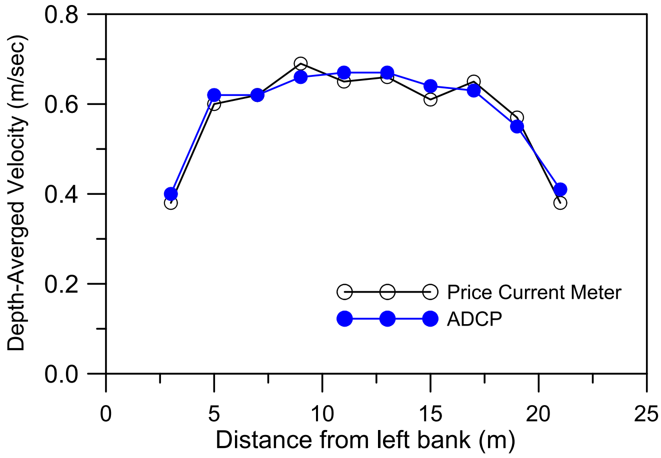

Fig. 5. Comparison between the depth-averaged velocities of Price Current Meter and ADCP

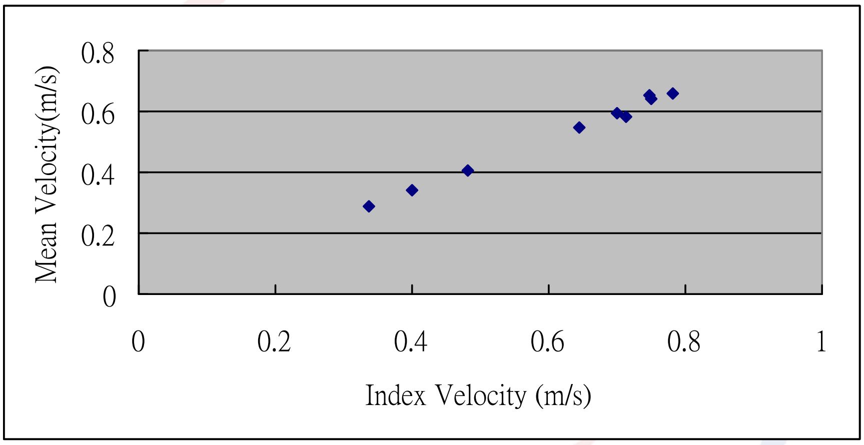

Fig. 6. Mean velocity and index velocity in irrigation canal

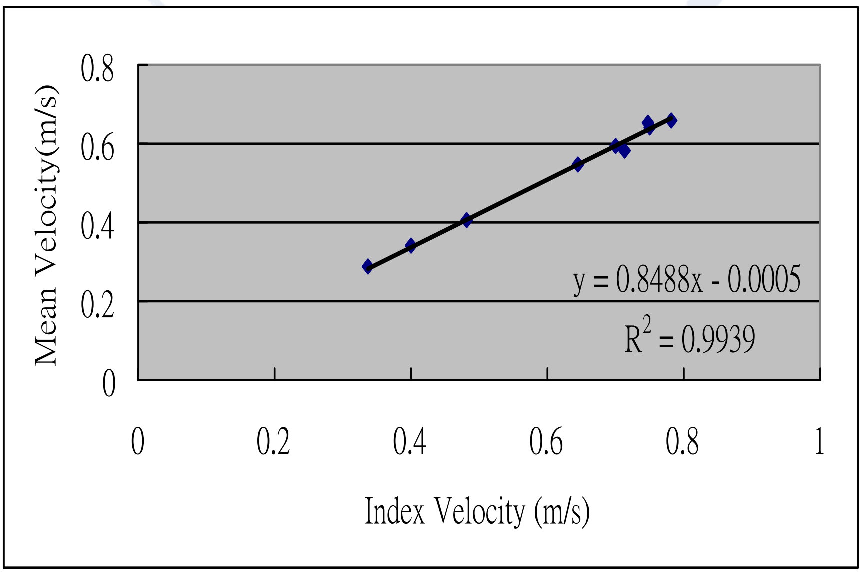

Fig. 7. Index velocity rating using simple linear equation

Table 1. Canal mean velocity and index velocity

No.	Stage(m)	Mean Velocity(m/s)	Index Velocity(m/s)
1	2.90	0.66	0.75
2	2.96	0.66	0.78
3	2.96	0.58	0.71
4	2.97	0.41	0.48
5	3.02	0.59	0.70
6	2.98	0.64	0.75
7	2.64	0.29	0.34
8	3.00	0.55	0.64
9	3.03	0.34	0.40

Table 2. Discharge difference between two different measurement

No.	cross section area of flow (m^2)	Discharge(cms) by Index-velocity method	Discharge(cms) by ADCP	Absoluted Difference (%)
10	58.39	34.41	34.78	1.1
11	60.03	35.13	35.59	1.3
12	58.65	36.36	36.84	1.3
13	58.34	37.50	37.88	1.0

Effects of Carbon-based Materials on the Hydrogen Desorption of $LiAlH_4$

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Abstract

$LiAlH_4$ was modified with carbon-based materials to improve its desorption behavior and desorption temperature. The mechanical ball milling was used to mix $LiAlH_4$ with the carbon-based materials including carbon aerogels (CAs), activated carbons (ACs), graphite, and multi-walled carbon nanotubes (MWCNTs). The hydrogen desorption was carried out in thermo-volumetric apparatus at atmosphere pressure with a heating rate of 2 °C/min from room temperature to 250 °C. The addition of the materials with different amounts affected the hydrogen desorption behavior and desorption temperature of $LiAlH_4$ differently. For example, mixing 15 wt% CAs with $LiAlH_4$ decreased the des[illegible] 5 wt% CAs, the desorption tempera[illegible]vior of the hydride mixed with 15 wt[illegible] the improvement. Comparison on the [illegible]ion was also made. In addition, XRD r[illegible]

Keywords: $LiAlH_4$[illegible]notubes

1. Introduction

As the main principal for global warming, green house gases like CO_2 and CH_4 have increased about 35 % from 1990 to 2006 (Metz, 2005). Thus, using a cleaner energy carrier like hydrogen is expected to reduce green house gas emissions from the combustion of fossil fuels in stationary and mobile sources (Akiba, 1999; Schlapbach and Züttel, 2001). To realize the use of hydrogen especially for vehicles, an efficient hydrogen storage method is needed. Currently used hydrogen storage r rogen storage have not met the target e hydrogen storage using light-metal l een considered as promising metal h aterials because of theirs high theoreti om $LiAlH_4$ to LiH following equation:

(1)

(2)

However, they ar slow kinetics and irreversibility (Sch r to improve these problems, the addit

There are a n d carbon nanotubes (SWCNTs), graphi t have been used to improve the hyd d the desorption temperature. Hydr was about 1.5 wt% higher than that of ite showed the best hydrogen storage performance and its desorption temperature was lowered by 60 °C (Wu *et al.*, 2006). In addition, Gross *et al.* (2008) found that the dehydrogenation rate of $LiBH_4$ filled with CAs was increased by 50 times. Its desorption temperature was reduced by up to 75 °C. The hydrogen capacity over multiple sorption cycles was also increased.

The purpose of our work was to study the effects of different carbon nanostructures on the desorption properties of $LiAlH_4$. Carbon nanostructures including carbon aerogels (CAs), graphite, activated carbon, and multi-wall carbon nanotubes (MWCNTS) were used in this work and all of mixing catalysts with $LiAlH_4$ were prepared by ball milling.

2. Experiment

All sample preparation was carried out in a nitrogen filled glove box to prevent oxidation and
moisture. $LiAlH_4$ (… urther purification.
Carbon aerogels (C … d multi-wall carbon
nanotubes (Baytub … is (2011). Different
CA to $LiAlH_4$ (C … pared by The ball
milling (Retsch ba … a speed of 300 rpm
with a ball-to-pow … t showed the best
hydrogen desorptio … anostructures.

About 0.3 g … thermo-volumetric
apparatus to meas … on was carried out
from room temper … heric pressure. The
librerated hydroge … ucer (Cole Parmer,
model 68073-6807 …

All samples … kV, 30 mA) over a
range of 20 to 70° … rome NOVA 1200
was carried out at … d to obtain surface
area, pore volume, …

3. Results and discussion

Surface areas and pore volumes of the carbon nanostructures used in this work are shown in Figure 1A-B. All the milled samples have slightly higher surface areas than the unmilled samples. The surface area of the milled ACs is about 820 m^2/g compared to 767 m^2/g of the unmilled sample. In addition, the surface areas of the other milled carbon nanostructures show the same trend as the

AC sample. The surface areas of CAs, MWCNTs, and graphite increase from 65, 249, and 0 to 92, 270, and 0.8 m^2/g, respectively. Furthermore, the pore volumes of the carbon nanostructures are also increased after the ball milling. In addition, the pore volumes increase for all the milled samples with a significant increase in the CAs and MWCNTs.

Figure 2A shows the hydrogen storage capacities and the initial desorption temperatures of
$LiAlH_4$ and $LiAlH_4$ mixed with CAs. For the desorption temperature, the as-received and milled
samples start to rel of both samples are
7.7 and 7.4 wt%, r l releases hydrogen
at same temperatur ; with 15 wt% CAs
reduces the desorpt *et al.* (2001), who
reported that addin rption temperature.
The hydrogen capa hich is higher than
with 15 wt% CAs, lH_4 during the ball
milling (Kojima *et* wt% CAs is better
than the as-receive l 15 wt%. The high
amount of added ca uently suppress the
diffusion of hydrog ball milling, which
is another reason orption kinetics of
$LiAlH_4$. The desor H_4 mixed with the
carbon-based mate phite decreases the
desorption tempera that the desorption
temperature of LiA of the carbon-based
materials. The resu porosity of carbon
materials did not a 010) suggested that
the carbon-based n nate electron to Li,
consequently, wea in the desorption
temperature of $NaAlH_4$. The hydrogen storage capacities of all samples mixed with carbon-based materials are about the same at 7.3 wt%. The desorption kinetics of $LiAlH_4$ mixed with CAs and ACs are better than those mixed with MWCNTs and graphite, which may be attributed to the different structures of the carbon-based materials. The structure of ACs and CAs may help the dispersion of $LiAlH_4$ particles and increase the surface area of $LiAlH_4$, which induces to faster hydrogen release. Lillo-Ródenas *et al.* (2008) explained that neither the porosity nor morphology

influences on the desorption kinetics of MgH_2, which is believed to be improved by the metal particles in the as-received or synthesized carbon structure.

The XRD results of the samples mixed with different amounts of CAs are shown in Figure 3A. The milled samples show lower relative intensity of $LiAlH_4$ than the as-received sample due to the average crystallite size of $LiAlH_4$ is reduced (Sun *et al.*, 2008) or the lost of hydrogen during the ball milling. The XRD patterns of $LiAlH_4$ mixed with 5 wt% CAs has same trend as the milled sample. This explai [illegible] 5 wt% CAs is close to that of the millec [illegible] nixed with 15 wt% CAs is higher than [illegible] of CAs affects the phase transformati [illegible] because the CAs have more unlocal [illegible] act with hydrogen. That, in turn, affect [illegible] igure 3B shows the XRD pattern of th [illegible] ative intensities of $LiAlH_4$ samples m [illegible] hose of the milled $LiAlH_4$.

The XRD pa [illegible] nounts of CAs are shown in Figure 4A [illegible] and $LiAlH_4$ mixed with 5, 10, and 15 [illegible] t may be due to the carbons or milling [illegible] dride after heating (Beattie and McGr [illegible] nple mixed 15 wt% CAs, which may be [illegible] vith Li_2C_2, which is expected to be forn [illegible] or LiH peaks of all dehydrogenated sai [illegible] han those of the as-received sample as [illegible] e agglomeration of $LiAlH_4$ can be prevented by adding carbon-based materials, which also preserves the grain size of the hydrogenated sample (Suttisawat *et al.*, 2010).

4. Conclusions

The desorption kinetics and desorption temperature of $LiAlH_4$ were improved by adding the carbon-based materials, CAs, graphite, ACs, and MWCNTs. The addition of 5 wt% CAs did not decrease in the desorption temperature, 145 °C, the same temperature as the as-received and milled samples. The desorption kinetics of $LiAlH_4$ mixed with 5 wt% CAs resulted in better than those of the other mixing ratios, 10 and 15 wt%, and its hydrogen capacity was about 7.3 wt%. Mixing 15 wt% CAs decreased only the desorption temperature of $LiAlH_4$ to 115 °C, but did not improve the desorption kinetics and hydrogen storage capacity, 6.9 wt% hydrogen, compared with $LiAlH_4$ mixed with 5 wt% CAs. The addition of ACs decreased the desorption temperature by 45 °C. The desorption temperature of $LiAlH_4$ may depend on the electrons in the structure of carbon-based materials or the metal particles in synthesized carbon. In addition, $LiAlH_4$ mixed with ACs also showed good deso [illegible] es. The desorption behaviors of LiAl [illegible] terials that help to disperse $LiAlH_4$ pa [illegible]

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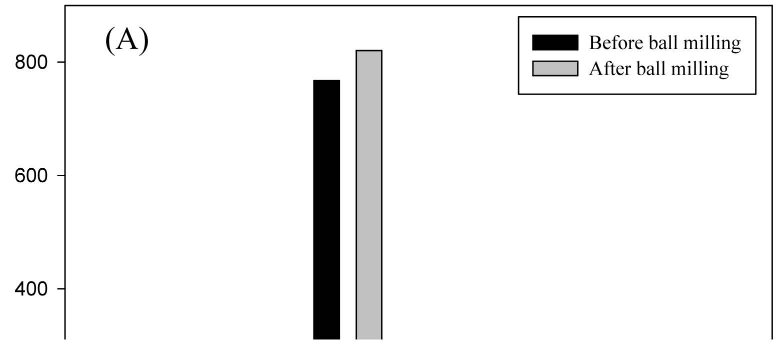
List of Figure Captions

Figure 1 Surface areas (A) and pore volume (B) of the investigated carbon nanostructures before and after the ball milling.

Fig. 2 Hydrogen desorption profiles of the $LiAlH_4$ mixed with different amounts of CAs (A), different carbon-based materials (B).

Fig. 3 XRD patterns of $LiAlH_4$ mixed with different amounts of CAs (A) and different types of carbon-based materials (B).

Fig. 4 XRD patterns of dehydrogenated $LiAlH_4$ mixed with different amounts of CAs (A) and different types of c



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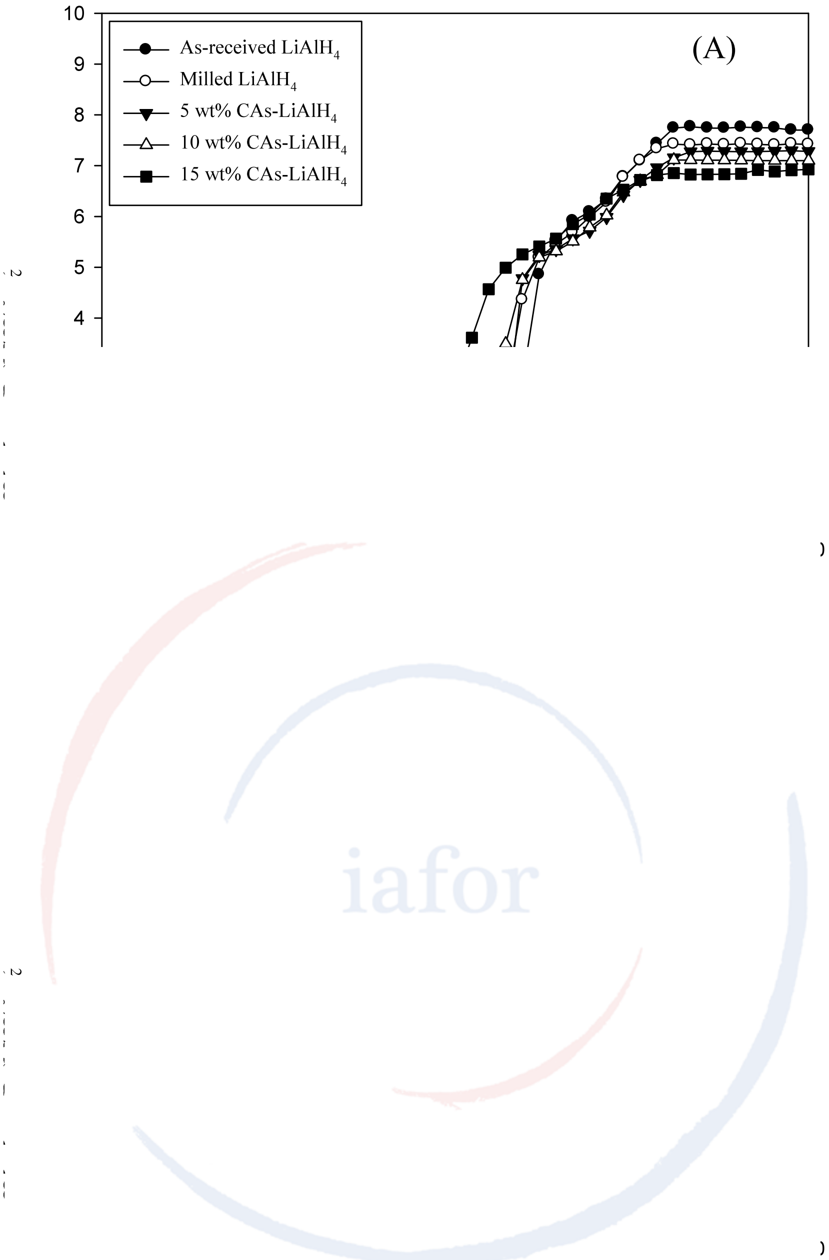

Fig. 2 Hydrogen de of CAs (A), different carbon-ba

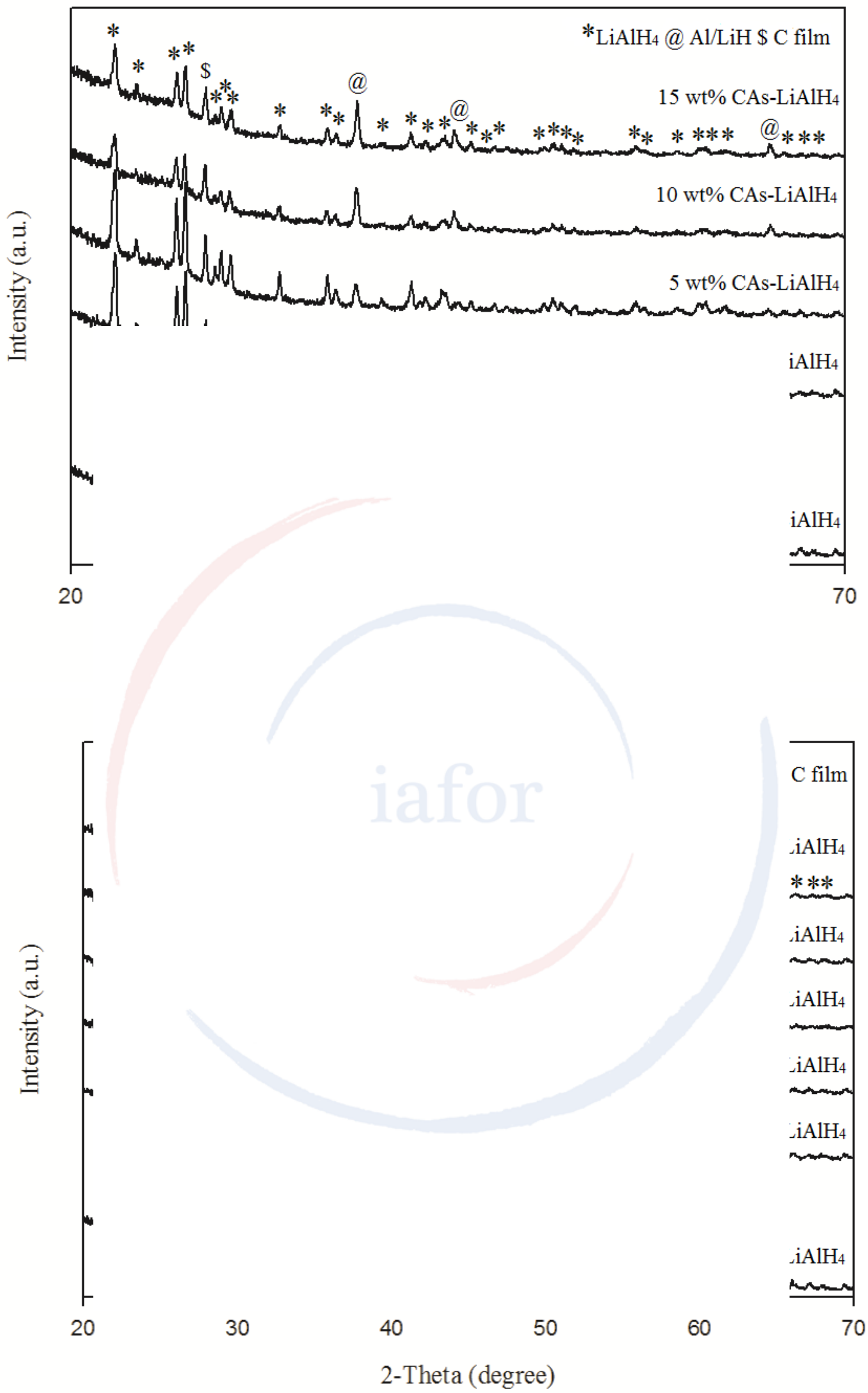

Fig. 3 XRD patterns of $LiAlH_4$ mixed with different amounts of CAs (A) and different types of carbon-based materials (B).

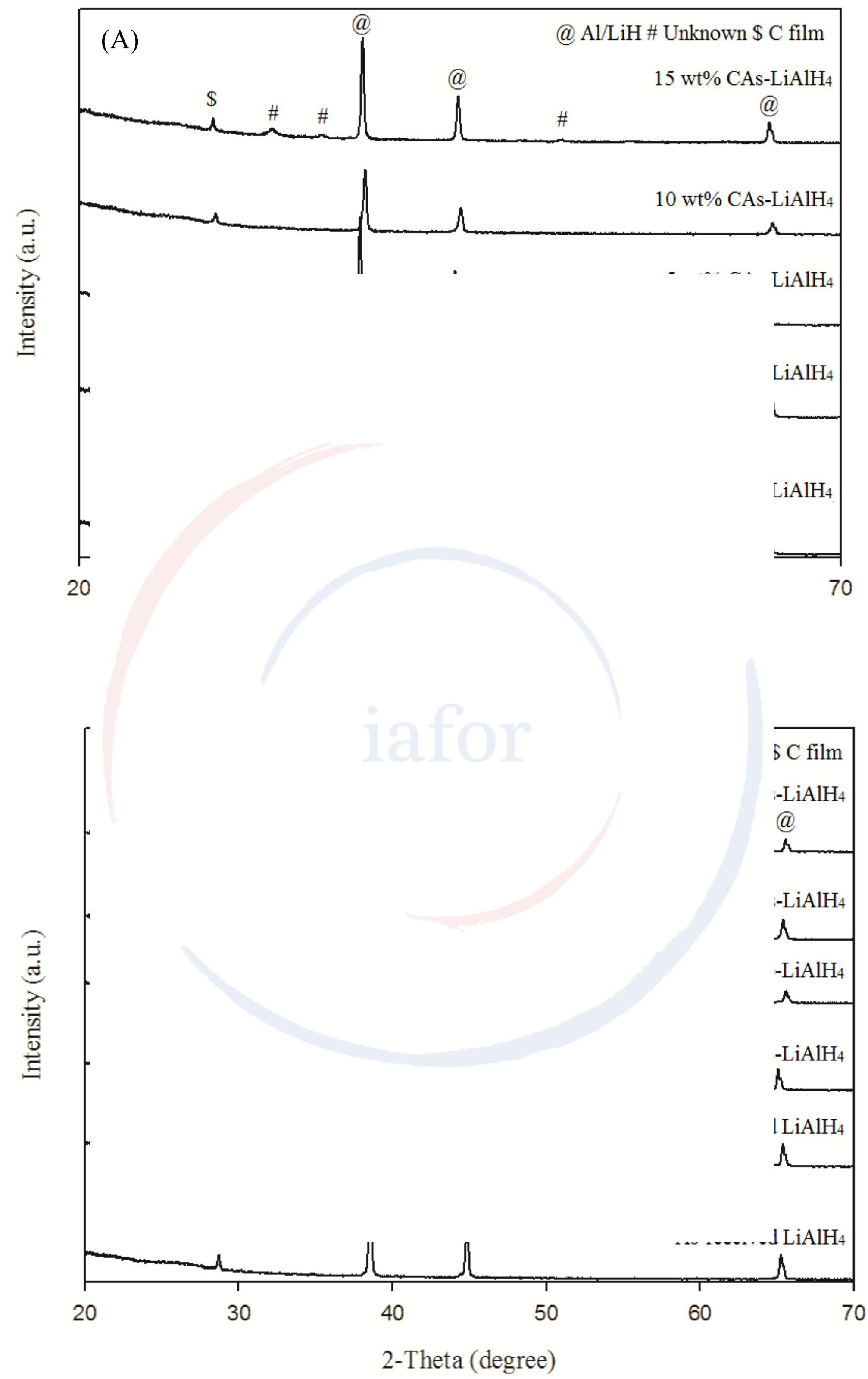

Fig. 4 XRD patterns of dehydrogenated $LiAlH_4$ mixed with different amounts of CAs (A) and different types of carbon-based materials (B).

Title

Are Italian firms proactive in Sustainability practices?

Topic

Environmental Management, Sustainability, Environmental Proactivity

Author

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Introduction

Sustainability is a very topical and debated issues both in the scientific and in the political context.

In recent decades the problems of pollution and deterioration of natural resources had been strengthened considerably. This has resulted in an intensification of environmental policy initiatives, both nationally and internationally, as they are now evident, on the one hand the crisis in the relationship between development and limited resources, and secondly the need to pursue the so-called sustainable development in other words, growth today should not impair the ability of future generations.

Therefore, this research aims at investigating the behaviour of Italian listed firms towards environmental management issues, which are, for some companies, an important component of the strategy. The sustainability issues affect the entire company and their objective is to go far beyond expectations and legal obligations.

This research focuses on the superficially investigated Italian companies, and, drawing from a large body of literature on environmental strategies, sustainable practices, corporate sustainability and strategic decision making, it aspires to put in evidence the real applications of the most common practices.

This work, in fact, points toward identifying a new method for classifying firms' Environmental Commitment, by presenting four different approaches to Sustainability themes. Moreover, the proposed analysis deepens the drivers of a firm's environmental strategies and practices, deriving the main factors from the key principles of sustainability issues.

Starting from the idea that Sustainability is strictly related to CSR themes for-profit firm, the article is therefore structured as follows: in the first part, we give an overview of the Sustainability literature, and examine the ties with CSR; afterwards, we analyze the various definitions related to Sustainability. In addition, we analyze the motivations that can lead firms to embrace a sustainable approach to its activities, and the academic frameworks for identifying environmental practices and processes. The description of the methodology used will contribute to a better understanding of the result, that is, the production of four clusters of firms. The description of the four types of sustainable approach will introduce the discussion of our findings and our contribution, which principally refers to the individuation of the new categories previously mentioned.

The importance of Sustainability

Sustainability has emerged as an influential, yet controversial, concept for business and policy. The awareness of the scarcity of resources and carrying capacity has imposed, mainly in the last decades, the development of new policies and strategies, as well as the need of a fundamental transformation in the way society consumes natural resources and produces Energy (Hall et al., 2010).

This theme in fact, has been a source of heated debate in both the doctrinal and institutional, that have led to regulations, agreements and regulations aimed at safeguarding the environment and reduce the social cost outside.

In 1972 in Stockholm was held the first World Conference of the United Nations (UN) on the Human Environment, which brought out the importance of collaboration and common focus on environmental problems, solved through use of specialized tools shared globally. The defense and improve the environment, together with peace and social and economic development became a priority objective of the collaboration between nations. The Conference concluded with an action plan containing 109 recommendations and the "United Nations Declaration on the Human Environment" based on 26 principles concerning human rights and responsibilities towards the environment. Were also established the World Commission on Environment Development (World Commission on Environment and Development WCED) and the Environment Programme of the UN (United Nations Environment Programme UNEP).

Afterwards, in 1987 the Brundtland report by the World Commission on Environment and Development (WCED), analyzed different methods for approaching environmental issues towards the realization of common objectives and formulated an agenda for action to be taken in the long term. This report, named “Our Common Future”, also proposed the first definition for Sustainable Development (WCED, 1987).

From Corporate social responsibility to Sustainability

The evolution of environmental sustainability issues within the company is clearly linked to the evolution of Corporate Social Responsibility as a whole.

Corporate social responsibility (CSR), indeed, has become one field of management studies, in the context of the broad discussion on the relation between Business and Society (Wood, 2010). It has been investigated by different approaches and sequential conceptual stages, through which it has been possible to explain the origin of the main related themes (Waddock 2004, Wood 2010). A recent study (Vilanova et al., 2009) put in evidence the main issues of CSR, such as social performance (Carroll, 1979; Swanson, 1995), business ethics (Solomon, 1993), corporate governance (Freeman and Evans, 1990), social contract (Donaldson and Dunfee, 2002), stakeholder management (Donaldson and Preston, 1995; Freeman, 1984; Lozano, 2002), corporate citizenship (Waddock, 2000; Zadek, 2001), accountability (Elkington, 1998; Valor, 2005) or bottom of the pyramid (Prahalad and Hammond, 2002).

The “triple-bottom-line“ concept (Elkington 1997) is the probably the most accepted approach to Sustainability themes under a CSR perspective. The three components of this model (economic, social and environmental) represent the dimension which the firm needs to undertake in order to achieve a sustainable development.

Among these components, the variable "environment" has become increasingly important and critical for firms’ competitiveness and profitability.

Most large firms now have explicit public sustainability policy statements and claim to apply a “triple bottom line”, in order to demonstrate good corporate citizenship (Clelland et al., 2000). In conclusion, the term “corporate sustainability” has become a synonym for “corporate social responsibility.” (Hall et al., 2010).

Definitions

There are different ways of labeling Sustainability, with different nomenclatures such as Sustainable Development, Environmental Management, Green Management Corporate Environmentalism and Corporate Sustainability

These terms are defined and interpreted in a variety of ways by a diverse group of researchers and practitioners.

Sustainable Development

The Brundtland report by the World Commission on Environment and Development , named "Our Common Future", defines Sustainable Development as the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987).

This definition implies that resources should be used according an intergenerational approach, and considering social and environmental objectives as important as economic ones. Moreover, this definition implies that it is possible for our society to to develop and grow in ways consistent with all three objectives, social, environmental and economic (Hall et al., 2010), without sacrificing opportunities for the future ones. This assumption has been also criticized by some researchers who put in evidence its contradictions (Robinson, 2004)

Environmental management

Environmental management deals with continuous improvement through appropriate management systems (Kautto, 2006), even if some studies analyze it exclusively in terms of economic profit (Denton, 1994).

Green management

It is difficult to assume a consistent and comprehensive definition of green management, as it is a relatively new term. A recent definition refers to practices that produce environmentally-friendly products and minimize the impact on the environment through green production, green research and development, and green marketing (Peng and Lin, 2008).

Corporate Environmentalism

One of the most important definition of the term identifies corporate environmentalism as “the organization-wide recognition of the legitimacy and importance of the biophysical environment in the formulation of organization strategy, and the integration of environmental issues into the strategic planning process” (Banerjee, 2002).

Recently, Corporate Environmentalism has been defined as “the organisation-wide recognition of the legitimacy and importance of the (…) environment in the formulation of organisational strategy, and the integration of environmental issues into the strategic planning process" (Singh et al., 2008). This definition derives from the acknowledgment environmental matters have to be to integrate in the firm's business functions (Hunt and Auster, 1990).

Corporate Sustainability

The Brundtland definition of Sustainable Development has been applied to firms in order to define the concept of corporate sustainability as "[…] meeting the needs of a firm's direct and indirect stakeholders […], without compromising its ability to meet the needs of future stakeholders as well. Towards this goal, firms have to maintain and grow their economic, social and environmental capital base […]" (Dyllick and Hockerts 2002).

Atkinson (2000), in addiction, has developed a similar definition, but he based his view on how businesses might adapt and improve environmental accounting and reporting practices, through a microeconomical approach .

This concept has been stressed by other authors, especially in comparison and distinction with CSR (Marrewijk, 2003; Wilson, 2003; Salzmann et al., 2005; Schaltegger and Burritt, 2005; Hediger, 2010)

Motivations

Many studies have identified motives for corporate "greening," such as regulatory compliance, competitive advantage, stakeholder pressures, ethical concerns, critical events, and top management initiative (Bansal and Roth, 2000).

It is possible to identify some main categories of drivers of a firm's environmental responsiveness: Economically-driven responses, stakeholder-driven responses, and strategicallydriven responses. (Dahlmann et al., 2008) .

Many studies observe that companies operate with primarily economic objectives and take into considerations environmental policies only in order to achieve their main goal (Berry, 2004; Biondi et al., 2000; Florida and Davidson, 2001; Ghobadian et al., 1995; Porter & van der Linde, 1995; O'Rourke, 2003). Other studies concentrate on the answers that firms have to present to their stakeholders who have an interest in the processes and outcomes of the firm such as employees, suppliers, government, communities, and pressure groups (Berry, 2004; Henriques and Sadorsky, 1999; Sharma and Vredenburg, 1998). A particular case is represented by national and international regulation, which has been recognized as a very important driver for companies' environmental responsiveness (Berry, 2004; Berry and Rondinelli, 1998; Biondi et al., 2000; Ghobadian et al., 1995; Henriques and Sadorsky, 1999; Kolk and Levy, 2001; Morrow and Rondinelli, 2002).

The strategic drivers deal with the need of firms to deal with environmental issues in order to create competitive advantage (Berry and Rondinelli, 1998; Ghobadian et al., 1995; Hart, 1995; Hart, 1997; Russo & Fouts, 1997; Shrivastava, 1995).

Some deeper analysis have been conducted in order to define more precisely the drivers for the adoption of environmental management strategies (Gonzalez-Benito and Gonzalez-Benito, 2006, x9). Some studies individuate the influence of organizational context and design (Sharma, 2000; Sharma et al., 1999) and organizational learning (Marcus and Nichols, 1999); some others consider the role of external and internal pressure to overcome regulatory compliance (Gunningham, Kagan and Thornton, 2003) or the influence of competitive forces (Aragon-Correa, 1998; Hart, 1995; Russo and Fouts, 1997; Sharma and Vredenburg, 1998).

Environmental management processes and systems

Recent researches analyze Environmental management and Environmental Management Systems (EMS) as ways to improve environmental and business performance (e.g. Florida and Davison, 2001; Darnall et al., 2008).

However, what really differentiates the implementation of Environmental themes in a firmi s the presence of formal managerial structures and processes dedicated to the environmental management (Dahlmann et al., 2008). have long been associated with strategic.

The most relevant areas in which environmental management can be applied are “Investments in conventional green competencies related to green product and manufacturing technologies; investments into employee skills; investments in organisational competencies; investments in formal (routine-based) management systems and procedures, at the input, process, and output sides; and efforts to reconfigure the strategic planning process, by explicitly considerino environmental issues and allowing individual(s) responsible for environmental management to participate in corporate strategic planning" (Buysse and Verbeke, 2003). Another research had previously determined other important areas, such as. waste minimisation and prevention; . demand-side management; . design for environment; product stewardship; and full-cost accounting" (Berry and Rondinelli, 1998). On a more formal perspective it is possible to take into account the introduction of environmental management systems, such as, for example, ISO 14001 and EMAS (Biondi et al., 2000; Florida and Davidson, 2001), but also Environmental Disclosure (Burstroem von Malmborg, 2002).

Research sample and methodology

Sample and data collection

During the summer of 2010, we administered a telephone survey to Italian CFs. We selected the sample from the Italian Stock Exchange List. Starting from the Italian Stock Exchange list (FTSE, 2010), we selected the 460 firms listed in the FTSE-All Share Index, including High-, Medium- and Small- Cap companies.With this initial analysis, we identified all the 460 listed firms, which are based in Italy. We administered the survey with a telephone call addressed to all the top managers of the selected index. The interviews lasted between 30 and 40 minutes. In total, 261 firms answered the survey, with a response rate of 56.7 percent. The response rate suggests that the survey may be a valid representation of Italian Listed Firms.

The interview consisted of a questionnaire composed of three main sections. In the first section, we collected data on the relevance of different types of CSR and Ecological activities the firms performed. In the second section, we gathered information on the adoption of Environmental management processes and systems in the firm. In the third section, we gathered information on interests that lead to a firm's decision to deal with sustainability themes. The last section addressed the issues associated with the implementation of Sustainability Practices.

After collecting the data, we statistically analyzed them using SPSS 17.0.

Variables

The data collected CSR activities performed by the firms were based on the typology developed by Waddock and Graves (1997). Indeed, the data collected on ecological activities performed by the firms were based on the typology developed by the Dahlmann et al. (2008). The relevance of all activities included was evaluated on a 5-point Likert scale (1 = strongly irrelevant; 2= irrelevant; 3 = undecided; 4 = relevant; 5 = strongly relevant).

Based on the gathered data, we conducted a factor analysis to develop two indexes: the CSR effort index and the Ecological effort index. To reduce the items in the data into two factors that would represent the original data as much as possible, we conducted principal components analysis. We examined factor loadings to determine whether they were meaningfully correlated with the factors. The CSR effort index measures the effort of the firms in facing CSR themes. . The Ecological effort index measures the effort of the firms in dealing with Sustainability main challenges. We used Cronbach's alpha to test the internal consistency of the scale used to measure the CSR and Ecological effort. The alpha coefficient was high for both indexes (Kline, 1999); see Table 1.

[Table 1 about here]

We also collected data on different processes and systems adopted by the firms, on motivations that lead firms to embrace sustainability themes, and on Sustainability practices implemented. These typologies have been developed on the basis of different lists adopted in some important studies (Dahlmann et al., 2008; Singh et al., 2008; Sangle, 2010;).

These variables were measured on a 5-point Likert scale (1 = strongly irrelevant; 2= irrelevant; 3 = undecided; 4 = relevant; 5 = strongly relevant). We decided to ask the top managers to perform the evaluation because they are in the best position to evaluate the relevance of motivations and practices for the firms.

The variable on Industry Environmental impact has been developed on the basis of the classification provided by the Carbon Disclosure Project (CDP, 2010).

Data analysis

We used cluster analysis to identify distinct meaningful groups that would be useful for analyzing the CFs (Hair and Black, 2000).[1] We clustered the firms based on two indexes, the CSR effort index and the Ecological effort index. We used a two-stage clustering approach: a hierarchical algorithm followed by k-means clustering (Punj and Stewart, 1983). The first step in this clustering process was to determine the number of groups contained within the sample, if any, using hierarchical methods. Specifically, we used Ward's method with squared Euclidean distances (the square root of the sum of the squared differences in values for each variable) to identify the number of clusters within the corporations sample, which is the most commonly used measure (Malhotra, 1996). The second step involved using non-hierarchical k-means analysis based on the number of segments (k) discovered in the hierarchical clustering procedure to define cluster membership. The k-means analysis assigned firms into clusters. Finally, we used a canonical discriminate analysis to determine whether the clusters could be distinguished from one another based upon the

[1] Cluster analysis is a statistical technique to assign of a set of observations into subsets, so-called clusters. The aim of this technique is group observation to have cases in the same

other variables collected from the firm respondents. In the subsequent descriptive analyses, we compared the four clusters. We then profiled the clusters, utilizing those variables not included in the initial analysis. We tested the difference between the means of the variables among the clusters. Because the data comprised different levels of measurement, we used non-parametrical test (Kruskal-Wallis and χ^2) techniques to test the statistical significance of the mean differences (Siegel, 1956; Field, 2009).[2]

Results and discussion

Before presenting the results obtained with the cluster analysis, we introduce the descriptive statistics of the sample analyzed. We computed a Pearson's correlation between all the variables collected to identify the potential relation, as Table 2 shows. We also produced the same analysis using non-parametrical Spearman ρ, and the findings were similar.

[Table 2 about here]

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cluster that are similar in some sense. Our intent was to generate subgroups that provide insight into the possibility of segmenting the corporations' activities.

[2] Non-parametric tests analyze statistical differences between group of observations, evaluating a similar object of a parametric test. These tests are less restrictive than a parametric test, because they do not have the assumption of normal distribution of the variables and they work on the principle of ranking the data rather than analyzing actual data (Field, 2009). For the non-parametric test, we utilized discrete variables (based on the Likert scale) rather than continuous ones collected from the CFs; consequently, our data broke the

The sample shows a major interest in Ecological activities (M=0.15; SD=0.24) rather than in CSR actitivies (M=0.09; SD=0.21); the firms are committed to sustainability themes mainly for cost reduction (M=1.77; SD=1,58) or legal compliance reasons (M= 1.76; SD=1.32), and just a minor relevance is due to the pursuit of Environmental Benefits (M=1.46; SD=1.28), improved Reputation (M=1.38; SD=0.86), even though we observed a significant relevance of Managerial Motivations (M=1.43; SD=1.24) and Risk Management (M=1.56; SD=1.19). Our research shows that companies tend to focus more on Management Systems and Certifications (ISO:14001, M=2.05; SD=1.42 – EMS, M=1.56; SD=0.95) than on a structured and well defined policy (Environmental Statement, M=1.32; SD=1.09 – Environmental Management Plan, M=1.25; SD=0.923).

The analysis identified four clusters that, as Table 3 demonstrates, differ significantly across a range of variables. The results showed that the first cluster had 115 members, representing 44.1 percent of the total sample; the second cluster had 28 members, 10.7 percent; the third cluster had 63 members, 24.1 percent; and the fourth cluster had 55 members, 21.1 percent. A profile of each cluster follows.

[Table 3 about here]

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parametric assumption of normal distribution, and it justified choosing non-parametric tests

We named the first cluster of firms *Eco-skeptical* because the member firms were scarcely engaged in CSR (0.02) and Ecological (0.03) activities. These firms operate in industries with a moderately low environmental impact (1.96) and therefore show modest motivations for engaging Sustainability themes, mainly related to Cost Reduction (1.38) and Legal Compliance (1.26). These firms generally don't realize Sustainability Report (1.03) and don't relate Environmental Principles (1.00). Among Environmental Processes, only the adoption of ISO:14001 has a modest relevance (1.47),while planning systems are almost ignored(E. Statement = 1.21 – E. Policy = 1.19 – E. Management Plan = 1.05).

In this case, the member firms are not committed to the implementation of Sustainability Practices, even though they could be eventually interested in Eco Products (1.21). These firms, indeed, are not interested in Environmental issues, because they operate in industries which have a not particularly strong environmental impact. Therefore, these firms moderately focus just on the regulatory and cost saving activities.

The second cluster includes the firms we named *Eco-driven* because it gathers those firms whose activity is driven by a Ecological orientation (0.63), which is associated to a significant CSR engagement (0.51). These firms operate in industries with a significant environmental impact (3.57) and therefore show considerable motivations for engaging Sustainability themes. Even in this case, the main motivations are related to Cost Reduction (3.71) and Legal Compliance

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that are free of this basic assumption

(3.04), but there is a major commitment also for Environmental Benefit (2.86). These firms make a large use of Sustainability Report (2.96) and show a substantial inspiration to Environmental Principles (3.68).

The general aim of this group is to consider Sustainability as an opportunity for a durable development. It is demonstrated by the adoption of many Environmental Processes, among which it is important to put in evidence a clearly stated Environmental Policy (3.29), a Environmental Management Plan (2.64) and, of course, the ISO:14001 (3.32). Eco-Products (3.75) represent the most important challenge for the firms, as well as the implementation of a Green Supply Chain (3.46) and the Employee Engagement through Environmental Training (2.89).

The third cluster, named *Eco-inadequate*, includes those firms by an environmental commitment inadequate to their industry environmental impact, which is very high (4.33). In fact, these firms have a low Environmental commitment (0.15), even not supported by a CSR commitment (0.01).

Considering the relevant impact of its core activity, these firms look at environmental challenges mainly for what concerns Risk Management (1.81), Managerial implications (1.57) and Legal Compliance (1.43), while being particularly uninterested in Environmental Benefits (1.13), as confirmed by a minimum interest for Sustainability Report (1.00) or Environmental Principles (1.00).

In terms of processes, it appears that only those components related to Legal compliance are issued, as ISO:14001 (2.43), Environmental Management Systems (1.70) and Environmental Disclosure (1.60). Dealing with Sustainable Practices, only the presence of Eco-Products is beyond expectations (2.57), while other practices are really inappropriately issued, such as Green Supply Chain (1.22) or Mobility Management (1.24) and use or Renewable Energies (1.14).

In conclusion, we named the fourth cluster *Eco-anspirant* because the member firms were scarcely engaged in CSR (0.12) and Ecological (0.18) activities, but they look potentially interested in dealing with environmental issues with a major commitment in the future. These firms operate in industries with a medium environmental impact (2.53) and therefore show moderate motivations for engaging Sustainability themes, mainly related to Legal Compliance (2.53) and Cost Reduction (2.02), but also enough relevant for Managerial Motivations (1.51) and Risk Management (1.62).

These firms show a very important inspiration to Environmental Principles (4.04) and also a relatively interesting use of Sustainability Report (1.49).

The main Environmental processes adopted are ISO:14001 (2.20), EMAS (1.51) and Environmental Management System (1.89), while there are still modest evidences of Environmental Policy (1.80).

In this cluster, the member firms are not significantly committed to the implementation of Sustainability Practices, even though data show that there is a moderate approach which involves all the analyzed practices, especially Eco-Products (1.73), Green Supply Chain (1.65), Environmental Training (1.55) and Mobility Management (1.56).

Conclusion

This research aspires to contribute to the literature about Sustainability practices, focusing on the superficially investigated Italian companies. In particular, the study aims at going over current studies' perspective, which deals with firm perspective, by putting in evidence how the firm can benefit many advantages by becoming more environmental proactive.

Beyond that, this research shows that the majority of Italian listed firms are not yet sufficiently committed to Environmental issues. The research also shows that the firms engaged with CSR themes are also active in dealing with Environmental themes, with many consequences in terms of motivations, environmental processes and choice of sustainable practices. We have been able to identify which characteristics are related to a specific general interests to the Sustainability Challenges.

If the firm is generically committed to the Environmental Challenges, there will be many valid motivations for the firm itself to approach Sustainability in a proactive way; furthermore, the firm will adopt important management processes, even those which are less related to regulatory constraints, showing also the tendency of implementing consistently

Sustainability practices, from the creation of Eco-product to the development of a Green Supply Chain.

The research demonstrates, in addiction, that there is a relevant group of firms which are potentially interested in facing environmental issues, but which have not yet completely stressed their orientation. These firms refer to environmental principles and obey to regulatory rules; however, they show a lack of environmental systems and practices, which should be implemented as the external conditions will appear more clear (regulations, costs, opportunities).

As already stated, the research underlines that the majority of companies are really far from being involved in a Sustainable Development process. For a deeper comprehension of this phenomenon it is valuable to specify that this disregarding approach has a double perspective. A greater amount of firms, in fact, is not involved in Sustainability because they operate in low-impact industries, and therefore have to comply with few regulatory rules. On the other hand, there are some companies which should be hard-working for managing its high-impact activities, but, on the contrary, reveal an inadequate approach, just focusing on merely legal requirements, without a shared and defined strategy.

These results suggest that the engagement with Sustainability of a firm is strictly related to the original commitment of the firm itself to the Society and the Environment, and, of course, should derive also from the industry in which the firm operates. This is confirmed by the fact that achieving a merely regulatory goal or trying to develop synergies between environmental interests and firm interests represents an important choice for the firms.

It is possible to affirm that this exploratory study is supposed to be improved in the future, in order to produce a more deep investigation and to recover current limitations. First of all, the geographical limit, since the sample is remarkably significant but focused exclusively on Italian Firms, that we plan to fulfill by fostering new researches abroad. Moreover the theme of "Sustainability Practices", which have been analyzed just under some variables and that could be investigated in a broader way and significantly improved in the next phase of the research by making a deeper study about strategic planning and corporate entrepreneurship.

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Tables

Table 1: Reliability of scales

Items	*Index*	*Cronbach's Alpha*
Stakeholder engagement	CSR effort	0.91
Welfare		
Social Services		
Health		
Safety		
Diversity		
Development and Training		
Voluntarism		
Corporate Philanthropy		
Community		
Human Rights		
Recycling	Ecological effort	0.88
Waste		
Water		
Energy		
Climate Change		
Emissions		
Hazardous Waste		
Biodiversity		

Table 2: Descriptive statistics and correlation

Variables	*Mean*	*S.D.*	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
INDEXES																								
CSR	0,09	0,21	0,54**	0,16**	0,30**	0,43**	0,21**	0,72**	0,24**	0,27**	0,23**	0,36**	0,26**	0,34**	0,16**	0,30**	0,19**	0,64**	0,45**	0,41**	0,44**	0,56**	0,38**	0,52**
ECO	0,15	0,24		0,21**	0,29**	0,66**	0,37**	0,45**	0,50**	0,57**	0,66**	0,49**	0,51**	0,59**	0,23**	0,32**	0,51**	0,71**	0,46**	0,53**	0,62**	0,68**	0,64**	0,71**
Industry Impact	2,82	1,49			-0,02	0,14*	0,17**	0,08	0,13*	0,20**	0,15*	0,03	0,03	0,05	0,12*	-0,02	0,20**	0,11	0,01	0,02	0,29**	0,12	0,13*	0,12
ENVIRONMENTAL MANAGEMENT PROCESSES																								
Environmental Statement	1,32	1,09				0,32**	0,34**	0,21**	0,18**	0,14*	0,02	0,43**	0,38**	0,39**	0,40**	0,42**	0,24**	0,23**	0,12	0,06	0,34**	0,27**	0,43**	0,47**
Environmental Policy	1,62	1,07					0,33**	0,38**	0,48**	0,57**	0,47**	0,49**	0,45**	0,63**	0,23**	0,42**	0,36**	0,55**	0,43**	0,42**	0,45**	0,51**	0,50**	0,58**
Environmental Disclosure	1,36	8,86						0,16*	0,29**	0,45**	0,38**	0,34**	0,23**	0,25**	0,52**	0,16*	0,44**	0,22**	0,07	0,11	0,49**	0,22**	0,42**	0,38**
Environmental Processes Plan	1,25	0,92							0,15*	0,21**	0,15*	0,29**	0,23**	0,29**	0,12	0,28**	0,18**	0,54**	0,31**	0,42**	0,38**	0,54**	0,31**	0,43**
EMAS	1,31	0,90								0,45**	0,43**	0,32**	0,32**	0,39**	0,21**	0,09	0,27**	0,31**	0,31**	0,41**	0,31**	0,38**	0,34**	0,44**
ISO: 14001	2,05	1,42									0,71**	0,29**	0,36**	0,38**	0,29**	0,18**	0,34**	0,39**	0,26**	0,31**	0,43**	0,36**	0,43**	0,34**
EMS	1,56	0,95										0,29**	0,43**	0,35**	0,19**	0,09	0,40**	0,46**	0,39**	0,27**	0,44**	0,36**	0,41**	0,34**
MOTIVATIONS																								

Cost Saving	1,77	1,58	0,55**	0,60**	0,52**	0,62**	0,38**	0,36**	0,31**	0,33**	0,46**	0,39**	0,34**	0,50**
Legal Compliance	1,76	1,32		0,46**	0,22**	0,42**	0,38**	0,39**	0,45**	0,26**	0,31**	0,41**	0,42**	0,46**
Reputation	1,38	0,86			0,34**	0,58**	0,46**	0,41**	0,32**	0,38**	0,39**	0,43**	0,45**	0,59**
Managerial Motivations	1,43	1,24				0,34**	0,43**	0,11	0,07	0,09	0,39**	0,13*	0,33**	0,27**
Environmental Benefit	1,46	1,28					0,20**	0,30**	0,16*	0,23**	0,25**	0,38**	0,28**	0,45**
Risk Management	1,56	1,19						0,35**	0,24**	0,19**	0,43**	0,29**	0,40**	0,27**
PRACTICES														
Sustainability Report	1,33	0,80							0,55**	0,43**	0,35**	0,61**	0,46**	0,58**
Environmental. Principles	1,93	1,42								0,36**	0,16**	0,43**	0,28**	0,35**
Eco-Packaging	1,22	0,82									0,24**	0,46**	0,30**	0,40**
Eco-Products	1,92	1,48										0,46**	0,46**	0,52**
Green Supply Chain	1,50	1,06											0,54**	0,61**
Environmental Training	1,47	0,99												0,65**
Mobility Management	1,45	1,04												
Renewable Energy	1,29	0,93												

*** = p<0.01; ** = p<0.05; * = p<0.1

Table 3: Clusters of firms

Variables	Cluster 1 Eco-skeptical n=115		Cluster 2 Eco-driven n=28		Cluster 3 Eco-inadequate n=63		Cluster 4 Eco-anspirant n=55		χ^2
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	
INDEXES									
CSR Engagement	0,02	0,09	0,51	0,31	0,01	0,04	0,12	0,20	8204.41***
Environmental Commitment	0,03	0,10	0,60	0,20	0,15	0,18	0,18	0,25	8309.26***
Industry Environmental Impact	1,96	1,00	3,57	1,20	4,33	0,95	2,53	1,49	15.61***
ENVIRONMENTAL MANAGEMENT PROCESS / SYSTEMS									
Environmental Statement	1,21	0,89	2,00	1,76	1,13	0,71	1,44	1,26	183.76***
Environmental Policy	1,19	0,59	3,29	0,90	1,51	0,95	1,80	1,19	489.25***
Environmental Disclosure	1,14	0,62	1,71	1,24	1,60	0,93	1,36	0,87	494.20***
Environmental Management Plan	1,05	0,42	2,64	1,83	1,00	0,00	1,25	0,95	639.00***
EMAS	1,05	0,39	2,07	1,25	1,29	0,89	1,51	1,18	769.48***
ISO:14001	1,47	1,09	3,32	1,12	2,43	1,51	2,20	1,48	394.38***
EMS	1,10	0,45	2,46	1,10	1,70	0,96	1,89	1,12	509.94***
MOTIVATIONS									

Cost saving	1,38	1,18	3,71	1,90	1,38	1,18	2,02	1,76	99.31***
Legal Compliance	1,26	0,85	3,04	1,43	1,43	1,06	2,53	1,55	382.66***
Reputation	1,16	0,54	2,68	1,22	1,19	0,59	1,40	0,89	658.41***
Managerial Motivation	1,17	0,82	2,00	1,76	1,57	1,41	1,51	1,35	161.02***
Environmental Benefit	1,35	1,13	2,86	2,03	1,13	0,71	1,36	1,16	154.79***
Risk Management	1,10	0,52	2,71	1,65	1,81	1,34	1,62	1,25	627.30***
PRACTICES									
Sustainability Report	1,03	0,26	2,96	0,88	1,00	0,00	1,49	0,90	507.51***
Environmental Principles	1,00	0,00	3,68	1,16	1,00	0,00	4,04	0,19	182.97***
Eco-Packaging	1,03	0,28	2,37	1,62	1,05	0,38	1,24	0,92	868.58***
Eco-Products	1,21	0,76	3,75	1,60	2,57	1,59	1,73	1,31	283.97***
Green Supply Chain	1,10	0,45	3,46	1,29	1,22	0,75	1,65	1,02	570.59***
Environmental Training	1,11	0,51	2,89	1,34	1,41	0,96	1,55	0,92	580.17***
Mobility Management	1,08	0,50	3,21	1,37	1,24	0,76	1,56	1,07	655.00***
Renewable Energy	1,08	0,50	2,71	1,67	1,14	0,67	1,16	0,71	596.03***

*** = $p<0.01$; ** = $p<0.05$; * = $p<0.1$

Applying Warping for Improving Land Subsidence and On Farm Water Supply-A Case Study for Choshui

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Abstract

Due to groundwater over withdraw for satisfying the water demand of Agriculture and fisheries that results imbalance of groundwater level and land subsidence in Yunlin County, south-central Taiwan. To improve land subsidence problems and to meet the needs of local vegetable farm irrigation water demand for sustainable use of agricultural land, the most importance is to reduce the agriculture and fisheries groundwater withdrawal that current status of water imbalance and the use of Choshui turbid water to improve the fallow paddy fields cultivation capability.This research proposes a conceptual system that storing turbid water into 30 cm high ridge fallow paddy field, called water cultivation, for sediment and recycle for irrigation.In order to build the model, the hydrometer test in the laboratory will be carried out to discuss the sediment concentration of Choshui turbid water at different flow rates and settling velocity distribution of suspended solids that the ratio of water and soil could be determined. Water and sediment will be separated due to gravity, the upper water will flow to the nearby vegetable field to satisfy its irrigation requirement instead of pumping water.In view of this, the current local multiplicity of the environment, policies, people's livelihood, one can take full advantage of fallow fields and in line with national policy that withdrawal groundwater is prohibited under the premise of solving the farmers irrigation water problems and improve the fallow fields cultivation capability, and indirect benefits groundwater that soil and resources to be used sustainably and efficiently.

*Keywords:*Warping Works, Ground Water Withdrawal, Water Logging Paddy Field

1.Introduction

The agricultural sector has played a major role in Taiwan's economy from way back as the Ming and Ching Dynasty. It was the catalyst which shaped Taiwan's development. Where it was observed that agricultural development has always stood on two main pillars, one being the land reclamation programme and the other being water exploitation. The importance of water exploitation however surpassed that of land reclamation because only through water exploitation can land value in Taiwan be increased. (Selvaraj and Chen, 2006)In Taiwan, steep erosional gradients, short transport distances, and short storage times have significantly increased the intensity of physical weathering. The sediments present only a moderate chemical weathering on the basis of major and trace element geochemistry.(Zhifei Liu a et al.,2008) Drainage area:2989km; Runoff : 1.2m/yr; Suspended sediment discharge: 54.1 Mt/yr.[11] (Gau and Liu,2002) results indicated that the optimum yield of groundwater in this region is 619 million ton/yr, which is far lower than the current annual groundwater consumption.[10 This was due to the unbalance of groundwater level within the aquifer water which caused land subsidence. According to(water and Statistics Bulletin, 2000) Taiwan region had a total area of 2,403 square kilometers of land subsidence, with Yunlin County accounting for 880 square kilometers of it is the most widely largest cumulative amount of the maximum subsidence of 2.02 meters, in 2010, the maximum cumulative total subsidence 2.43 m, 7.3 cm subsidence rate in 2009. We can see in the Yunlin area continued to the present ground subsidence. Yunlin County fallow area of the cultivated area, from 42% (2002) to 52% (2009) (Yunlin County Statistical Yearbook, 2002, 2009).Although wells were closed to prohibit the extraction of groundwater problem still not resolved. Thus the county of Yunlin in Taiwan is currently facing water crisis due to long-term extraction of groundwater by the agriculture and aquaculture industries. The long-term indiscriminate extraction by these industries has caused variations of water which could be supplied by the aquifer. A practice which was condemned by Lin et al., 2004 especially after his study discovered in the Cho-Shui alluvial fan area, where rainfall is extremely seasonally uneven. Assessing and monitoring pumping amounts and all fluxes in groundwater flow is essential sustainable usage of the regional water resources. Results of his study indicated that in year 1995, the cumulative pumping volume was 155.4 million cubic meter, the rainfall recharge was 81.3 million cubic meter, and the constant head inflow was 18 million cubic meter. The effect unmonitored withdrawal of water in the region have been studied by several researchers Leu (2010)in his study focuses on the relationship between different layers of groundwater levels and utilize spatiotemporal related interpolate value of settlement of each groundwater station to conclude the critical groundwater station and the critical changes of water level in an aquifer. Although (Shu-Zi Wang,et al., 2001) focused his study close to the coast of Holung Chi and Taan Chi the results observed were the same where rapid rising trend of salinization which exceeded the upper limit for irrigation criteria was recorded in recent years. Among six major rivers, only Tachia Chi and Choshui Chi retain the suitability for the purpose of irrigation. Where it was observed water quality for these six rivers was determine by a high water flow in the summer season or a low flow in the late spring season with a reduction in flow being interpreted as poor water quality environment.[7] Since (Yi-Hao Hou,2009)As compared between field measurement data and simulation results with three models, it indicated that the trend of simulation results of the land subsidence corresponds to the field measurement of land subsidence. We know that low-flow and sediment entrainment is proportional to the relationship. (Shi-he LIU et al.,2007)In this article, a mathematical model for low-concentration sediment-laden flow was suggested based on the two-phase flow theory, and a solving scheme for the mathematical model in curvilinear grids was worked out. The observed data in the Zhang River in China was used for the verification of the model, and the calculated results of the water level, velocity and river bed deformation are in agreement with the observed ones.[12](T. S. Lee et al.,1974)This shows that the HCO3 content in the soil solution of some of the soils in this experiment did reach a level which retarded potassium uptake. The phosphorus content in the rice plant were also found to be negatively correlated with the pH values of the soil solution. Phosphorus absorption was retarded in some of the soils with higher pH values in this experiment. It is due to the fact that when pH values is above 7, the excess calcium may further hinder phosphorus absorption and utilization. In conclusion, the low yield of some slate alluvial soils in central Taiwan may be caused by the abnormally high concentrations of HCO3, $Ca^{2+}$and Mg^{2+} produced during the course of rice growth.[13] Chen et al., (2010)Through an assumed linear relationship, the inferred results showed that the Global Positioning System data are closely correlated to the groundwater level variations of deep aquifers. The highest correlations between elevation changes and groundwater level variations have been found in the land subsidence area, even under drought conditions. The responses on the surface vertical displacements from the groundwater level changes of deep aquifers can be quantitatively estimated.[1] Chen et al.,(2010) Overdraft of groundwater in the Choshuichi Alluvial Fan has been the major mechanism for a negative impact of land subsidence. The elevation changes in the subsidence area are primarily affected by two factors: the current groundwater level variations and a long term trend caused by the past excessive extraction in aquifers. The two factors can be separated and estimated by a linear relationship and temporal functions. In addition, the correlation coefficient between the synthetic and observed elevation changes can be served as an effective and quantitative indicator in differentiating the normal and/or subsidence area and weighting factor for various aquifers. The results of this study can provide a useful reference of remediation strategy for the land and water resources management in active subsiding areas. [1] Chen et al.,(2010) explained that the causes of land subsidence can be multiple and complex; consolidation of thick mud layer is the most important factor among them. However, extensive and costly observations are needed to obtain data for quantitative confirmation of consolidation in thick mud layers. Chen et al.,(2010) examined the correlation between the land subsidence (deduced from GPS data) and the groundwater level variations of monitoring wells in the period between 1994 and 2006. Our aim is to quantitatively describe the relationship between vertical displacement on surface and groundwater level variation in identifying the distinctive effects among aquifers and derive the long-term trend for the land subsidence area. The behavior of aquifers is vital in order to understand land subsidence process. The long-term trend is very valuable in developing an effective and appropriate remediation strategy for the land and water resources management on a large scale. Where it is seen in the Choshui River that due to, excessive floods or suspended matter siltation blocked water intake which then resulted in a diversion function imbalance (Caiwen Hao et al., 2010). (Fang-Hua Lin,2010)This study discussed the groundwater characteristics of the apex of the Zhuoshui river alluvial fan. It was discovered that there were two to three months of response delay between the river water level and groundwater level in the studied area and there is a prominent period of one year analyzed from the data.[3] (Jen-Kuo Huang, Kwan-Tun Lee,2009) Also studied the time-varying soil moisture content under watershed environment, whereby they made analysis based on a current precipitation index (CPI). An exponential function was selected to describe the relationship between the CPI and the partial contributing area (PCA) during storm events.[4] (He-Chin Chen et al.,2008)also located another area under threat of land subsistence, the Changhua coastal area is located on the north Jhuoshuei River alluvial plain. Which based on the studies of the Ministry of Economic Affairs recorded velocities of land subsidence during 2001, 2002, 2003 respectively were 17.6 cm/yr, 11.7 cm/yr and 10.4 cm/yr,. Realizing this dire problem, we need to study the land subsidence in this area in order to prevent or mitigate the possible impact on local infrastructure. The achievement demonstrated that the Changhua coastal area has been still the serious land subsidence area. With location VR02 seen as the most vulnerable land subsidence point with a recorded displacement of almost 80mm per year. The displacement of 1^{st}order benchmarks were nearly 17~56mm per year during the monitoring period.[5]

2. Paddy Water Balance model

(L.O. Odhiambo, V.V.N. Murty,1995)In the case the fields which consist of independent plots, each plot should be constructed with an independent irrigation inlet and drainage outlet. Thus, paddy field layouts are broadly classified as plot-to-plot and independent layouts. The primary objective of layout improvement was to control the field water balance condition in order to obtain optimal conditions for increasing productivity such as soil-water regime suitable for plant growth and yield, soil moisture allowing traffic ability, higher water use efficiency and low harmful effects on the environment (e.g. waterlogging, salinity, pollution and soil erosion). In Japan, Korea and a few other countries, the recent trend of land readjustments are made in connection with mechanization in order to minimize the labor requirement for rice cultivation.[16]

The water balance components considered in the model are shown in Fig. 1. The inflow to the field consists of the total water supplied through rainfall and irrigation, and the outflow consists of water leaving the field through evapotranspiration, seepage, percolation, and surface runoff. The field storage was assumed to be adequately represented by the ponded surface water since, in a properly irrigated paddy field, the plow layer exists under saturated condition and the soil moisture is constant during most of the crop growth period.

A generalized water balance equation for a single paddy plot can be expressed as follows(Fig 2-1)

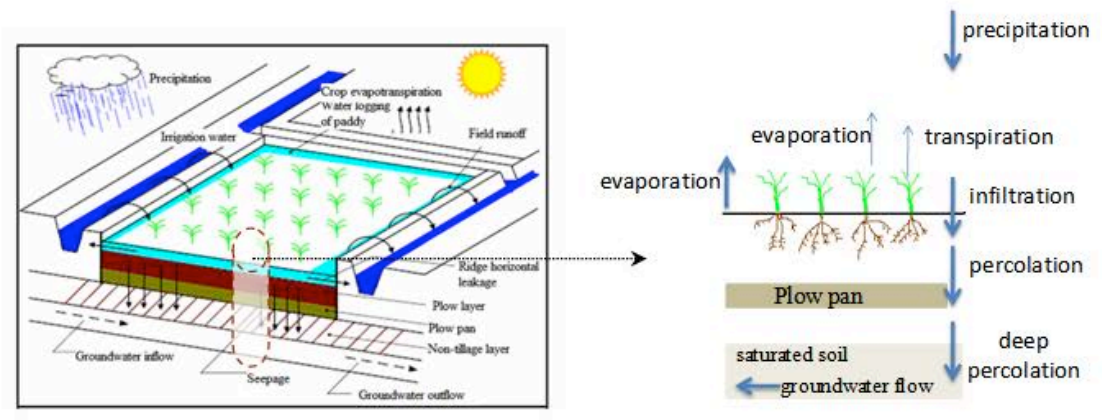


Fig 2-1 Water balance of water logging paddy field

Important source of groundwater recharge areas is often irrigated irrigation water. Paddy's field water consumption, in addition to some of the crop evapotranspiration, about half of the deep percolation, this deep percolation for the Basin Recharge of groundwater recharge. Whereby we can apply large quantities of irrigation water into paddy fields to promote groundwater recharge and in the event of any excess water Fallow land or in non-irrigated period, should still be irrigated in order to artificially recharge groundwater.

When in the fields of suspended solids sediment accumulated over time, farmers will till once. This time plow pan (7 ~ 25cm in depth under the surface) will be local damage. we use turbid water of Zhoushui River conduit diversion into the paddy fields. Implementation of water allocation strategies in the paddy fields. This strategy is 40 times the original leakage direct subsidies to groundwater. And consider the resumption of farming land in the impoundment of the function. The results showed that infiltration rate is 0.33 times the background value. After fully tillage once the field that can be quickly restored paddy fields of the impoundment features. (Ye Yilong, 2005) [17]The components vary with climate, scale, and local/ regional geologic/ hydrogeo- -logic conditions. For the sake of reference, on a global annual basis, evaporation and evapotranspiration is 58% of precipitation, streamflow is 40% (direct runoff is 28% and baseflow 12%), and deep percolation is 2% (Fig. 2-2) (World Water Balance, 1978; L'vovich, 1979; Ponce, 2006).

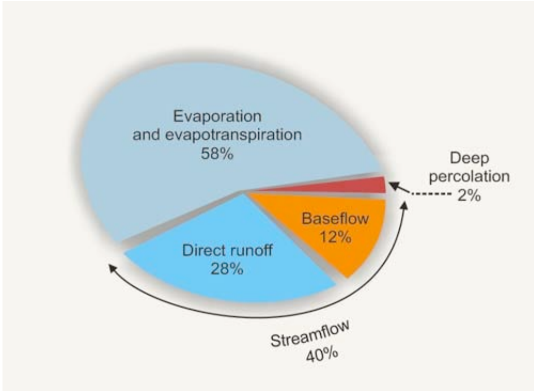


Fig. 2-2 Global components of precipitation(source:FAO)

Return to the ocean through deep percolation is totally independent of the surface waters; therefore, it may be a potential candidate for capture by groundwater systems. Thus, on a global annual basis, up to 2% of precipitation may be potentially tapped by groundwater systems with minimum encroachment on established [surface water] rights. In practice, specific values of deep percolation would have to be established on a local, subregional, or regional basis. For groundwater basins lying in close proximity to the ocean, the capture of all or fractions of deep percolation should be examined carefully because of the possibility of salt-water intrusion.

3. Model Application

Introduction and background information Huwei Township, Yunlin County. Followed by the experimental method that describes the use of the Specific Gravity test to estimate the water turbidity of the Zhoushui River. Inside the flask(Units sedimentation height) and (water) ratio. Application of warping method in Fallow fields as (Water field), to achieve (land re-use) and (promote fertility) features.Other hand, we use surface water irrigate vegetable fields, to achieve low-cost irrigation purposes. Further exploration, we use (Water field) method of access to clean water.Using the optimal operation of the various ancillary scenarios to achieve the maximum (water capacity) utilization.

3.1 Description of the study area

The Yun-Lin basin is located in the western part of central Taiwan, as depicted in Fig 3-1-1. Experimental paddy field and data Station (Fig 3-1-2). The Cho-Shui River and Pei-Kong River are the two major rivers flowing through the basin. The basin extends 48 km from east to west and 24 km from north to south and has a total area of approximately 1000 km^2. Rainfall is concentrated in the wet season from May to October while the dry season is between November and April. The annual average rainfall and temperature are 1416.8 mm and 22.6 °C, respectively (Agricultural Engineering Research Center, 1989)

Fig 3-1-1 Yun-Lin basin

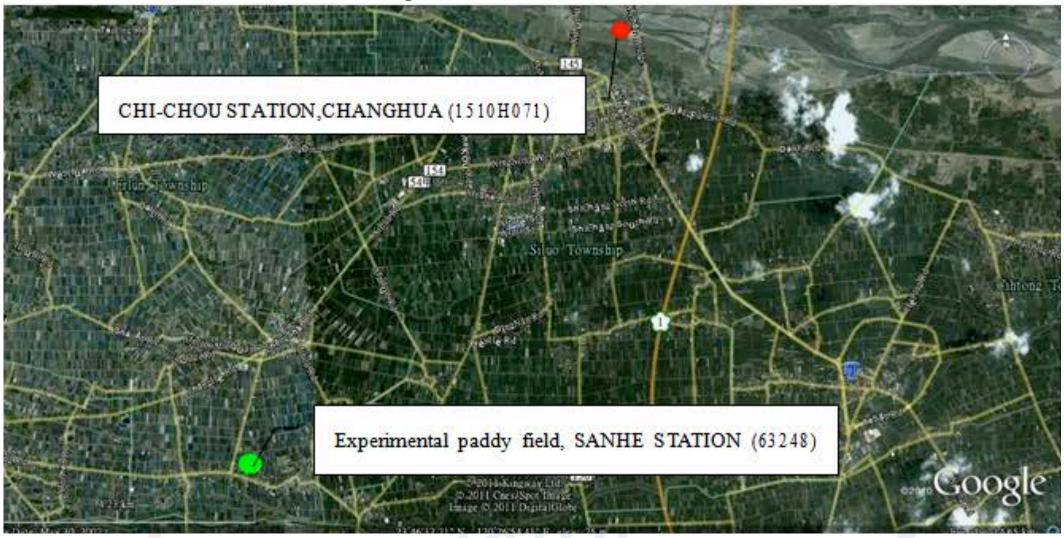


Fig 3-1-2 Experimental paddy field and data Station

3.2 Flow and Sand content data analysis

We used CHI-CHOU 2000 ~ 2009 □ (Table 3-2-1) of water flow, Sand content, Sediment discharge data, to obtain a scatter plot. Which illustrated in Fig3-2-1 expressed Flow and Sand content to see the distribution pattern, with physical exponential function relationships. During the period from 2000 to 2009, the average sand content of about 7500ppm, in addition to the high numeric sand content in 2001 (23000ppm), 2002 年 sand content is low (850ppm).

Table 3-2-1 CHI-CHOU,CHANGHUA (ex:2009 year)

Date	Flow	Sand content	Sediment discharge
2009/1/20	6.4	242	133.75
2009/2/9	5	141	60.86
2009/3/2	5.06	355	155.26
2009/3/9	43.56	1170	4403.6
2009/3/19	7.33	891	564.05
2009/4/8	6.97	185	111.46
2009/4/20	15.24	132	173.81
2009/4/23	171.06	1280	18918.2
2009/5/11	11.93	198	204.16
2009/5/21	4.26	226	83.24
2009/6/12	5.91	239	121.94
2009/6/19	59.73	484	2497.6
2009/6/30	30.86	224	597.23
2009/7/10	16.07	123	170.8
2009/7/29	30.16	373	971.88
2009/8/4	60.57	1760	9210.06
2009/8/8	4130.94	41600	14847604.16
2009/8/10	2789.91	55600	13402257.24
2009/8/14	726.56	18700	1173894.92

2009/8/21	375.29	13300	431252.1
2009/9/4	98.9	4430	37853.79
2009/9/14	38.33	1920	6357.99
2009/9/25	13.92	423	508.55
2009/10/16	55.48	4290	20564.37
2009/10/26	22.38	1330	2571.39
2009/11/9	11.22	365	353.71
2009/11/27	8.72	1580	1189.84
2009/12/10	5.52	157	74.89
2009/12/25	16.02	3020	4180.33

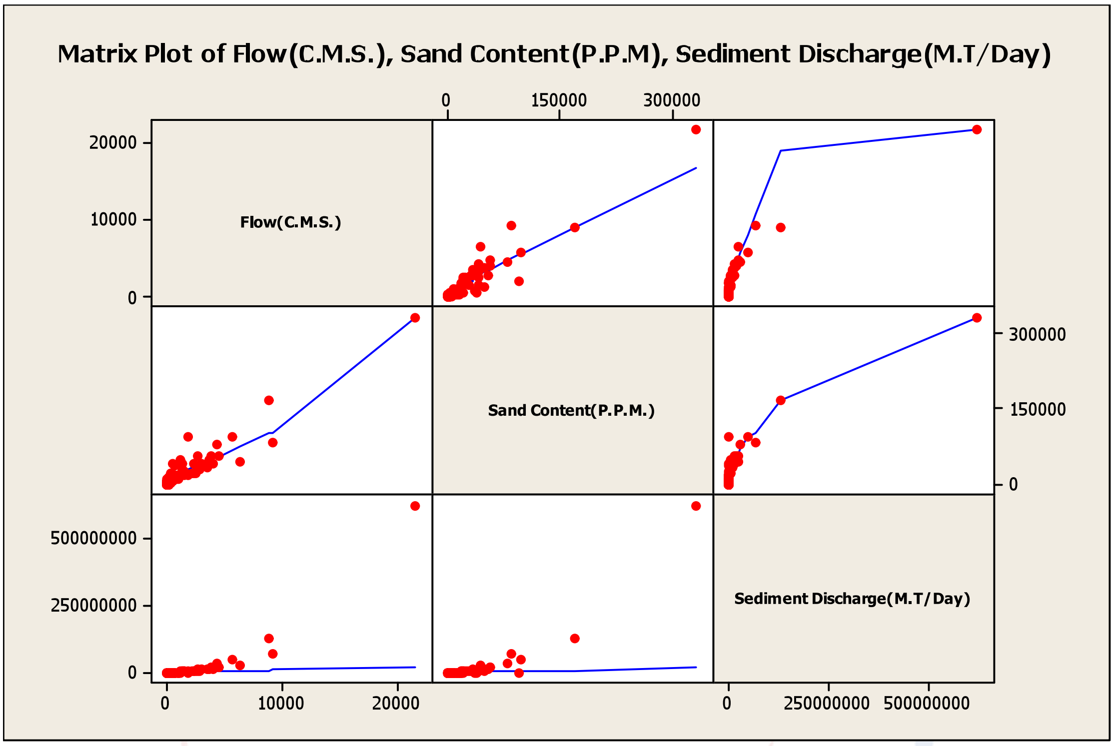


Fig 3-2-1 Flow,Sand Content,Sediment Discharge scattergraph

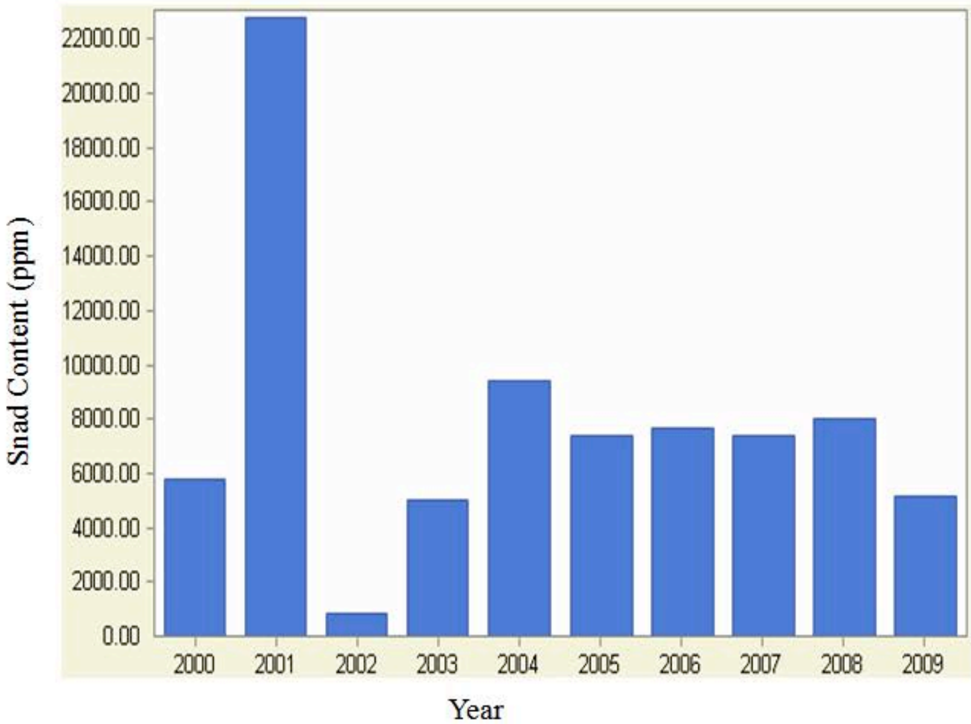


Fig3-2-2 Sand Content, year histogram

3.3 Estimation of irrigation water consumption- crop irrigation during the each *irrigation water consumption*

The vegetable crops (Bok Coy) using Open type and facility cultivation can be grown throughout the year. Growth number of days 30 to 45 days.The definition of growth days for 30 days. According to Agricultural Engineering Research Center (2002) of the Yunlin Irrigation common cultivated(crop irrigation during the each irrigation water consumption) of information. Planted cabbage spring and fall crop water requirement is estimated at Bok Coy water demand. The initial period from 1 to 2 days, irrigation 8 ~ 15mm;Peak period from 2 to 3 days, irrigation 15 ~ 20mm;Late period from 3 to 5 days, irrigation 20 ~ 25mm.

3.4 Specific gravity test

Identified by the ASTM hydrometer analysis of the scope is the size of particles smaller than 0.075mm in diameter (Keller andGee, 2006), so in this study used the screen to # 200 (0.074mm), and its steps can be Summarized as follows:

(1) Take 40g of water multiplied by the factor (MF) of dry soil, add 100ml of distilled water and 50ml of 5% of the partial sodium, and dispersed by ultrasonic disperser for 10 minutes, if the texture of the soil recommendations smaller dispersion than 15 minutes.

(2) to prepare an aqueous solution of the control group and thus to practice (hydrometer) placement and reading. And measure (graduated cylinder) (1000ml) of the cross- sectional area (section A '). Figure 3-4-1 shows the actual operation.

Fig 3-4-1 CNS 11776 specific gravity test step

3.5 Hydrological balance (water logging paddy field) depth of highly derived

3.5.1 Basic assumptions：

H_1 □ turbid water height

H_2 □water height

ER □effective rainfall

ET □evaporation and evapotranspiration

F □infiltration

D □high ridge

T □rainfall delay

F □total infiltration

f □Any time (t) of the infiltration rate

f_0 □ initial infiltration rate

f_c □final infiltration rate

A_1 □Inflow fallow fields (trapezoidal opening sectional area)□ T_1 □upper bottom□ T_2 □ lower bottom□ h_1 □high; S_1 □sediment high; Γ □crop coefficient; PET □potential evapot- ranspiration; $PETK=F\times$; $Ftp=\times\varsigma$ % ; K □evapotranspiration correction factor

t □outflow times

$$ffffe-2_{00}\ (\quad _{c})^{2kt}$$

$$Ffdtffff\ TTT\ 000\ \qquad 00 \qquad (\quad _{c})^{2kt}$$

$$FfTe_{0}\ \frac{(ff_{0}2\ _{c})}{k}^{2kT}$$

$$H_{1}=\frac{Qt}{A}$$

$$HERDETFHS$$

when ERD ? ERD then

$$HERD$$

3.5.2 Flow determined by the energy equation:

$$gz=\frac{u^{2}}{2}$$

$$ug=\sqrt{2}$$

Flow volume need consider about water surface dz per unit time dt changes: $uAdtLL2dz()$

$$ATTh/2$$

Or A_{1} ?pumping tube cross-sectional area

$$dtdz2\ \frac{(LL}{Agz\sqrt{2}}$$

$$tdz\ \frac{LL}{Agz\sqrt{2}}$$

$$\Gamma \times VPETR_{\text{vegetable field and irrigation water}}$$

$$=\times KFr_{5}\ ()\ _{12}$$

$$h_{\text{vegetable field and irrigation water high}}=\frac{V_{\text{vegetable field and irrigation water}}}{A_{\text{vegetable field area}}}$$

$$3600\times \frac{LL}{Agz\sqrt{2}}=dzQA_{\text{inflow of field}}\ \text{vegetable field area}\ h_{\text{vegetable field and irrigation water high}}$$

3.6 Fallow field test site configuration

A fallow field in each area marked with a number of red flags.Pumping of dirty water, according to label and date, turns into the fallow fields.For example, February 1 water storage in the (No. 1 fallow fields). February 2 water storage in the (No. 2 fallow fields) as shown in Figure 3-6-1. For 24 hours after the extraction of surface water to irrigate crops.Diagram shown in Figure 3-6-2. This is the warping of its primary mechanism for the improvement of solid and liquid separation.

1			12,30	
				18,29
2	5	8	13,31	
			14	19,28
3		9	15	

	6			20,27
		10	16	
4				21,26
		11		22,25
	7		17	23,24

Fig 3-6-1 50ha is expressed as one rotational irrigation, a grid of 1ha each field zone (dark grid for the (Species of paddy field), sequentially numbered, numbered to 31 said 31 days; white squares for the vegetable fields)

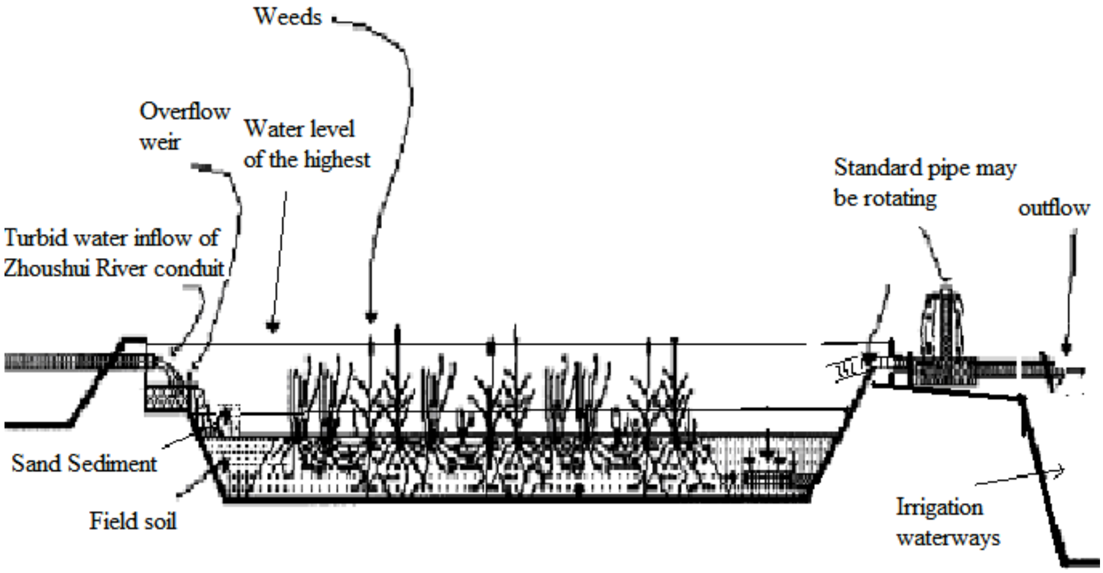


Fig 3-6-2 warping the surface flow model modified profile

3.7 Optimal of the paddy field operations measures

Basic assumptions□

L_1 :fallow field length (m)□ L_2 □fallow field width (m)□ $A_1 = L_1 \times L_2$ □fallow field area (m^2)□ H □ridge height (m)□ H_1 □24 hours after the sediment Sediment height□ $A_1 H$ □ storage turbid water volume□ $A_1(H - H_1)$ □24 hours after storage turbid water volume. L_3 : vegetable field length (m) □ L_4 □ vegetable field width (m) □ $A_2 = L_3 \times L_4$ □ vegetable field area(m^2)□ D_{w1} □the initial water demand for vegetable field (mm)□ D_{w2} □peak water demand for vegetable field (mm)□ D_{w3} □later period water demand for vegetable field (mm)□

Assumptions□

When standing 24 hours later, when the water depth 38cm (1000c.c.), can be pumped30cm depth (800c.c.), can be regarded as not disturb the bottom sediment.When standing for 30 minutes, 1,12,24 hours later, we can pump the water depth was 5cm, 9cm, 20cm, 30cm.

We assume that (eraly, peak, late period) of irrigation demand water growing vegetables (we use the median value to calculate), D_{w1} = 12 (mm): early period vegetable irrigation demand, D_{w2} = 18 (mm): peak period vegetable irrigation demand, D_{w3} = 23 (mm): late period irrigation vegetables demand.

By mass conservation law we have to balance water supply and water demand is based. Estimating following formula:

$$P + I - O - E + R_g - R_f = \Delta S$$

Assumptions:

Where P is precipitation is constant (to simplify the model, not to consider); I (upper field) inflow constant (due to continuous inflow fills the water, so the constant); O for the (down field) outflow (as vegetable field and water demand); E is the evaporation per unit time (for the simplified model, not to consider); is (from the field at the bottom) of groundwater inflow (To simplify the model, not to consider); to (the field at the bottom), theSeepage volume (for the simplified model, not to consider); ΔS is change in the amount of water per unit time (for the simplified model, storage capacity does not change.)

1. When A_2 is constant, the estimated A_1:

early period: $A_1 H_{11} = A_2 \times D_{w1}$; $A_1 (1) H_1 = D_{w1} \times A_2$; $A_1 = \frac{D_{w1} \times A_2}{H_1}$

peak period: $A_1 H_{12} = A_2 \times D_{w2}$; $A_1 (1) H_1 = D_{w2} \times A_2$; $A_1 = \frac{D_{w2} \times A_2}{H_1}$

later period: $A_1 H_{13} = A_2 \times D_{w3}$; $A_1 (1) H_1 = D_{w3} \times A_2$; $A_1 = \frac{D_{w3} \times A_2}{H_1}$

2.When the A_1 set constant, according to the type anti-push, estimated A_2 :

early period: $A_1 H_{11} = A_2 \times D_{w1}$; $A_1 (1) H_1 = D_{w1} \times A_2$; $A_2 = \frac{A_1 \times H_1}{D_{w1}}$

peak period: $A_1 H_{12} = A_2 \times D_{w2}$; $A_1 (1) H_1 = D_{w2} \times A_2$; $A_2 = \frac{A_1 \times H_1}{D_{w2}}$

later period: $A_1 H_{13} = A_2 \times D_{w3}$; $A_1 (1) H_1 = D_{w3} \times A_2$; $A_2 = \frac{A_1 \times H_1}{D_{w3}}$

4. Results and discussion

4.1 Estimating the sand content

Zhoushui River conduit flow by month minus monthly varying degrees of sand content.The remaining amount of water is fresh water.Used to supply irrigation to meet the vegetable fields (50ha for the 1 unit rotational irrigation) monthly crops (cabbage) water demand.Flow data can be estimated by the dry season and wet season in the sand content, as shown in Table 4-1-1.

Table 4-1-1 The CHI-CHOU Brigde station flow rate and sand content (exponential) regression equation

station name	CHI-CHOU Brigde station 2000~2009	
N(data number)	143	110
period	Dry period	Wet period
POWER Regression Formula	$Y=3.985X^{0.806}$	$Y=3.251X^{0.918}$
Adjusted R Square	0.607	0.837

Y:sand content ,X:flow

4.2 water logging paddy field depth height

Test results such as (Figure 4-2-1 specific gravity test) the effective depth curve that Maximum cylinder depth 18cm.Reached maximum at 24hr after the effective depth of precipitation quantities 16.0598cm.Upper layer of water volume is about 600c.c..4hr after the effective depth of 15.6982 cm. Did not reach maximum sediment volume. There are 6.21% suspended matter (diameter 0.002994485mm) in slightly turbid water, (Figure 4-2-2 size distribution curve).Because of slightly turbid water rich in trace elements and organic matter, suitable for irrigation of plants, so consider using the upper slightly dirty water about 650c.c.

Fig 4-2-1 (specific gravity test) the effective depth curve

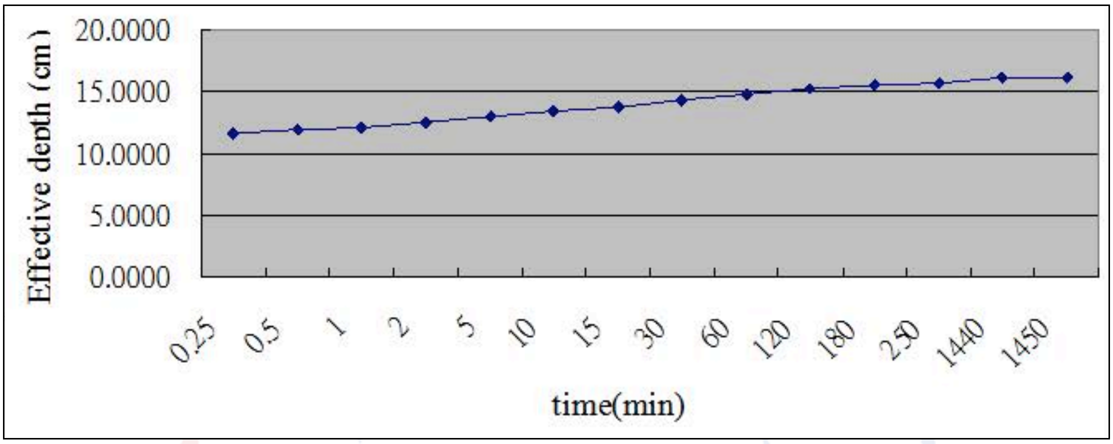
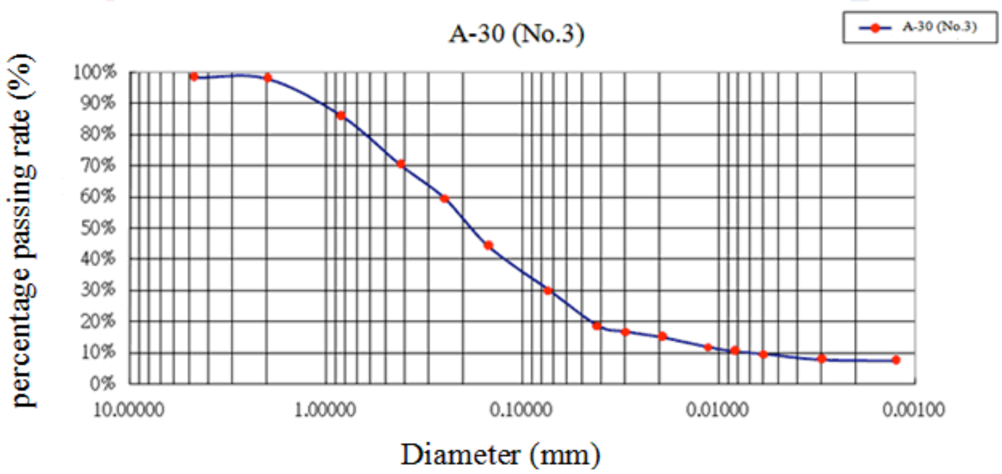


Fig 4-2-2 size distribution curve



4.3 Estimation of crop water demand scenarios

By calculating the proportion of fallow land and (bok choy) early, peak, late water demand, we can estimate the required area of water logging paddy field.By calculating the proportion of fallow land and (bok choy) early, peak, late water demand, we can estimate the required area of paddy fields.Example One, if the ridge up to 80 cm depth, ie the early peak, the late water logging paddy field: vegetable fields= 1:80,1:43,1:32, as shown in Table 4-3-1.Example two, if the ridge up to 30 cm depth, ie the early peak, the late water logging paddy field: vegetable fields= 1:30⍰1⍰16⍰1:12, as shown in

Table 4-3-2.

Table 4-3-1 1 ha of paddy field (design water depth of 80 cm) of about 8000 cubic meters of turbid volume, standing at different times. We can irrigate the area of Bok choy.

Water logging at different times		30min	1hr	12hr	24hr
Irrigation area of bok choy (ha)	early period	3	10	50	80
	peak period	1.6	5.33	26.67	42.67
	late period	1.2	4	20	32

Table 4-3-2 1 ha of paddy field (design water depth of 30 cm) of about 3000 cubic meters of turbid volume, standing at different times. We can irrigate the area of Bok choy.

Water logging at different times		30min	1hr	12hr	24hr
Irrigation area of bok choy (ha)	early period	1.125	3.75	18.75	30
	peak period	0.6	2.00	10.00	16.00
	late period	0.45	1.5	7.5	12

Table 4-3-1 shows the initial, peak, late species were 1ha paddy field can take care of 80ha, 42.67ha, 32ha vegetable fields. Particularly in the irrigated bok choy (late), the extreme demand for water.1ha 32ha of paddy field can only take care of the early vegetable fields about 2 / 5 Scale.Design considerations must be noted.

For example:

Situational one: A rotational irrigation area is 50ha. Design 1ha of the water logging paddy field in the early bok choy water demand is small, only the day before in the water and standing water is completed after 24hr.We intercept the upper water, and then can fully watered (about 80ha) of bok choy field.

Situational two:

A rotational irrigation area is 50ha. We need to design 1.1718ha (about 1.2ha) of the water logging paddy field (0.1ha farm area can take care of 4.267ha bok choy field).In peak time, bok choy water demand is large. Only one day before the irrigation water has been completed and put it aside after 24hr.We intercept the upper water, and then can fully watered (about 50ha) of bok choy field.

Situational three:

A rotational irrigation area is 50ha. We need to design 1.5625ha (about 1.6ha) of the water logging paddy field (0.1ha farm area can take care of 3.2ha bok choy field.)In late time, bok choy water demand is large. Only one day before the irrigation water has been completed and put it aside after 24hr.We intercept the upper water, and then can fully watered (about 50ha) of bok choy field.

Yunlin County farmland / fallow area ratio, we know that (fallow area) accounted for 52% of Yunlin County, so the estimate in (50ha area) in the area of fallow fields area of 26ha, 24ha for the farmland area.According to the above estimated results. We can according to different rotational irrigation region to design different types of paddy field area.

Situational four:

A rotational irrigation area is 50ha. We need to design 0.75ha (about 0.8ha) of the water logging paddy field (0.1ha farm area can take care of 3.2ha bok choy field.)In peak time, bok choy water demand is large. Only one day before the irrigation water has been completed and put it aside after 24hr.We intercept the upper water, and then can fully watered (about 24ha) of bok choy field.

4.4 Estimate the cost of electricity savings

The farmers each year (original using a pump groundwater pumping) electricity costs and maintenance of water pumps a total cost of $ 8760NTD in Yunlin County. We can immediately help farmers save money each year $ 6320NT. As shown in Table 4-4-1.

This study used a pump horsepower: 1HP (power 750W), the water Diameter: 4 ", Voltage: 110V/220V.60HZ, the highest lift: 9m, pumping capacity of 60 tons per hour, with a total weight of 20 kg.

Table 4-4-1 irrigated 50ha (bok choy field), water pumps 1HP, 1hr 64 tons can be pumped

estimate the cost of water logging paddy field		original using a pump groundwater pumping cost	
project	cost(NTD)	project	cost(NTD)
pump horsepower 1HP-2" 0104 model	$3500	Dug wells with water pumps	$150,000
Each share (water pumps) maintenance costs (service life 5 years)	$1000	Each share (water pumps) maintenance costs (service life 5 years)	$3000
Cost of electricity per year (about $ 4NTD to 1 day)	$1440	Cost of electricity per year (about $ 16NTD to 1 day)	$5760
Total annual payments (excluding water pumps)	$2440	Total annual payments (excluding water pumps)	$8760

5.Conclusions and suggestions

1. Reached maximum at 24hr after the effective depth of precipitation quantities 16.1cm.Upper layer of water volume is about 600c.c..4hr after the effective depth of 15.7 cm. There are 6.2% suspended matter in slightly turbid water. We can suitable for irrigation of plants, so consider using the upper slightly dirty water about 650c.c.

2. The sand content of Zhoushui River conduit to the by CHI-CHOU Brigde station data (2000 ~ 2009 year) of experience formula to estimate：
the sand content =3.865* $(\text{Flow})^{0.824}$.

3. Design 1ha of the water logging paddy field in the early bok choy water demand is small, only one day before set water logging paddy field measure and standing water is completed after 24hr. We intercept the upper water, and then can fully watered (about 80ha) of bok choy field.In peak time, bok choy water demand is large. We need

to design about 1.2ha of the water logging paddy field (0.1ha farm area can take care of 4.267ha bok choy field). We intercept the upper water and then can fully watered (about 50ha) of bok choy field.In late time, bok choy water demand is large too.We need to design 1.5625ha (about 1.6ha) of the water logging paddy field (0.1ha farm area can take care of 3.2ha bok choy field).

4. The farmers original total cost of $ 8760NTD per year per water pump unit in Yunlin County.We can immediately help farmers save money each year $ 6320NT.

5. Planning for the current study to an irrigation area 50ha vegetable area.Continued research can consider the proposed multi-regional distribution of irrigation water, irrigation water distribution pipeline optimization time.Future researchers can explore the use of multi-objective planning approach.Will make the study (water logging paddy field concept) can be widely applied to various types of vegetable area.

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Using Geographical Information System to Evaluate Evapotranspiration Models Accuracies in Belize

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Abstract

Accurate reference Evapotranspiration ($ET_{o)}$ estimation can be computed through the use of the well known FAO Penman-Monteith (FPM) method which is globally accepted. However; one of the major drawbacks to the FPM method is its relatively high data demand. This research evaluates the use of three evapotranspiration models including Blaney-Criddle; Hargreaves and Thornthwaite and their performances are compared against the standard FPM model in Geographical Information System (GIS) interface. The study employed the data from Belize, where the full set of the meteorological data are always lacking. For this study, the data have been collected in Belize from six districts i.e. Corozal, Orange Walk, Cayo, Belize, Stann Creek and Toledo. The results show that the temperature-based models have a slight under estimation which increase, as its proximity to the coast becomes closer. The Thornthwaite model grossly overestimated the ET_o at all sites within the study area. All this empirical models are not recommended for determining the crop water requirement in the country.

Keywords: Evapotranspiration, Geographical Information System, Metereological Stations

Introduction

As the global population increases so has its demand for more resources, one such natural resource is water. The sector which is known to extract the most water from the global reservoir is the agricultural sector, irrigated agriculture in particular. Prasad et al., (2006) stated that water shortage has become worldwide problem for which the only solution is to make efficient use of water in agriculture. Without the judicious use of water resource the goal of sustainable food production to meet future demands will not be accomplished (Smith 2000; Xu and Singh 2005; Wang 2005 and Tesfaye and Walker 2004). Therefore a better understanding of water requirement and better management of irrigation water will result in higher crop productivity. To attain this it needs to be acknowledged that evapotranspiration is one of the basic elements of the hydrological cycle, a key factor for water balance and for estimating irrigation water requirement (Chattopadhyay et al., 2009). According to Wang et al., (2009b) the direct measurement of reference evapotranspiration ET_o for the calculation of crop water requirement is difficult, time consuming and expensive therefore the most common procedure is the estimate ET_o from climatic variables. The most globally accepted and recommended is the FAO Penman-Monteith (FPM) method which is a standard ET_o method, with which the evapotranspiration of a hypothetical reference vegetated field is unambiguously determined (Allen et al., 1998) and is said to be able to provide consistent ET_o values in many regions and climates (Cai et al., 2007). A major drawback to apply the FPM method is its relatively high data demand. The method requires, apart from site location, air temperature, wind speed, relative humidity and shortwave radiation data (Gong, 2006). The number of meteorological stations where all of these parameters are observed is limited in many areas of the globe. The number of stations where reliable data for these parameters exist is even smaller, especially in developing countries (Droogers and Allen, 2002). Therefore this study explored the use of three other models which could be used such circumstances of poor data availability. In combination with GIS mapping be able to answer the question often posed to an irrigation planner which is when and how much to irrigate (George et al., 2000). Through this study as well be able to determine most suitable areas to conduct plant production.

Materials and Methods

Study Area

Belize is a country which belongs to both the Caribbean and Central America. Its capital bears latitude and longitude of 16 º 13´and 88 º 48´. The total area of Belize is 22,966 square kilometers. Belize is divided into four main geographical regions the low lying Maya Mountains in the south, the Northern lowlands, the flat swampy coastal plains and numerous islands of its Coastline. More than 50% of Belize is covered by a tropical rainforest and its most important river stretches from the Guatemala border to the west of the country and empties out in the Caribbean Sea. Belize's highest point is the Victoria Peak which reaches a height of 1,160 m and its lowest point is the Caribbean Sea 0 m. The country itself is divided into six districts Corozal and Orange Walk which are in the Northern part of the country. The Cayo district in the western part, the Belize District in the east and the Stann Creek and Toledo District are in the South.

Belize has a sub- tropical climate with two seasons the wet which typically runs from June to December and the dry season from January to May. The temperature in Belize range from 10˚C to 35˚C with an average annual temperature of 26˚C. November through January are traditionally the cooler months with an average temperature of about 24˚C. The period from May to September are considered the months with an average temperature of 27˚C. The temperature in the western part of the country is determined by location. The temperature in the Cayo District can be several degrees colder than that of the coast. Belize annual rainfall ranges from 1524 mm in the North to 4064 mm in the South. The main features which produce a lot of rain are tropical waves, tropical storms and hurricanes, which move in a westward motion through the Caribbean during the months of June to November. These tropical waves are categorized as being active or inactive systems with the peak of the activity occurring during the months of June and July. Tropical Storms and hurricanes peak during the month of September and October.

Data Source and Characterization

The data for this section of the report which pertain to climatic conditions (minimum, maximum, average temperature, evaporation, and relative humidity) of this study area have been collected from six meteorological stations located in each of the respective districts **Table 1.** The results from the above mentioned data have been graphically portrayed in **Figures 2** thru **7**. The lowest temperature of 16.9˚C was recorded at the Libertad station in the month of January whilst the highest temperature of 34.5˚C was recorded at the Central Farm station in the month of May as they can be seen in **Figure 2** and **Figure 3**.

Figure 1. Weather Stations within the Country of Belize

Observing the relative humidity data from the six stations, the relative humidity recorded at the Central Farm station was constantly higher than those recorded at the other stations. There was however two months out of the year where its average relative humidity was surpassed as seen in **Figure 5**. Where in the month of June the Libertad station recorded an 83.4% high and in September where the Towerhill station recorded a high of 86.2%.

Table 1. Weather station geographical coordinates in the study areas

District	Station	Latitude	Longitude	Record Length	Altitude (m)
Corozal	Libertad	18.3	-88.5	1991-2005	12
Orange Walk	Towerhill	18.0	-88.6	1992-2005	13
Cayo	Central Farm	17.2	-89.0	1966-2005	90
Belize	PGIA	17.5	-88.3	1960-2005	5
Stann Creek	Pomona	17.0	-88.4	1966-2005	40
Toledo	Big Falls	16.3	-88.8	1985-2005	20

The evaporation reading collected through the pan evaporation method showed the higher readings in **Figure 7** which coincided with the seasonal high temperatures of **Figure 3**. The peak value of 6.9 mm/day evaporation was recorded at the Towerhill station in the the dry season as presented in **Figure 7**. The lowest reading of all six stations was 2.3 mm/day in the month of December at the Pomona Station.

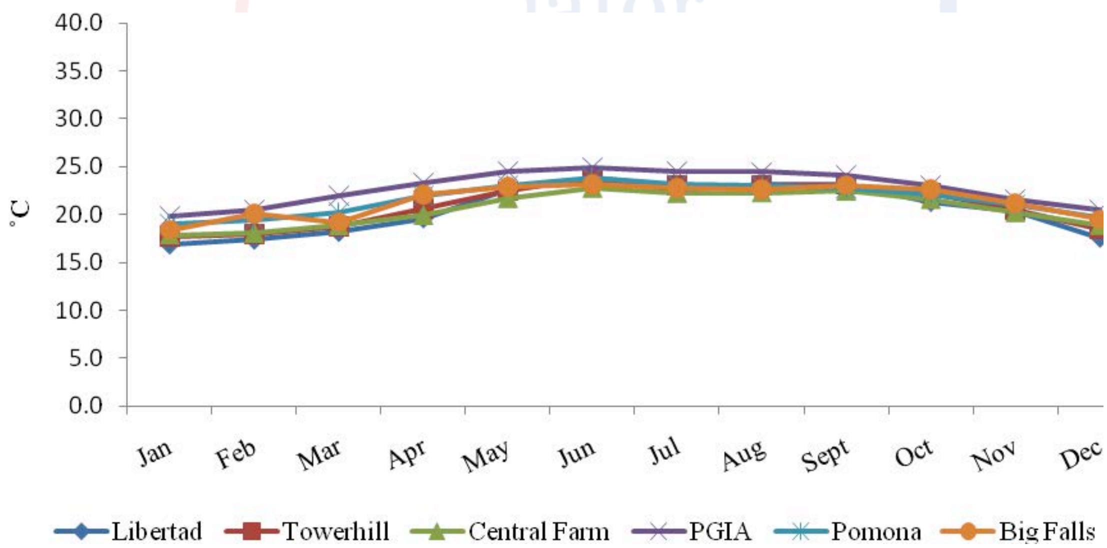

Figure 2. Monthly Minimum Temperature of Study Area

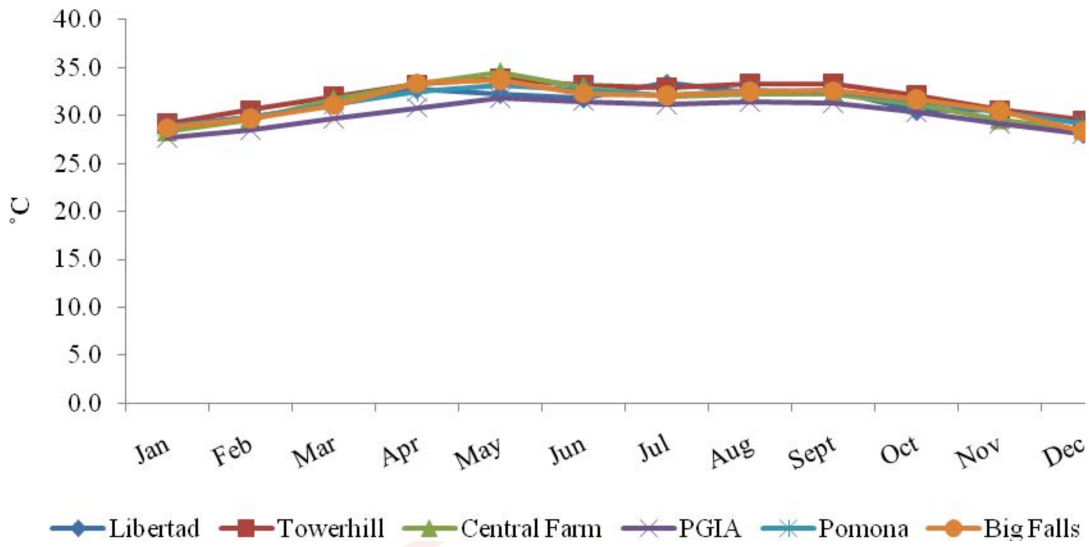

Figure 3. Monthly Maximum Temperature of Study Area

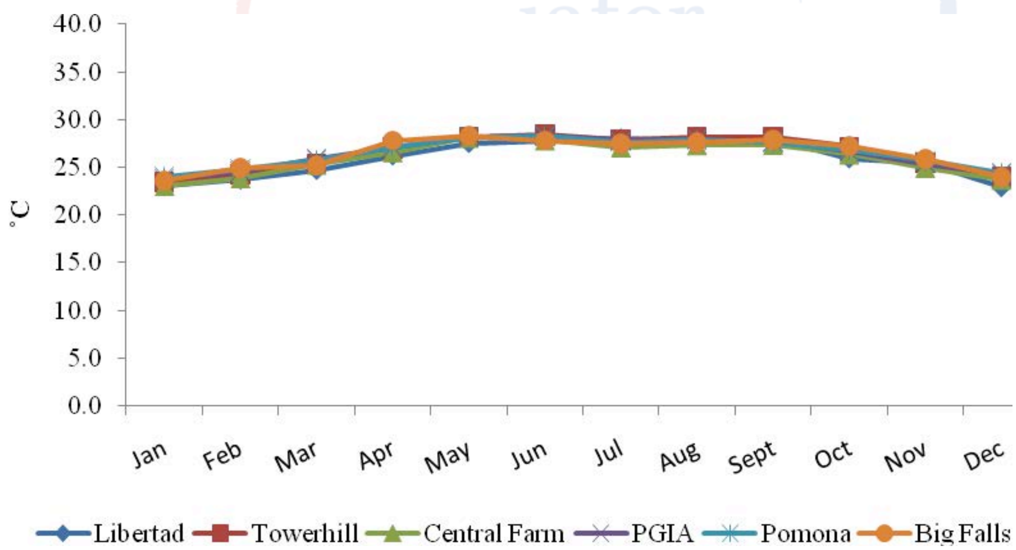

Figure 4. Monthly Average Temperature of Study Area

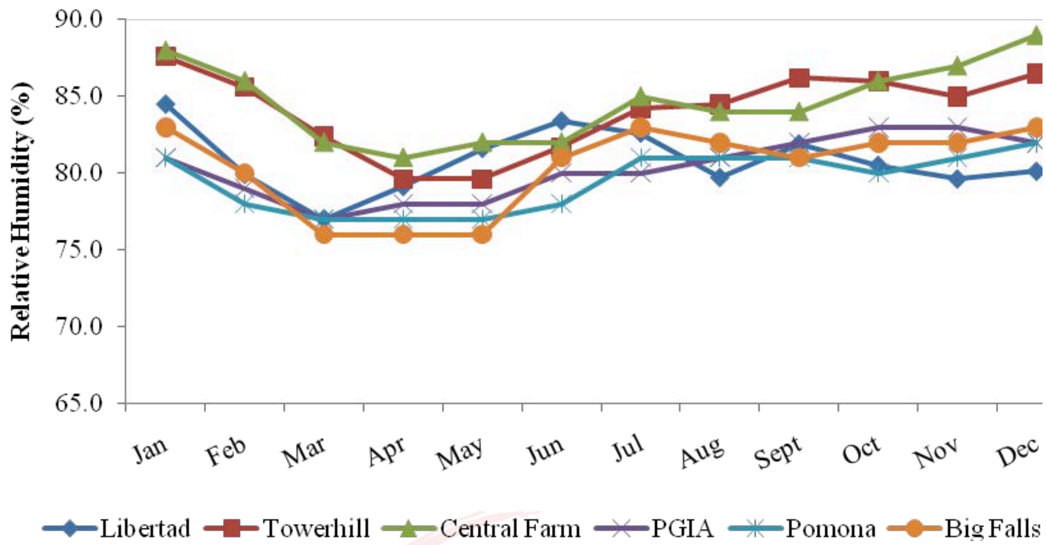

Figure 5. Monthly Relative Humidity of Study Area

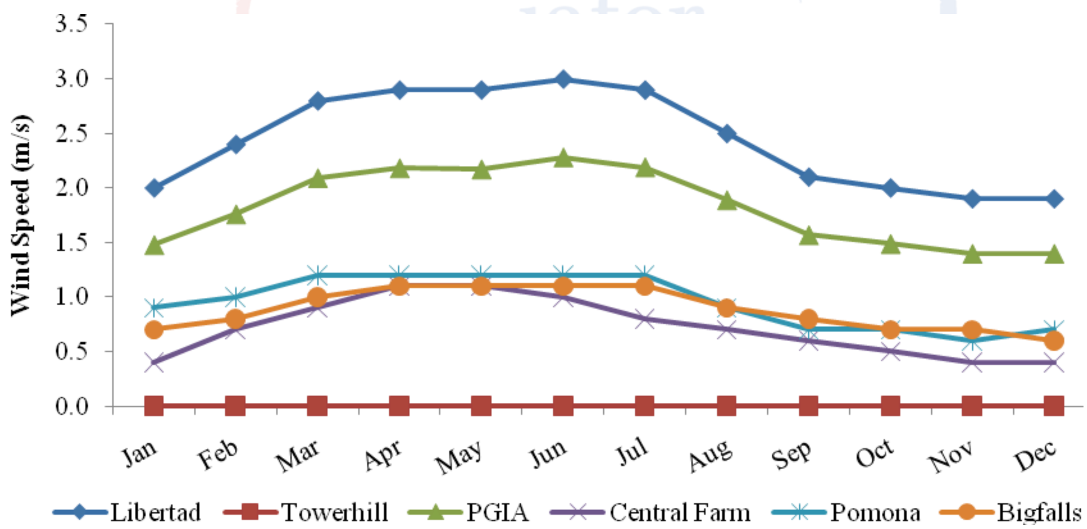

Figure 6. Monthly Wind Speed of Study Area

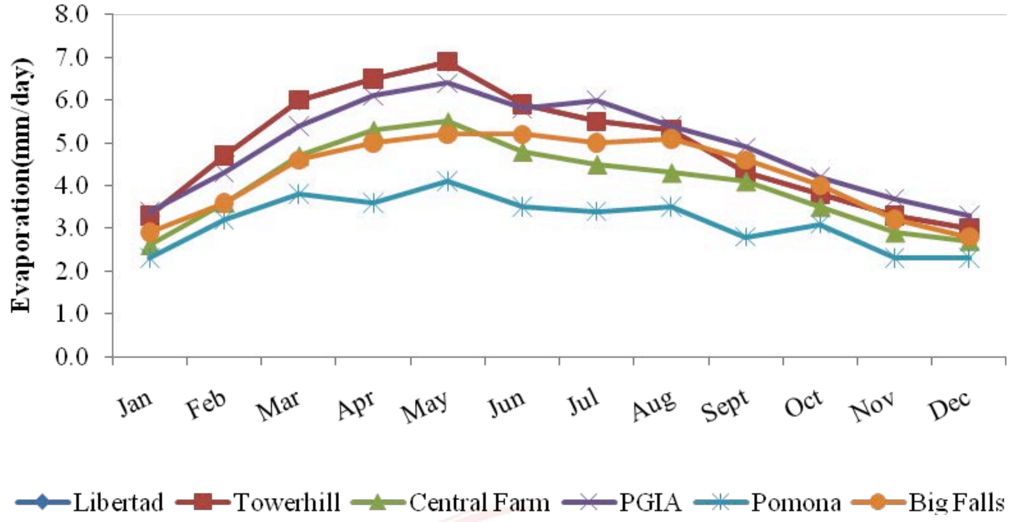

Figure 7. Monthly Evaporation of Study Areas

Estimation of Reference Evapotranspiration

Penman-Monteith (FPM) equation was given by Allen et al., (1998) as following:

$$ET_o = \frac{0.408\Delta(R_n + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{1}$$

where ETo is the reference evapotranspiration [mm day^{-1}]; R_n is the net radiation at the crop surface [MJ m^{-2} day^{-1}]; G is the soil heat flux density [MJ m^{-2} day^{-1}]; T is the mean daily air temperature at 2 m height [°C]; u_2 is the wind speed at 2 m height [m s^{-1}]; e_s is the saturation vapour pressure [kPa]; e_a is the actual vapour pressure [kPa]; e_s - e_a is the saturation vapour pressure deficit [kPa]; Δ is the slope vapour pressure curve [kPa $°C^{-1}$]; and γ is the psychrometric constant [kPa $°C^{-1}$].

The -Hargreaves (HRG) method was developed by Hargreaves and Samani in 1985. The model is a temperature based model and requires only mean, maximum and minimum air temperature and extraterrestrial radiation. This equation can be written as:

$$ET_o = 0.0023 \times RA \times ((T_{max} - T_{min}))^{0.5} \times (T_{mean} + 17.8) \tag{2}$$

where ETo is the reference evapotranspiration given in mm day^{-1}; RA is the extraterrestrial radiation; T_{mean} is the mean temperature; T_{min} is the minimum temperature and T_{max} is the maximum temperature.

Blaney-Criddle (BCR) method was developed by Blaney & Criddle in 1962. This model was developed for arid western portion of the United States and has demonstrated accuracy in estimating ETo under these conditions. The Blaney-Criddle equation given by Doorenbos & Pruitt, (1977) and can be expressed as follows:

$$ET_o = p \times (0.46 \times T_{mean} + 8.13) \quad (3)$$

where p refers to the mean daily percentage of annual daytime temperature for respective latitudes.

Thornthwaite (THT) formula is used to calculate the evapotranspiration (ETo) on a monthly basis. The approach is based mainly on temperature, even though a latitude adjustment factor based on day length is also included in the equation. The formula is given as follows:

$$ET_o = 16d\left(\frac{10T_{mean}}{I}\right)^a \quad (4)$$

$$I = \sum_{i=1}^{12}\left(\frac{t_i}{5}\right)^{1.514} \quad (5)$$

$$a = (6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.792 \times 10^{-2})I + 0.49239 \quad (6)$$

where T_{mean} stands for the mean temperature for the month (in °C), *I* stands for the annual thermal index which is the sum of monthly indices *.d* stands for a correction factor which depends on latitude and month.

Model Performance Evaluation

Several statistical measures are used for the comparison between the ETo values calculated by the Hargreaves, Blaney and Criddle and Thornthwaite equations and those obtained by the FPM. For each location, the statistical criteria of root mean square error (RMSE), percentage error of estimate (PE) and coefficient of determination (R^2) were calculated for the models performances evaluation. The RMSE, PE and R^2 are defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \quad (7)$$

$$PE = \left|\frac{\bar{P} - \bar{O}}{\bar{O}}\right| \times 100\% \quad (8)$$

$$R^2 = \frac{\left[\sum_{i=0}^{n}(P_i - \bar{P})(O_i - \bar{O})\right]^2}{\sum_{i=0}^{n}(P_i - \bar{P})^2 \sum_{i=0}^{n}(O_i - \bar{O})^2} \quad (9)$$

where n is the number of observations, and O_i and P_i are, the *i*th observed (calculated with the FPM method) and predicted data (using data calculated with HRG, BCR and THT method); $\bar{P}$ and $\bar{O}$ are the averages of P_i and O_i..

Results and Discussion

Model Comparison

The statistical analysis for each station between the estimated ETo by FPM and HRG, BCR and THT equations are presented in Table 2 and depicted in Figure 8. Not only were the variations between stations apparent but the models utilized at these stations as well. The Thornthwaite equation showed a grave overestimation of PE at all stations. This is due to the model incapacity to catch up the effect of some critical variable which can significantly affect the ETo in the area. The model which showed the lowest results, observing the percentage error of estimates was the Hargreaves equation. Where the PE were the lowest of the three models at all station with the exception of the Central Farm station where the ETo was underestimated by 0.75% in comparison to a 5.46% overestimation by the Hargreaves equation Table 2 The RMSE values coincided with the PE values which establish highest overestimation of the three models compared was that of the Thornthwaite model with the highest overestimation being recorded at the Big Falls Station. RMSE values ranged from 0.135 to 9.898 mm day-1. Results indicate that the minimum RMSE was obtained at the Big Falls station and the maximum RMSE was also obtained from the Big Falls station but from the Thornthwaite model. Further comparison of ETo values using FPM and HRG, BCR, THT models showed the coefficient of determination (R2) ranged from 0.494 to 0.986. The highest value being found at the Central Farm station (Hargreaves Equation) and the lowest value at the Libertad station (Thornthwaite Equation). The results are in agreement with the study done by Allen et al., (1998) where he recommended that when sufficient data to solve the FPM equation is not available, which is the case at many of the weather stations in Belize. The Hargreaves equation can be use in replacement of the FPM equation. However this equation has a general tendency to overestimate ETo at locations that are more humid (Kashyap and Panda, 2001). The results from this study is inconsistent with findings from Xu and Singh (2002) which agreed with the statement by Kashyap and Panda (2001) that the HGR method tend to overestimate ETo in humid climates

Spatial Distribution Comparison of ETo Models

Geographical Information System (GIS) is designed for the collection, storage and analysis of objects and phenomenon where geographic location is an important characteristic or critical to the analysis (Aronoff, 1989 and Chang, 2010). Fayer et al., (1996) stated that the use of GIS can help identify all possible combinations of soil, weather, land and water use. In this study GIS was used to map the spatial distribution of ETo throughout the country of Belize using results derived from four different reference evapotranspiration estimation models. Results of which can be seen in Figure 8. The maps generated offered a visual communication of the spatial distribution of the estimated reference evapotranspiration models.

.**Table 2**: Performance Evaluation of Reference Evapotranspiration Estimation Models

Station	Model	(PE)%	RMSE (mm/day^{-1})	R^2
Libertad	Thornthwaite	+173.913	8.967	0.494
	Blaney-Criddle	-10.090	0.622	0.766
	Hargreaves	-4.520	0.342	0.883
Towerhill	Thornthwaite	+167.943	9.336	0.585
	Blaney-Criddle	-14.190	0.949	0.942
	Hargreaves	-9.090	0.647	0.934
PGIA	Thornthwaite	+180.067	9.491	0.563
	Blaney-Criddle	-30.820	1.601	0.702
	Hargreaves	-22.280	1.173	0.713
Central Farm	Thornthwaite	+196.987	9.180	0.655
	Blaney-Criddle	-0.750	0.191	0.955
	Hargreaves	+5.460	0.263	0.986
Pomona	Thornthwaite	+205.829	9.875	0.633
	Blaney-Criddle	-9.470	0.493	0.920
	Hargreaves	-2.190	0.191	0.941
Big Falls	Thornthwaite	+209.057	9.898	0.618
	Blaney-Criddle	-6.650	0.361	0.954
	Hargreaves	+0.740	0.135	0.969

(+) Shows overestimation and (-) underestimation with respect to the measured value

Although the results from the above table revealed the use of the Hargreaves model as suitable replacement for the FPM method, there are regions of Belize where both the Hargreaves Model and the Blaney and Criddle Model performed poorly. This is in comparison to the FPM method, the areas of which can be seen in Figure 8 (b) and (c). Where a lighter color according to the legend signified a lower estimated reference evapotranspiration value. Figures 2 thru 7 showed that there were no significant trend amongst the meteorological variables at the stations where a lower ETo was calculated. However with these stations proximity to the coast it could have been assumed that these sites had a relatively high wind speed which according to Sabziparvar and Tibari (2010) and Wang et al., (2009a) noted that wind speed is one of the meteorological variables which can cause either an increase or decrease in the ETo. In Figure 6 in could be seen that the wind speed variable was not sufficient to ascertain that it was the reason for a lower ETo estimation. The PGIA and the Pomona weather station did however have another variable in common, which when coupled with the average wind speed could give a reasonable explanation to why there was an underestimation. This was the similarity of topography shared by theses stations which according Essery (2001) mentioned that topography can have a strong influence on the windflow near the surface. In this study it was observed there were regions where these temperature-based models had underestimated ETo. The same region in which estimated ETo based on the recommended model same region had its highest reading of ETo **Figure 8 (a)**. A phenomenon that might have been overlooked by water resource managers, without graphical representation to make a comparison between these four reference evapotranspiration estimation models.

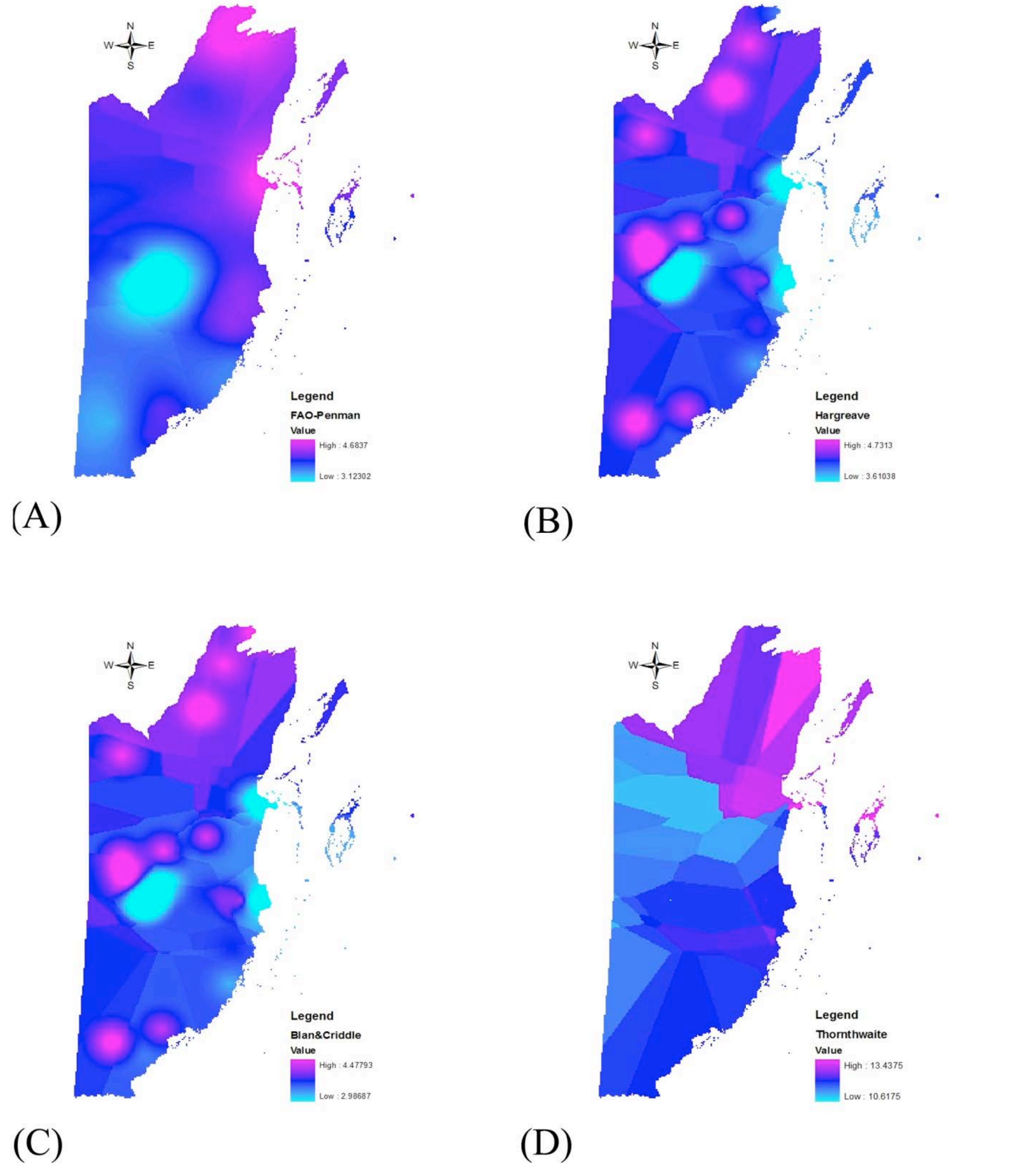

Figure 8: Comparison of ETo spatial distribution in Belize as calculated by four references evapotranspiration estimation equations: (A) FPM 56, (B), Hargreaves (C) Blaney and Criddle (D) and Thornthwaite

Conclusions

With the growing demand from different sectors for water, numerous countries are experiencing shortages and water for agriculture especially irrigated agriculture is facing the same dilemma. To try and meet the basic food production requirements strategies are being developed to optimize the crop production per unit of water applied. Therefore water use for crop production is highly dependent on the climatic parameters and their interaction with models which assist in the estimation of crop water requirement. This study provided a graphical comparison of ET_o calculated from Penman, Blaney-Criddle, Hargreaves and Thornthwaite model. Which when combined with a precipitation distribution map would aid in the strategic planning of agricultural production in the country of Belize. A practice done in various developing nations but to the knowledge of the authors is not being conducted in Belize.

Acknowledgements

The authors wish to express their gratitude to Mr. Ramon Frutos former Chief Meteorological Officer at the Belize Weather Bureau and Mr. Ricardo Thompson from the Ministry of Agriculture and Fisheries in Belize for providing some of the data for this study. We gratefully acknowledge the International Cooperation and Development Fund (ICDF) - Taiwan for the financial support provided during this study. Finally, the effort from the reviewers for this manuscript is also highly appreciated.

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Trends of Biofuels Derived from Renewable Biomass as Sustainable Energy and Environmental Solution

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Category: Energy--Renewable Energy and Environmental Solution

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Abstract:

There is an increasing awareness that climate change is caused by anthropogenic emission of greenhouse gases that mainly originate from the use of fossil fuels. Global energy policies are being developed that discriminate fossil fuels and/or promote the use of renewable biomass driven biofuels. Biofuels include bioethanol, biodiesel, biogas, bio-synthetic gas (bio-syngas), bio-oil, bio-char, Fischer-Tropsch liquids, and biohydrogen. Among these bioethanol, biodiesel, biogas, bio-syngas and pyrolysis oil (bio-oil) are predominant which can be produced using bio-chemical, physico-chemical and thermo-chemical conversion processes from biomass. This paper reviews the global status and progress of technology development for harnessing the biofuels for the sustainable energy and environmental solution. Biomass pyrolysis and gasification for production of bio-oil and bio-syngas are not yet mature enough to be widely applied in the market. These two technologies are still in a stage of variation and there has been no dominant design yet. In most markets these are unable to compete with other biofuel technologies.

1. Introduction

A reliable, affordable and clean energy supply is of major importance for society, economy and the environment – and will prove to be crucial in the 21st century. In this context modern use of biomass (as opposed to traditional use) is considered very promising. The promise includes a widely available, renewable and CO_2-neutral resource, suited for modern applications for power generation, fuels and chemicals. Biomass has a distinct advantage over the use of other renewables, like solar cells and wind power, which are restricted because of the intermittent power generation. Biomass is by far the most applied renewable at this moment and a further increase is believed to be possible [1].

Biofuels are the fuels that are derived from biomass-recently living organisms or their metabolic byproducts, such as manure from cows. Biomass is a renewable energy source, unlike other natural resources such as petroleum, coal, and nuclear fuels. Like coal and petroleum, biomass is a form of stored solar energy. The production of biofuels to replace oil and natural gas is in active development, focusing on the use of cheap organic matter (usually cellulose, agricultural and sewage waste) in the efficient production of liquid and gas biofuels which yield high net energy gain. The carbon in biofuels was recently extracted from atmospheric carbon dioxide by growing plants, so burning it does not result in a net increase of carbon dioxide in the Earth's atmosphere. Therefore, many people believe that a way to reduce the amount of carbon dioxide released into the atmosphere is to use biofuels to replace non-renewable sources of energy. Another advantage of biofuels over most other fuel types is that it is biodegradable, and so relatively harmless to the environment if spilled.

Although political instability and slowing production are raising concerns over the future of oil, demand for oil is predicted to increase by 22 percent between 2003 and 2015, largely due to growth in the transportation sector [2]. Producing biofuels as an alternative to petroleum fuels reduces a country's dependence on foreign oil while also creating domestic jobs and stimulating the rural economy. In addition, biofuels generate less smog-producing carbon monoxide (currently responsible for 800,000 premature deaths each year) and result in fewer greenhouse gas (GHG) emissions than oil. In this report an overview has been drawn from the recent international literature on the trends of production and utilization of biofuels.

2. Biomass and their conversion processes to biofuels

Typical biomasses and their features are listed in Table 1. You can find that the sites where generate biomass is widely spread all over the world: agricultural field, our home, factories and the nature. Different materials have different properties, and then different technologies which are suitable for their conversion into biofuels.

Table 1. Typical biomasses and their features

Typical biomasses	Generation	Moisture	Components	Conversion technologies	Products
Sugarcane, corn	First	Wet	Sugar, starch	Fermentation	Bio-ethanol
Palm, coconut	First	Wet	Fat	Ester exchange	Bio-diesel
Landfill gas	–	(Gas)	CH_4, CO_2	–	Electricity
MSW*	–	Wet	Various	Incineration etc.	Electricity, heat
Wood	Second	Dry	Lignocellulose	Thermochemical	Various
Husks, straws	Second	Dry	Lignocellulose	Thermochemical	Various
Sewage sludge	–	Wet	Protein etc.	Torrefaction	Solid fuel
Animal manure	–	Wet	Various	Compost, digestion	Fertiliser, methane
Miscanthus, Switchgrass	Second	Dry	Lignocellulose	Thermochemical	Various

* Municipal Solid Wastes

The energy available in biomass may be used either by direct use as in combustion, or by initial upgrading into more valuable and useful fuels such as charcoal, liquid fuels, producer gas or biogas. Thus, biomass conversion technologies can be separated into three basic categories:

(i) Physico-chemical (the route to biodiesel).
(ii) Bio-chemical processes (anaerobic digestion and fermentation) and
(iii) Thermo-chemical conversion processes (incineration, pyrolysis and gasification)

The basic energy conversion pathways for biomass into biofuels are presented in Fig. 1. In general, wet biomass is suitable for biochemical conversion. Dry biomass is often converted by thermochemical conversion technologies.

3. Trends of common biofuels in the civil society

The common biofuels that have been proving their sustainability as alternatives to petroleum fuels are: bioethanol, biodiesel, biogas, bio-syngas and pyrolysis oils. The use of one particular type of biofuel cannot fulfill the current global energy demands and it is necessary to use a combination of all available biofuels.

3.1. Bioethanol

Bioethanol (ethyl alcohol, grain alcohol, CH_3–CH_2–OH or ETOH) is a liquid biofuel which can be produced from several different biomass feedstocks and conversion technologies. Bioethanol is an attractive alternative fuel because it is a renewable bio-based resource and it is an oxygenated fuel that contains 35% oxygen, which reduces particulate and NO_x emissions from combustion [3]. The density of bioethanol is 790 kg/m^3. Octane number, auto-ignition temperature, latent heat of vaporization and lower heating value for typical ethanol are 107, 606

K, 0.91 MJ/kg and 26.7 MJ/kg, respectively. The corresponding values for isooctane are 100, 530 K, 0.26 MJ/kg and 44.4 MJ/kg, respectively. Ethanol has a higher octane number, broader flammability limits, higher flame speeds and higher heats of

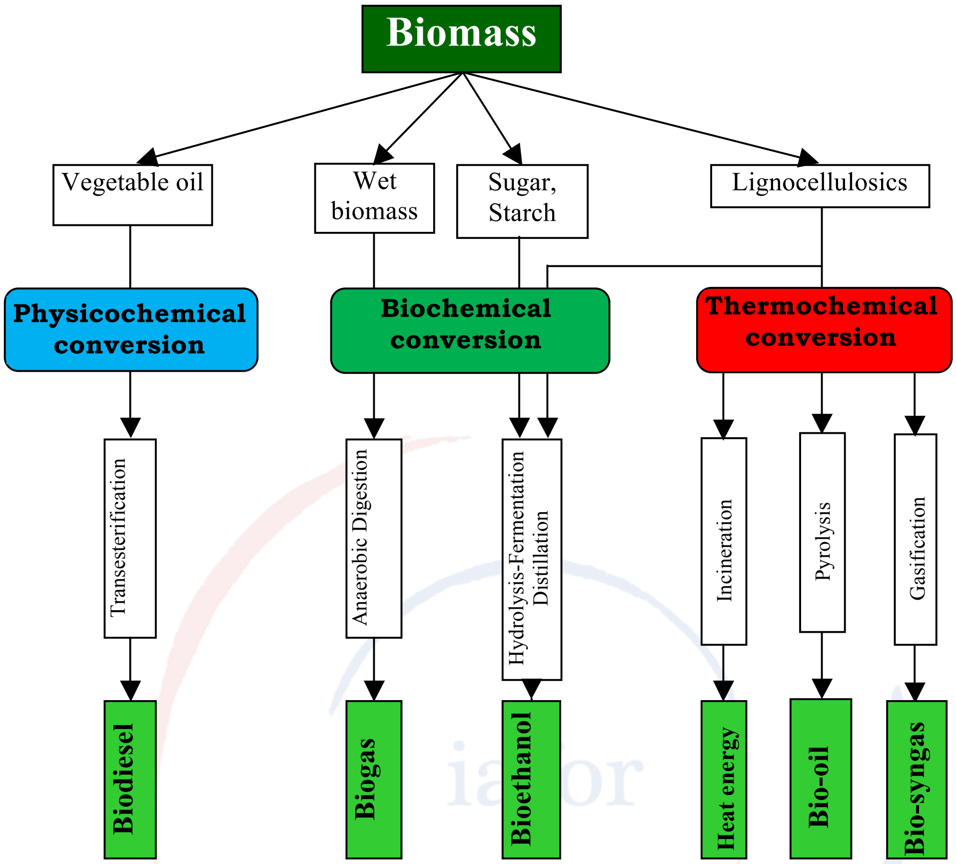

Fig. 1: Biomass conversion processes into biofuels

vaporization. These properties allow for a higher compression ratio and shorter burn time, which lead to theoretical efficiency advantages over gasoline in an internal combustion engine (ICE) [4]. Octane number is a measure of the gasoline quality and can be used for prevention of early ignition which leads to cylinder knocks. Higher octane numbers are preferred in internal combustion engines. An oxygenate fuel such as bioethanol provides a reasonable antiknock value. Also, as it contains oxygen, fuel combustion is more efficient, reducing hydrocarbons and particulates in exhaust gases. Complete combustion of a fuel requires in existence the amount of stochiometric oxygen. However, the amount of stochiometric oxygen generally is not enough for complete combustion. Oxygen content of a fuel increases its combustion efficiency. Because of this the combustion efficiency and octane number of bioethanol are higher than those of gasoline [5].

The presence of oxygen in bioethanol improves combustion and therefore reduces hydrocarbon, carbon monoxide, and particulate emissions; but oxygenated fuels also tend to increase nitrogen oxide emissions. Bioethanol is appropriate for the mixed fuel in the gasoline engine because of its high octane number, and its low cetane number (8) and high heat of vaporization impede self-ignition in the diesel engine. So, ignition improver, glow-plug, surface ignition, and pilot injection are applied to promote self-ignition by using diesel–bioethanol blended fuel [6]. The most popular blend for light-duty vehicles is known as E85, and contains 85% bioethanol and 15% gasoline. In Brazil, bioethanol for fuel is derived from sugar cane and is used pure or blended with gasoline in a mixture called gasohol (24% bioethanol, 76%

gasoline). In several states of the United States, a small amount of bioethanol (10% by volume) is added to gasoline, known as gasohol or E10. Blends having higher concentrations of bioethanol in gasoline are also used, e.g. in flexible-fuel vehicles that can operate on blends of up to 85% bioethanol-E85 [7]. Some countries have exercised biofuel program involving both form bioethanol-gasoline blend program, e.g. the United States (E10 and for Flexible Fuel Vehicle (FFV) E85), Canada (E10 and for FFV E85), Sweden (E5 and for FFV E85), India (E5), Australia (E10), Thailand (E10), China (E10), Columbia (E10), Peru (E10), Paraguay (E7), and Brazil (E20, E25 and FFV any blend) [8].

The history of ethanol as a fuel dates back to the early days of the automobile era. However, cheap petrol (gasoline) quickly replaced ethanol as the fuel of choice, and it was during the late 1970s, when the Brazilian government launched their ‘‘Proalcool’’ Programme, that ethanol made a comeback to the market place. Bioethanol is derived from biological feedstock that contains appreciable amounts of sugar or materials that can be converted into sugar by fermentation to produce alcohol. The world ethanol production in 2009 was 73.95 billion liters and the major producers of ethanol are Brazil and the USA, which account for about 88% of world production [9, 10]. The main feedstocks for ethanol production are sugar cane in Brazil and India; and corn grain in the USA; corn and wheat grains in China; sugar beet, wheat and sorghum in EU. While, ethanol can be produced from any sugar or starch crop. Another potential resource for ethanol is lignocellulosic biomass, which includes materials such as agricultural residues (e.g., corn stover, crop straw, and sugar cane bagasse), herbaceous crops (e.g., alfalfa, switchgrass), forestry wastes, wastepaper, and other wastes. However, the efficient utilization of lignocellulosic biomass for fuel ethanol is still under development. Global production scenario of bioethanol is presented in Fig. 2.

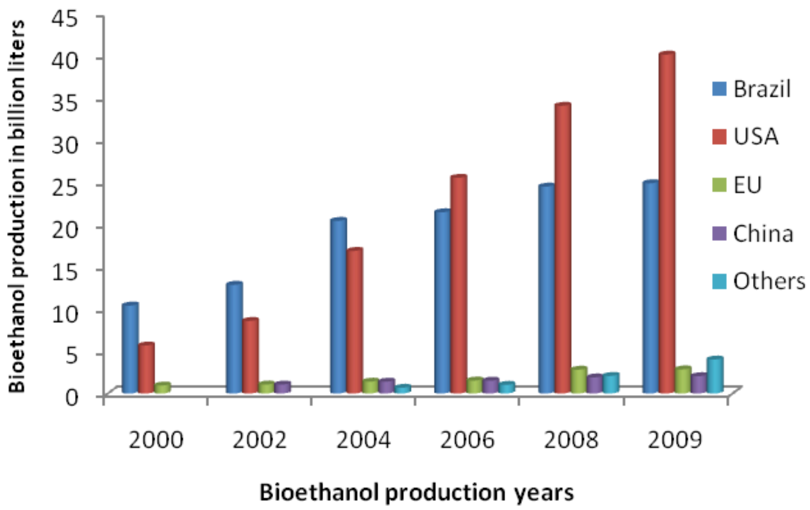

Fig. 2. Global bioethanol production scenario [9, 11].

3.2. Biodiesel

Biodiesel is a nearly colorless liquid made from the transesterification of vegetable oils and animal fats and has properties similar to petroleum-based diesel. The density and lower heating value of biodiesel and petroleum diesel are 888 kg/m^3 and 37.20 MJ/kg; and 840 Kg/m^3 and 42.8 MJ/kg, respectively. In particular, it has a relatively high cetane number and about 90% of the energy content of petroleum diesel, making it an attractive direct substitute or blend component. The current (in 2009) global production of biodiesel is approximately 18 billion liters and this figure is likely to increase due to the implementation of 10:90 blends of biofuels and conventional diesel fuel in many countries [9].

Europe is currently the leading producer of biodiesel, which is processed from vegetable oils that are derived from soy beans, oil palm, and rapeseed, among other crops. The automotive industry is transforming as well. Biodiesel has been produced on an industrial scale in the European Union since 1992. The production has grown significantly over the past 10 years. There has been an average increase of 35% per annum between 1992 and 2009 [9]. Today, there are approximately 120 plants in the EU producing more than 10 billion liters of biodiesel annually. These plants are mainly located in Germany, Italy, Austria, France and Sweden. More than 30% of the biodiesel in the EU is today produced in Germany. The production of biodiesel in Asian countries (Thailand, China, Korea, India, Malaysia, Philippines, Indonesia, etc.) in 2009 is estimated at about 2 billion liters.

Biodiesel feedstock markets worldwide are in a transition from increasingly expensive first generation feedstocks, such as soy, rapeseed, and palm oil to alternative, lower cost, non-food feedstocks. Biodiesel production from non-food feedstocks is gaining attraction around the world. For example, China recently set aside an area the size of England to produce jatropha and other non-food plants for biodiesel. India has up to 60 million hectares of nonarable land available to produce jatropha and intends to replace 20% of diesel fuels with jatropha-based biodiesel. Also in South America and Africa, there are significant programs underway dedicated to producing non-food crops such as jatropha and castor oil for biodiesel [12].

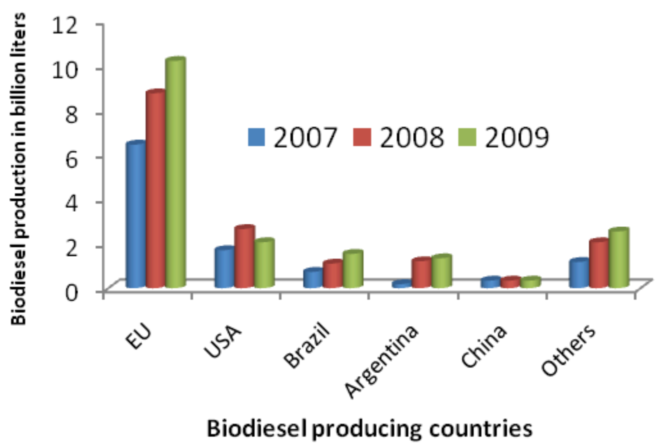

Fig. 3: Global biodiesel production scenario [9]

The suitability of fats and plant oils for diesel use is due to their molecular structure and high energy content. However, fats or plant oils as such are not suitable for high-speed diesel engines (light- and heavy-duty vehicles), and further processing is required. The traditional transesterification process with methanol, using sodium or potassium hydroxide as a catalyst, results in traditional biodiesel, FAME and glycerol as a co-product. Another option is to use a hydrotreatment process (e.g. the NExBTL process) for the production of high-quality paraffinic biodiesel.

3.3. Biogas

Biogas typically refers to a gas produced by the anaerobic digestion or fermentation of organic matter including manure, sewage sludge, municipal solid waste, biodegradable waste or any other biodegradable feedstock, under anaerobic conditions. Biogas is comprised primarily of methane and carbon dioxide. Typical composition of biogas: Methane (CH_4) 50–75%, Carbon dioxide (CO_2) 25–50%, Nitrogen (N_2) 0-10%, Hydrogen (H_2) 0-1%, Hydrogen sulfide (H_2S) 0-3% and Oxygen (O_2) 0-2%. As a fuel, only the methane proportion is usable. Whereas, natural gas comprise of Methane 96%, Ethane 2% and Carbon dioxide 0.3%. The density and heating value of biogas and natural gas are 1.15 kg/Nm^3 and 24.50-27.60 MJ/Nm^3; and 0.73 Kg/Nm^3 and 35.80-39.90 MJ/Nm^3, respectively. Depending on where it is produced, biogas is also called: Swamp gas, Marsh gas, Landfill gas and Digester gas. Biogas can be used as a vehicle fuel or for generating electricity. It can also be burned directly for cooking, heating, lighting, process heat and absorption refrigeration.

Biogas is an attractive source of energy primarily because it is renewable and enables the recycling of organic waste and has other advantages too. Biogas can also play a role in the distribution, storage and the veterinary aspects of manure. It can reduce fertilizer use, and can contribute to the reduction of the greenhouse gas methane. Biomethanation is a serious option, not only in the production of energy in an environmentally friendly manner but also the clean-up of solid wastes in urban areas [13]. Biogas does not contribute to increasing atmospheric carbon dioxide concentrations because the gas is not released directly into the atmosphere and the carbon dioxide comes from an organic source with a short carbon cycle.

Compared with bioethanol from wheat and biodiesel from rape seed, biogas production based on energy crops could generate about twice the net energy yield per hectare per year and biogas production could be used for improving the resource efficiency of current production methods for bioethanol and biodiesel, using the byproducts generated by these methods [14].

EU is the world leading producer of biogas. Biogas constitutes a sizeable and renewable form of energy, with EU production of 5347 KTOE in 2006. This is more than double the capacity produced in 2001 (2572 KTOE). Biogas production scenario in the EU is presented in Fig. 4. Currently biogas technology is used in rural areas of developing countries where plenty of agricultural and animal waste is available [16]. In the EU biogas is mainly used for electricity generation whereas in developing countries it is usually used for cooking of the rural peoples.

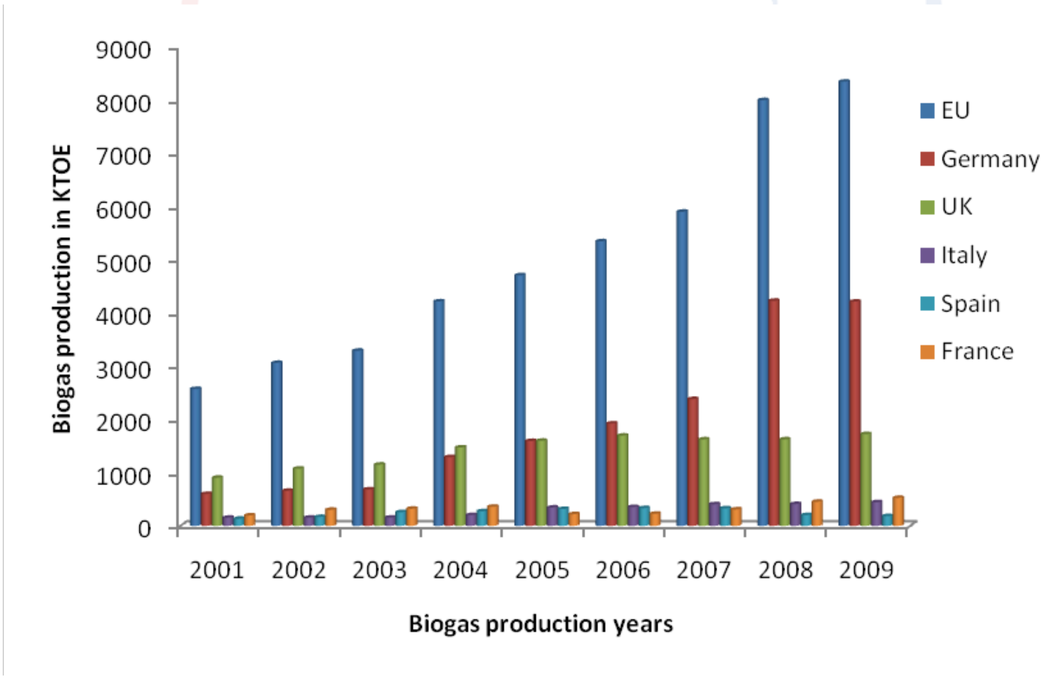

Fig. 4: Biogas production scenario in EU [15]

Biogas technology is based on the biochemical phenomenon of methane-generating bacteria operating in the absence of air on organic matter containing cellulose in a water solution. The anaerobic biological conversion of organic matter occurs in three steps:

(i) The first step involves the enzyme-mediated transformation of insoluble organic material and higher molecular mass compounds such as lipids, polysaccharides, proteins, fats, nucleic acids, into soluble organic materials (i.e., into compounds suitable for the use as sources of energy and cell carbon such as monosaccharide, amino acids and other simple organic compounds). This step is called hydrolysis and is carried out by strict anaerobes such as *Bactericides*, *Clostridia* and facultative bacteria such as *Streptococci*, etc.

(ii) In the second step, acidogenesis, another group of microorganisms ferments the break down products to acetic acid, hydrogen, carbon dioxide and other lower weight simple volatile organic acids like propionic acid and butyric acid which are in turn converted to acetic acid.

(iii) In the third step, these acetic acids, hydrogen and carbon dioxide are converted into a mixture of methane and carbon dioxide by the methanogenic bacteria (acetate utilizers like *Methanosarcina* spp. and *Methanothrix* spp. and hydrogen and formate utilizing species like *Methanobacterium*, Methanococcus, etc.).

3.4. Bio-syngas

Bio-syngas or producer gas is produced by gasification of biomass and its wastes. Gasification is the result of a high temperature reaction (>700 °C), where carbon reacts with steam or a limited amount of air or oxygen producing carbon monoxide (CO), molecular hydrogen (H_2), and carbon dioxide (CO_2). Gasification is a thermochemical conversion technology of solid and liquid fuels into gaseous fuels. The first commercial gasification plant was installed in 1839. Gasification was widely used for heat, power and automotive applications until oil and natural gas industry replaced the main stream of energy sources gradually in 1920-1950 [17]. After the oil crisis in 1970's, biomass gasification technology has attracted much attention from many researchers and companies across the globe. The basic of the main gasification technologies are:

(i) Fixed bed technology: a fixed bed of feedstock is being gasified using a gasification medium, generally air at low velocity. Main subtypes are downdraft and updraft gasifiers, which are mainly applied at smaller scales.

(ii) Fluid bed technology: a small fraction of feedstock is added to a much larger fraction of bed material, which is fluidized by a gasification medium (air, oxygen, steam) that flows through the bed at a high enough speed. Main subtypes are the bubbling and the circulating fluidized bed, which are mainly applied for biomass at medium scales.

(iii) Entrained flow gasification: small droplets or particles of feedstock are 'entrained' in a flow of gasifying medium-in general oxygen or steam. It has been mainly applied at larger scales for coal and petroleum based feedstock.

Canada, Finland, Sweden and the USA have been initially involved in the development of biomass gasification. Each of them has large woody biomass and/or peat resources. In the 1970s especially the USA fulfilled a leading role in response to the disruption of oil supply and high oil prices. This involved research and rapid development of gasification concepts. The potential to substitute natural gas or transportation fuels was viewed as being very important. However, initial applications were less advanced and focused on heat and power applications. Energy research in the 1980s shifted focus to long-term high risk research. Most financial incentives that were needed to stimulate the commercial use of biomass energy were eliminated – and so were many projects and plants [18–20].

Circulating fluid bed (CFB) gasifiers have been first applied in the early 80s by Lurgi (Germany) and Ahlstrom (Finland, now Foster Wheeler). According to Basu [21] both were based on their respective CFB combustion designs that were developed separate from the large government funded programs. Lurgi used its experience in ore roasting fluidized beds. Ahlstrom, a Finish engineering company and established producer of pulp and paper products, became interested in the technology as a method of burning a wide range of 'difficult' fuels for this sector – including biomass and bark [22].

The 1990s brought increased awareness of climate change, which resulted in a renewed interest in biomass gasification [18, 23-24]. While some developments in the USA continued, European countries became increasingly involved. Germany and Austria have joint Sweden and

Finland as leading countries, while many others became involved in development and implementation, including Netherlands, Italy, UK, Switzerland and Denmark [25–27]. Especially in countries with strong support for renewable and with availability of biomass, the development of biomass gasification has become an established practice [17]. By 2005, the status of the technology was such, that there was significant interest for gasification but hardly any new commercially projects were implemented.

An overview of accumulated operational capacity of biomass gasifiers for different applications is provided in Fig. 5, based on Hellsmark [28]. All applications of biomass gasification show an increase over time. This increase is most significant for CHP, which has become the main application.

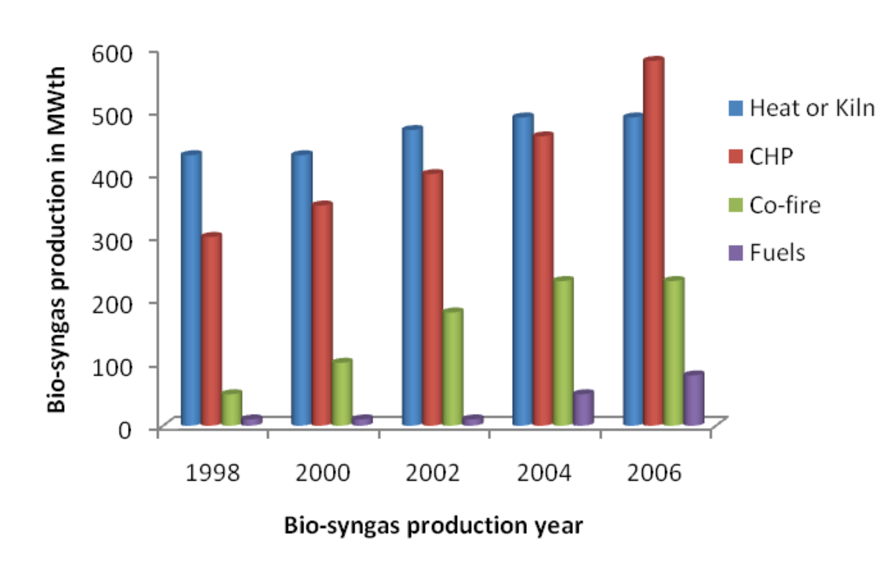

Fig. 5: Main application of bio-syngas in EU

A selection of leading companies (most applied or advanced) for developed countries is presented in Tables 2 and 3.

3.5. Pyrolysis oils (Bio-oils) and gases

Pyrolysis is also a new and emerging technology that is able to produce energy from biomass and its wastes without burning them directly. This technology is considered to generate renewable energy and is widely perceived to be more publicly acceptable. In the pyrolysis process the biomass and its wastes are heated at a temperature of around 500^{o}C in absence of oxygen/air to produce oil, char and gas. The pyrolytic liquid and gas can be used as boiler fuels for power generation and also for cooking, heating, lighting, process heat etc.

Like gasification technologies the basic pyrolysis technologies are also categorized as the following three groups:

(i) Fixed bed technology: a fixed bed of feedstock is being pyrolysed using an inert atmosphere, generally nitrogen/helium gas at low velocity. Fixed bed technology is mainly applied at smaller scales.

(ii) Fluid bed technology: a small fraction of feedstock is added to a much larger fraction of bed material, which is fluidized by an inert gas medium that flows through the bed at a high enough speed. Main subtypes are the bubbling and the circulating fluidized bed, which are mainly applied for biomass at medium scales.

(iii) Entrained flow pyrolysis: small particles of feedstock are ‘entrained’ in a flow of an inert gas medium. It has been mainly applied at larger scales.

Table 2: Leading small scale (updraft and downdraft) manufacturers and technologies in developed countries [29].

	Technology/company	Country	Gasifier
1	Bioneer (now Foster Wheeler)	Finland	Updraft, heat
2	PRM Energy Systems Inc. (PRME)	USA	Updraft, heat/power
3	Babcock Wilcox Volund	Denmark	Updraft, heat and power
4	REL Waterwide technology	New Zealand	Downdraft, heat
5	Chiptec Wood Energy Systems	USA	Downdraft, heat
6	Fluidyne Gasification	New Zealand	Downdraft, power
7	Xylowatt	Belgium	Downdraft, power
8	AHT Pyrogas Vertriebs	Germany	Double zone, heat and power
9	COWI/DTU 'Viking' gasifier	Denmark	Multi stage, electricity
10	Biomass Engineering	UK	Downdraft
11	ITI Energy	UK	Fixed bed, proprietary design
12	Puhdas Energia Oy	Finland	Downdraft
13	Host	Netherlands	Fixed bed
14	Condens Oy – Novel gasifier	Finland	Fixed bed, counter current bottom

Researchers have learned much about the science and engineering of pyrolysis of biomass especially in the last twenty-five years. This knowledge base has contributed to rapid advances in process hardware design improvements in addition to a broad understanding of the physical and chemical properties of the resulting bio-oil product during the same time period. Even with these advances, significant technical and economic challenges remain to be addressed before fast pyrolysis technology gains commercial acceptance. The following section will summarize the current state-of-the-technology, where it needs to go, and suggested paths to get it there.

Power production from biomass derived pyrolysis liquids has been under development for the past few years. If technically successful, it would make decentralized bio-energy production possible. Several technologies and system components have been developed by academia, R&D organizations, and industrial companies in many countries. Power plant technologies addressed are diesel engines, gas turbines, and natural gas/steam power plants. The analysis shows that even for the most promising solutions long-term demonstration has not yet been achieved.

Biomass pyrolysis liquids differ significantly from petroleum-based fuels in both physical properties and chemical composition. The density, viscosity, flash point, pour point, LHV, pH of the biomass derived pyrolysis oils are 1.1-1.3 kg/dm^3, 15-35 cSt, 40-110 ^oC, -10 to -35, 13-18 MJ/kg, 2-3, respectively. The corresponding values for light fuel oils are 0.89 kg/dm^3, 3.0-7.5 cSt, 60 ^oC, -15, 40.3 MJ/kg, neutral, respectively. Light fuel oil consists mainly of saturated olefinic and aromatic hydrocarbons (C_9–C_{25}) that are immiscible with highly polar pyrolysis liquids [30-31]. Pyrolysis liquids are acidic, unstable, viscous liquids containing solids and a large amount of chemically dissolved water. Heating value, density, and viscosity of pyrolysis liquids vary with water and additives.

Table 3: Leading gasification concepts for large scale or advanced cycles [17].

	Company	country	Gasifier
1	Gas Technology Institute (GTI) - Renugas technology (Institute of Gas Technology (IGT))	USA	BFB, air/oxygen blown, pressurized
2	Repotec Umwelttechnik/Austrian Energy and Environment (Gu¨ ssing CHP plant)	Australia	BFB, indirectly heated, steam blown (CFB air combustor)
3	Enerkem Technologies Inc. - BIOSYN technology	Canada	BFB, air/oxygen blown, pressurized
4	ThermoChem (Manufacturing and Technology Conversion International (MTCI))	USA	BFB, pulse enhanced, indirectly heated, steam blown, atmospheric (also) black liquor gasification

5	Envirotherm GmbH, part of Allied Environmental Solutions Inc. (Lurgi technology, BGL at Schwarze Pu¨mpe)	Germany/USA	- BGL fixed bed, slagging bottom, ressurized; - CFB, atmospheric
6	Rentech Inc. - Rentech-Silvagas technology (Battelle Columbus Lab/Future Energy Resource Corporation (FERCO))	USA	CFB, indirectly heated, steam/air blown, atmospheric/low pressure
7	TPS Termiska Processor AB (ex Studsvik Energiteknik AB)	Sweden	CFB, air blown, atmospheric
8	Foster Wheeler (ex Ahlstro¨m)	USA/ Finland	CFB, air blown, atmospheric/pressurized
9	Ebara - Twin Rec UEP Gasification technology	Japan	CFB, gas to slagging combustor, air blown, waste
10	Choren Industries GmbH - Carbo V technology (Deutsche Brennstoff Institut)	Germany	Entrained, involving pre-gasification or pyrolysis, air/oxygen blown, sewage sludge
11	Chemrec A.B. (ex Kvaerner Pulp & Paper)	Sweden	Entrained, air/oxygen blown, black liquor
12	Thermoselect S.A.	Switser land	Pyrolyzer and entrained char gasifier, oxygen blown, waste
13	Siemens Fuel Gasification Technologies GmbH (Future Energy, BBP, NOEL-KRC, Deutsche Brennstof Institut)	Germany	Entrained, oxygen blown, pressurized
14	Energy Products of Idaho	USA	BFB

As regards the cetane number, a very important parameter which correlates the ignition properties of oil fuels when injected into a diesel engine combustion chamber, the predicted cetane numbers for pyrolysis liquids were evaluated as 13–14 by means of the ignition quality test (IQT) at CANMET, Canada. Typical cetane number values for diesel oil is 48.

Pyrolysis liquid quality may further be improved by alcohol addition. Addition of alcohol improves the homogeneity and storage stability [32–34] of the liquid and decreases its viscosity. Addition of alcohol is beneficial also in solids removal. It dilutes the liquid, reducing its stickiness thus enhancing the filterability of the liquid and minimizingthe organic losses in filtration/centrifugation. The decrease of flash point has to be carefully taken into account when adding ethanol.

Moderate scale fast pyrolysis plants have gained enough operating experience that reasonably good economic data is available to assess the economic viability of this emerging technology. No large scale plants have been built to date. This is primarily due to the lack of demand for the pyrolysis product. There have been modest size pilot plants built and operated at a number of locations worldwide. These have mostly been for demonstration purposes and are listed in the Table 4. The two plants at Red Arrow WI can be considered commercial operations but they are producing food flavoring compounds and there is a limited market for those products. Larger scale plants needed for producing fuels have yet to be developed from a commercial status.

Table 4. Worldwide current biomass pyrolysis operating plants

Reactor design	**Capacity (dry biomass feed)**	**Organization or company**
Fluidized bed	400 kg/hr (11 tons/day)	DynaMotive, Canada
	250 kg/hr (6.6 tons/day)	Wellman, UK
	20 kg/ hr (0.5 tons/day)	RTI, Canada
Circulating Fluidized Bed	1500 kg/hr (40 tons/day)	Red Arrow, WI; Ensyn design
	1700 kg/hr (45 tons/day)	Red Arrow, WI; Ensyn design
	20 kg/hr (0.5 tons/day)	VTT, Finland; Ensyn design
Rotating Cone	200 kg/hr (5.3 tons/day)	BTG, Netherlands
Vacuum	3500 kg/hr (93 tons/day)	Pyrovac, Canada
Other Types	350 kg/hr (9.3 tons/day)	Fortum, Finland

5. Discussion and conclusion

The potential appetite of the world's 800 million car owners is vast--it took 13 percent of the U.S. corn harvest in 2005 to displace less than three percent of fuel needs. As the fuel market increasingly competes with food and livestock feed markets over the same crops, the prices of food commodities--from bread to poultry to cooking oil--are expected to rise, which could have serious consequences for the over 800 million people worldwide facing persistent hunger. Confirming these fears, corn prices doubled last year, causing social unrest in Mexico where corn tortillas are a dietary staple (BBC News, 2007).

On the other hand, biofuel production can boost incomes in rural areas, where three-quarters of the world's poor reside, which may increase their ability to secure food supplies. The extent to which higher crop prices will hurt or help poor people in developing countries will likely vary from region to region. Deeper analysis is needed to understand the global and local impacts of expanded biofuels demand.

When crops grow, they absorb carbon dioxide from the atmosphere, thus negating any greenhouse gas emissions that result from burning biofuels. However, planting, fertilizing and harvesting the crop requires machinery that utilize fossil fuels, as do the fermentation, distillation and transportation processes. All together, the energy required to generate one gallon of corn-based ethanol is equal to about 60-75 percent of the energy produced As a result, GHG emissions are only reduced by 15-40 percent relative to oil on a per gallon basis [35]

More positively, biodiesel and sugar-based ethanol yield higher net energy gains than corn ethanol, decreasing GHG emissions by 45-75 percent and 40-90 percent respectively. However, decisions to increase biofuel use to levels that have measurable impacts on greenhouse gas concentrations must be carefully weighed against the environmental costs of production--agriculture is a leading driver of deforestation, soil erosion and water pollution.

Cellulosic ethanol is made from a wide variety of plant materials, including wood wastes, crop residues and grasses, some of which can be grown on marginal lands not suitable for food production. The process for converting these to fuel is often more efficient because plant material rather than fossil fuels can be used to provide heat and power. As a result, cellulosic ethanol has an energy yield at least four to six times the energy expended during production and can reduce greenhouse gas emissions by 65-110 percent relative to gasoline [35]. A 2005 study by the US Departments of Energy and Agriculture estimated that cellulosic ethanol could displace 30 percent of the nation's transportation fuel needs without impacting food harvests.

However, generating cellulosic ethanol remains technically complex and commercially unprofitable. Bringing the price down to competitive levels will require significant investment and, in some cases, additional research and development; it remains unclear how long this will take. Even then, some cellulosic feedstocks may cause environmental problems, depending on how they are grown, processed, transported and used.

The future of biofuels is uncertain, depending largely on the price of oil, government policies, and technological developments. The potential social and environmental risks associated with biofuels must be carefully weighed when deciding how much to produce and in what types of feedstocks to invest. One can be certain that ethanol and biodiesel cannot solve all of the economic and environmental problems associated with fossil fuels. Measures that reduce overall demand for energy, such as increasing the fuel economy of automobiles and expanding mass transit options in cities, will also be necessary.

Recently, Anex et al., [36] studied a techno-economic comparison of biomass-to-transportation fuels via pyrolysis, gasification, and biochemical pathways. These analyses employed similar assumptions to allow comparisons among the results. The feedstock was assumed to be corn stover and plant capacity was 2000 tonne/day for each plant. They found large differences in the total capital investments required among the three platforms. The standalone biomass-to-liquid fuel plants are expected to produce fuels with a product value in the range of $0.53–1.45 per liter gasoline equivalent, with pyrolysis the lowest and biochemical the highest.

It is useful to discuss which of the five biofuel technologies described here have the most potential for meeting the world's energy needs. The production of ethanol and biogas both suffer from product inhibition. In the case of ethanol by the end product itself and for biogas by volatile fatty acids that are generated as metabolic intermediates. Ethanol in concentrations above a certain threshold will drastically reduce the fermentative capacity of the organisms used. Storage of these fuels is costly due to its hygroscopic and corrosive nature. In the case of biogas, an enrichment of volatile fatty acids in the reactor might stop the process altogether. Whereas, in case of biodiesel these drawbacks are eliminated. The main issue associated with biodiesel is the formation of soap when acid or alkali catalysts are used but this can be solved by using an enzymatic catalyst.

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Desalination Powered By Entropy

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Abstract *We describe in this paper a novel water distiller. The water distiller utilizes a thermal gradient device which spontaneously generates and maintains a thermal gradient through a process similar to osmosis. A theoretical derivation of the process which we call an entrochemical process is presented. The device utilizes the thermal gradient to induce a flow of energy through the system. This flow of energy is used to induce the distillation of water. The device may be recharged using a low-temperature evaporation process. We describe the design of the device, which has a distillation process that has an efficiency of 12.6 ± 2.6 % in utilizing the energy which moves through the system.*

1 Introduction

The need for drinking water has grown considerably over the last century. Currently, 1.6 billion people have limited access to water, specifically in developing countries in Africa, South Asia, and the Middle-East [26]. The lack of potable water attributes to 80-90% of diagnosed diseases in a total of 88 developing countries [19]. If current global trends continue, 1.8 billion people will have little or no access to drinking water by the year 2025 [3].

In order to meet the water needs of people in both the immediate and distant future, it is important to improve both water usage and the methods of producing potable water from non-potable sources. Much of the water used in Western households (estimated in the United States to be 300-378 liters per day) leaves the home as grey water [21]. This water is of relatively mild contamination and can be reused. The reuse of this water would serve to significantly lower the overall demand for water, greatly extending the lifetimes of the supplies of water currently in use.

In addition to reusing water at the household level, much is gained from the conversion of water sources from non-potable water to potable water. This is typically done in desalination plants, in which saline water brought from the ocean is converted to two separate supplies of concentrated brine and relatively fresh water. Generally speaking, the main desalination methods in use today are thermal distillation technologies and membrane-based reverse osmosis technologies, though new competing technologies are on the drawing board or in early stages of industrial use[27]. Solar distillation methods utilizing low temperatures are one such example that is currently in development [17,5]. However, these technologies cannot yet economically compete with other conventional desalination technologies, without significant improvement [4].

What ties all technologies thus far developed together is that their power sources are positive in nature, in the sense that they utilize concentrated of energy sources (high pressure, high temperature, etc.) to enable the desalination process [13,8,7,23,6,9,18]. A simple corollary is that the process requires a constant input of energy, and some part of this energy generally makes its way into the environment as heat. Another way of characterizing such processes is that they are ones in which work is done on the water and the external environment.

The main limitation in the utilization of positively energetic technologies is that they require the input of significant quantities of energy in order to function [16]. In general, small scale devices require relatively large amounts of energy per unit of distilled water than larger scale devices [24,2,17,25,10,1,28,22]. It is currently economically unfeasible to use household-scale devices, as the cost of desalination or water reclamation is much higher than industrial scale devices [Jones 2003]. As a result, water reuse at the domestic scale is currently unlikely unless the reused water is simply diverted to other household uses (such as providing for toilets, groundskeeping or agriculture).

We are interested in developing systems that are energetically negative in nature. That is, we are interested in developing systems in which the external environment does work on the systems, enabling distillation. This paper examines a process that is entropically driven and generates distilled water as a result of entropically favorable events. We have constructed a device that spontaneously generates a thermal gradient through a thermodynamically favorable process. This thermal gradient is arranged so that part of the device is colder than the external environment [15]. Energy flowing into the device from the outside environment is carried by water in such a way that the distillation process occurs. The result is that external environmental energy spontaneously flows into the device, generating distilled water in the process.

The paper proceeds as follows. Section 2 describes the function of the device. Section 3 details the construction, experimental tests, and data obtained from the device. Section 4 is a discussion of these results. Section 5 concludes the paper.

2 Enabling Distillation via Thermal Gradients

Environmental water systems are designed to extract water from the environment. Such systems operate by generating a refrigeration effect, cooling one or more surfaces below the environmental dew point, and causing condensation of water vapor on these surfaces. Pumping air past the refrigerated surfaces is generally sufficient to provide enough vapor to generate a significant amount of water, though additional processing is generally required in order to make the water suitable for consumption. This use of refrigeration technology to generate water is the basis for a significant number of different commercial products.

In this section, we describe a method that ostensibly functions in a similar way. We utilize a process that generates a thermal gradient spontaneously. The device producing the thermal gradient is thermally coupled to the external environment in such a way that part of the device is warmer than the external environment, and part of the device is colder than the external environment. This coupling of the two regions produces an energy flow into the device at one point and out of the device at the other point. This flow of energy is then coupled to water flow, which yields distilled water. Application to distillation of other liquids such as ethanol can also be employed through the same process [33].

2.1 The generation of the entrochemical effect and equilibrium DT

The appendix provides a theoretical derivation of what we call the entrochemical effect. This effect refers to the spontaneous generation of a thermal gradient in the presence of a chemical potential difference between two reservoirs of a volatile liquid. In general, the idea behind the entrochemical effect is that putting two reservoirs containing the same volatile substance in vapor communication with one another "shares" thermal energy between the two reservoirs [11]. Energy sharing is mediated by movement of the volatile substance from one reservoir to the other. The difference between the temperatures of the two reservoirs is given by

$$\tau_2 = \tau_1 \frac{\left(\mu_2 - 2\frac{\partial U_1}{\partial N_1}\right)}{\left(\mu_1 - 2\frac{\partial U_1}{\partial N_1}\right)} \qquad (1)$$

where $T_1=k_Bt_1$ is the temperature of reservoir 1, $T_2=k_Bt_2$ is that of reservoir 2 (k_B is the Boltzmann constant), m_1 is the chemical potential of reservoir 1, m_2 is that of reservoir 2, and $¶U_1/¶N_1$ is the energy required to remove a single atom from the liquid in reservoir 1 in the absence of the chemical potential. As a result,

$$\Delta T = T_1 \left(\frac{\mu_2 - \mu_1}{\mu_1 - 2\frac{\partial U_1}{\partial N_1}} \right) \tag{2}$$

in equilibrium.

The immediate question arises as to how this chemical potential difference can be arrived at. The chemical potential must refer to that experienced by a physical process, i.e., the evaporation of fluid. A number of recent papers have reported that the vapor pressure of liquid can be affected by strong electrical fields. These tend to change the boiling point of the liquid, indicating that the chemical potential also has changed.

Our approach is similar in effect, but simpler in execution than the creation of electrical fields. It is also true that adding soluble salts to liquid changes the vapor pressure of the salts, and therefore, the chemical potential. As a result, we create a salinity gradient between the two sides. This leads to a movement of vapor[20]. In our case, the thermal isolation of the two sides allows the relatively larger transient flow of fluid, which generates the thermal gradient.

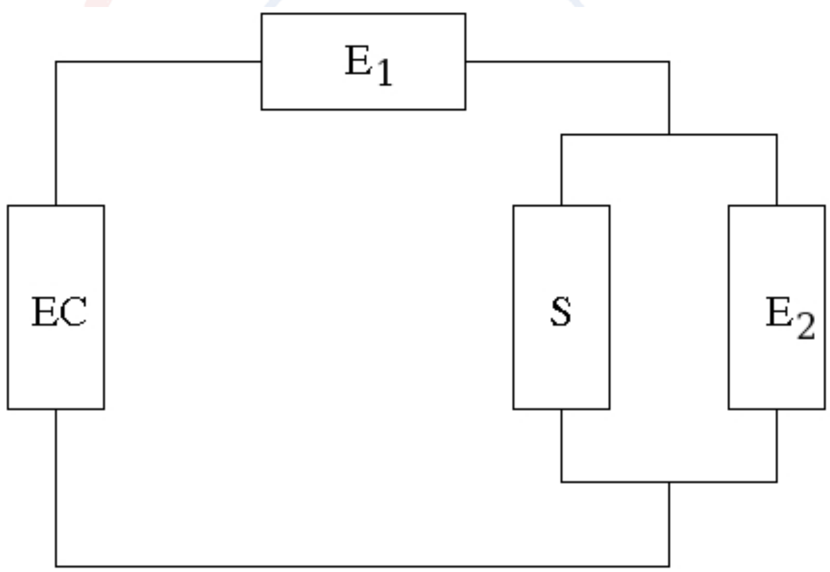

Figure 2.1: The conceptual “energy-circuit” diagram. Each of the components labelled with an “E” is an energy pathway while “S” is a thermal storage and “EC” is an entrochemical driving device.

The resulting system can be well modeled similarly to a nonlinear electrical circuit in which one energetic pathway charges a storage device (storing the thermal gradient), while a second pathway discharges it. The circuit is represented in Figure 2.1. The voltage across the storage represents the temperature difference between the two reservoirs while the two devices marked “E_1” and “E_2” represent the thermal conductivity pathways between the reservoirs. E_1(DT) represents the thermal “resistance” mediated by the vapor flow. Resistor E_2(DT) represents the thermal “resistance” mediated by the flow of heat back from the warmer reservoir to the colder through other means than vapor flow. Clearly, if E_1(DT)>>E_2(DT) then the two reservoirs retain the same temperature, with thermal discharge capacity exceeding thermal charging capability. On the other hand, if $E_1(DT) << E_2(DT)$ then the reservoirs will approach the maximal thermal difference. In general, the observed thermal difference will be

$$\Delta T_{obs} = T_1 \left(\frac{\mu_2 - \mu_1}{\mu_1 - 2\frac{\partial U_1}{\partial N_1}} \right) \left(\frac{R_2(\Delta T)}{R_1(\Delta T) + R_2(\Delta T)} \right). \quad (3)$$

As indicated in the Appendix, the generation of a chemical potential in one of the two reservoirs is a sufficient precondition for the generation of a thermal gradient between the two reservoirs. As a result, one reservoir must be warmer than the other. The precise size of this thermal difference is determined by Dm, which is the chemical potential differential between the two reservoirs. Dm is temperature and pressure dependent, and so the thermal gradient can be expected to vary with pressure and temperature as well.

2.2 Use in generating a distillation effect

The generation of a thermal gradient may be coupled with physical systems so as to generate useful work. As alluded to previously, environmental water systems which absorb water from the air by lowering the temperature of one or more surfaces below the dew point of the air function by absorbing thermal energy from the water vapor in the air, transitioning the vapor to a liquid state. We examine the design of such a system in this subsection.

In what follows, we assume that the warmer reservoir of our two reservoir system is coupled to an external reservoir by a heat sink or some other means. In this case, the temperature of the warmer reservoir will be that of the external reservoir, making the temperature of the cooler reservoir less than that of the external reservoir. The situation is diagramatically indicated in Figure 2.2.

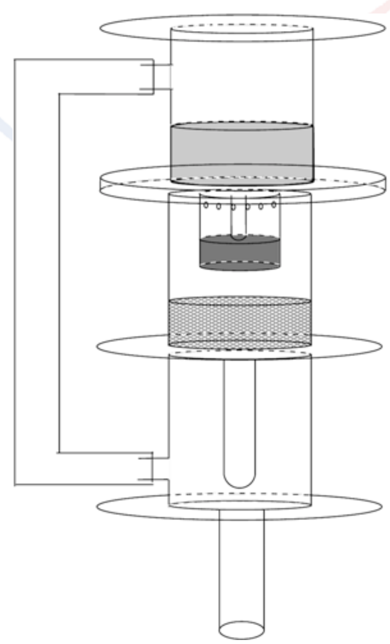

Figure 2.2: A diagrammatic illustration of an entrochemical distiller.

In the event that the cooler reservoir is in thermal contact with a second chamber filled with water vapor and water, itself in thermal communication with the external reservoir, then the cooler reservoir will absorb thermal energy from the water vapor, transforming it to liquid water. This generates a reduction in pressure in the chamber, inducing evaporation of the water, and subsequent cooling of water. Energy is then drawn in from the external reservoir, regenerating the temperature and pressure in the chamber. Meanwhile, the energy drawn into the cool reservoir causes evaporation of the fluid in that reservoir, transferring the thermal energy to the warmer reservoir and out into the external reservoir.

Such a process will continue as long as there is a concentration gradient in the thermal gradient device or until all of the liquid in the cool reservoir has evaporated. At the same time, the condensation of the liquid on the cool surface coupled to the cool reservoir may be collected as distilled water, entirely powered by this entrochemical effect.

It can be shown that each cycle of energy through the system reduces the amount of energy available for subsequent cycles by a factor of

$$\rho = 1 - \frac{\Delta H_{diss} S(T_h)}{H_v}$$

where DH_{diss} is the enthalpy of dissolution, $S(T_h)$ is the solubility of the salt or salt solution at the temperature of the warmer reservoir T_h, and H_v is the volumetric heat of vaporization of the liquid [30]. Various temperature-dependent graphs of these factors are presented in Figure 2.3.

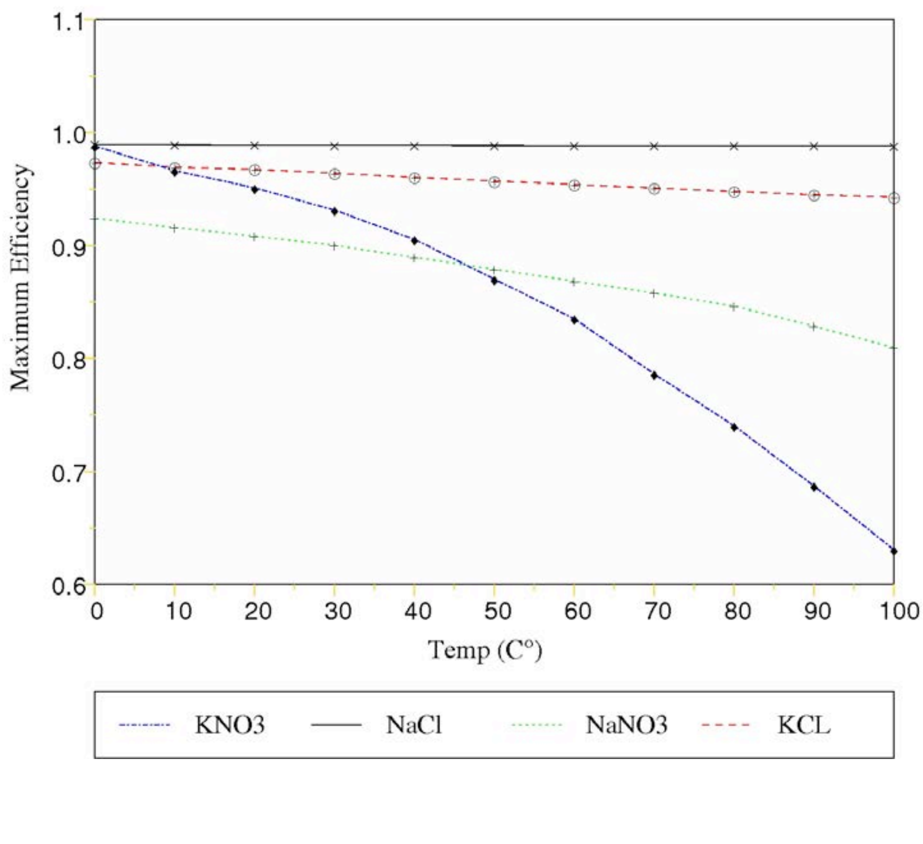

Figure 2.3: The maximum efficiency of a one stage system as a result of the endothermic nature of the salt distillation.

This factor naturally limits the amount of water one can distill, given the transfer of a volume of water in the entrochemical unit. Generally speaking, the device will produce a smaller amount of water than that which moves through the entrochemical system. However, despite this, the energy required to run the device can be absorbed naturally from the environment by evaporating the water in a number of passive evaporative devices, as opposed to insertion by power generation or capture using any conventional technique.

3 Experimental Procedure Procedures, and Results

We constructed a device to evaluate the distillation process using the entrochemical system. Our device consists of three sub-systems arranged in a vertical tower. The device is pictured in Figure 3.1.

Figure 3.1: The prototype entrochemical distiller.

System one comprises a sealed copper tube with a diameter of 2.3 inches and length of 4.1 inches. This copper tube has a brass nipple attached to the tube and a smaller vertical tube connected to one sealing face. The smaller vertical tube has a diameter of 0.64 inches and a length of 3.75 inches.

System two comprises two sealed acrylic, coaxial tubular chambers of different lengths. The first chamber has a diameter of 2.75 inches, a length of 3 inches; the second chamber has a diameter of 3.25 inches, a length of 4.33 inches. Acrylic flanges eight inches in diameter and 1/2 inch thick are fused to the other ends of both tubes. The first chamber is nested within the second chamber. The two flanges rest on one-another, sealing the lower chamber. Vertical, acrylic tubes are fused onto holes on the bottom of the first chamber. A 7/16 inch diameter and 9 inch long copper tube, closed at the bottom, is threaded into the bottom of the second chamber, forming a contiguous interior with the second chamber.

System three comprises a closed vertical acrylic tube 3 inches in diameter 10 inches in length.

This acrylic tube is directly fused onto the bottom of system two, and contains the copper tube. A closed PVC tube is attached to the bottom of this closed tube. A funnel underneath the copper tube allows liquid dripping from the copper tube to flow directly into the PVC tube. Two hose barbs are attached to the side of the closed vertical acrylic tube with one near the top and the other near the bottom.

When the system is assembled, system one sits atop system two, and seals the first chamber. System one is connected to system three via a vacuum hose connecting to hose barbs on each system. The second hose barb on system three is connected to a valve through which air may be drawn to generate an internal vacuum. System two is also designed to allow evacuation of the interior, which accelerates the entrochemical effect, allowing measurable temperature differences to be generated.

3.2 Experimental Procedure

The device was utilized at 20°C, with “activation” occurring when the vacuums were initiated in the device. The liquid utilized is water, with both system 1 and chamber 2 of system 2 being primed with distilled water. We utilized $NaNO_3$ for these runs. Initial vacuum priming entailed generating and maintaining a vacuum sufficient enough to generate a slow boil of the water within all chambers. The run time recorded began after the vacuum was sealed and pump turned off. Run times varied from three to forty-eight hours.

Each entrochemical device was primed with 80 g of distilled water in the second chamber, 30 g of saturated $NaNO_3$ solution in the first chamber, and an additional 52.5 grams of additional $NaNO_3$ salt in the first chamber.

During each run we recorded the volume of distilled water produced and the volume of water which moved from the distilled water pool in the entrochemical device to the highly saline water pool in the entrochemical device. From these, we determined the efficiency of the device as well as the power equivalence for the device.

The data collected indicated that the current device has an energy efficiency of 12.6 ± 2.6% when run in the current configuration with a power equivalence of 16.4 ± 6.0 mW. We calculate a maximum efficiency of 89.9% for this device owing to the endothermic nature of $NaNO_3$.

4 Discussion

This article describes the development of a device that utilizes a thermodynamically spontaneous process for the distillation of water, which may come from sea water. What makes this particularly intriguing is the fact that the process may be continually used without the need for any specialized equipment for refitting the materials in the entrochemical device. Rather, the unconcentrated water in the distiller may be put through an evaporative process at room temperature and at typical atmospheric conditions. The evaporation can happen in the day or night, eliminating the need for direct sunlight, and will have an enhanced effect in wind, even when the wind speed is quite low.

In essence, the evaporation of water, which is spontaneous at various environmental conditions of temperature and relative humidity, is like storing the thermal energy in the high concentration brine. By evaporating the water when environmental conditions are amenable, which can be both during the day and night, this system allows the generation of a spontaneous process by which distillation can be achieved without additional energy input. Thermodynamically, what is happening is that the entropy of the saline solution is decreasing during the evaporation, with a concomitant increase in overall entropy. The low entropy brine has the potential for energetic movement which can be coupled to useful industrial applications [31].

It is interesting to note that the process is also refreshed using the day/night cycle. During the day, water vapor content of the air increases as water evaporates from water sources during the day. During the night, however, falling temperatures produce dew, which collects on plants, rooftops, cars, etc. This cycle resets the system daily. As a result, the capacity for evaporation, which concentrates the brine and primes the entrochemical effect, increases daily.

This means that the process of entropic extraction is cyclical and therefore reliable as a potential source of motive energy for water distillation. Interestingly, the process does not store energy directly, but rather stores the potential to move energy from one part of a system to another. As a result, rather than requiring the input of energy to occur after which the energy goes out to the atmosphere, this process requires the absorption of atmospheric energy to prime the system [34]. This priming allows additonal environmental energy to be utilized to achieve the distillation process.

The process also yields an immediate use for the brine currently produced in desalination plants utilizing sea water and either thermal distillation or membrane desalination technologies [32, 29, 12]. Such a process might improve the yield of existing plants without the need for retrofitting or upgrades, providing brine of a lower concentration as a byproduct. Moreover, given the costs of brine disposal, the current process may provide an economical use of existing concentrated brine that partly mitigates the cost of the brine disposal.

5 Conclusion

The paper has analyzed the use of the entrochemical effect in the distillation of water. The entrochemical effect is one in which a thermal gradient evolves in the presence of a chemical potential gradient between two reservoirs of volatile material. This paper presents a theoretical model of how the entrochemical effect occurs.

Since the entrochemical effect is spontaneous, it is attractive as an effector of the distillation process. This paper describes an entrochemical distiller and examines the flow of ambient thermal energy through the system. The system may be characterized as a non-linear circuit model in which the flow of energy in the system when it is not in the entrochemical equilibrium state is the motive force driving heat through the system. Using this model, it is easy to see that the contribution of the energy flow through the vapor state can overwhelm the return flow, generating a measurable temperature difference. The "capacitor" represents the physical system which has a temperature difference induced in it. It is equally easy to discern how the temperature difference can be eliminated using very high thermal conductivity across the "capacitor".

The paper describes experimental use of the device in which an average energy efficiency of 12.6 ± 2.6 % with a power equivalence of 16.4 ± 6.0 mW. This very small system indicates that larger systems would be necessary in order to generate significant supplies of water from saline or contaminated supplies.

Future work will improve the efficiency by exploring different configurations of the device. These configurations include those with appropriate vacuum insulation and improvements in the areas of vapor generation and/or condensation. The performance of the device under the action of differing liquid/solute combinations will also be evaluated.

Appendix

In this appendix, we demonstrate that thermal gradients may be spontaneously generated in systems in particulate and thermal equilibrium. This is a consequence of the following theorem.

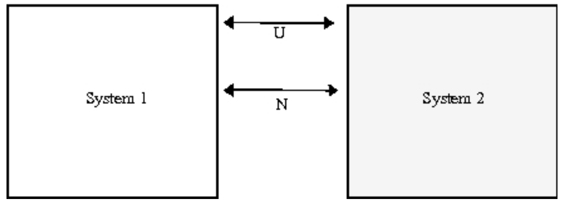

Figure A.1: This image describes the basic system. It consists of two subsystems in thermal and particulate contact.

We begin with a thermodynamic system composed of two smaller systems. We begin by proving the following theorem .

Given two systems in thermal equilibrium such that there is a free flow of energy and particles between them, the temperature of one system relative to the temperature of the second system is given by

$$\tau_2 = \tau_1 \frac{\left(2\frac{\partial U_1}{\partial N_1} - \mu_2\right)}{\left(2\frac{\partial U_1}{\partial N_1} - \mu_1\right)}$$

where m_i is the chemical potential of system i and

$$\frac{\partial U_i}{\partial N_1}$$

is the energetic cost of removing one particle from the reservoir.

The two smaller systems S_1 and S_2 are in contact with one another. We assume that the total system consists of these two systems and that there is no other outside coupling. Energy and particles can freely flow back and forth between the two systems. We assume that there is a total energy U in the system and that there are a total number of particles N. The multiplicity function g gives the degeneracy of the system with total energy U and total number of particles N. The multiplicity function of the combined system can be determined from those of the subsystems in the following manner.

$$g\left(U,N\right) = \sum_{N_1,U_1} g_1\left(U_1,N_1\right) g_2\left(U-U_1,N-N_1\right) \qquad (4)$$

The sum is assumed to run over all values of U_1 between 0 and U, and over all values of N_1 between 1 and N.

In equilibrium, the system is assumed to take on the state for which the multiplicity function is stationary. I.e.

$$dg = \frac{\partial g_1}{\partial U_1} g_2 dU_1 + \frac{\partial g_2}{\partial U_2} g_1 dU_2 + \frac{\partial g_1}{\partial N_1} g_2 dN_1 + \frac{\partial g_2}{\partial U_2} g_1 dN_2 = 0. \quad (5)$$

As energy and particles are conserved, this means that

$$dU_1 = -dU_2 \qquad (6)$$

and

$$dN_1 = -dN_2. \tag{7}$$

As a result, (5) becomes

$$\left(\frac{\partial g_1}{\partial U_1}g_2 - \frac{\partial g_2}{\partial U_2}g_1\right)dU_1 + \left(\frac{\partial g_1}{\partial N_1}g_2 - \frac{\partial g_2}{\partial N_2}g_1\right)dN_1 = 0. \tag{8}$$

$$\left(\frac{\partial \sigma_1}{\partial U_1} - \frac{\partial \sigma_2}{\partial U_2}\right)dU_1 + \left(\frac{\partial \sigma_1}{\partial N_1} - \frac{\partial \sigma_2}{\partial N_2}\right)dN_1 = 0. \tag{9}$$

$$F_1 = U_1 - \tau_1\sigma_1 \tag{10}$$

$$F_2 = U_2 - \tau_2\sigma_2 \tag{11}$$

Using the fact that s=ln(g), (8) finally becomes, after dividing through by g_1g_2
Switching gears a bit, we consider the Helmholz free energy of the two subsystems.
and

where F is the Helmholz free energy, and t is defined by

$$\frac{1}{\tau} = \frac{\partial \sigma}{\partial U}$$

Then, the chemical potential in each system is given by

$$\mu_1 = \frac{\partial U_1}{\partial N_1} - \tau_1\frac{\partial \sigma_1}{\partial N_1} \tag{12}$$

and

$$\mu_2 = \frac{\partial U_2}{\partial N_2} - \tau_2\frac{\partial \sigma_1}{\partial N_2} \tag{13}$$

Rearranging, these become

$$\frac{\mu_1}{\tau_1} = \frac{1}{\tau_1}\frac{\partial U_1}{\partial N_1} - \frac{\partial \sigma_1}{\partial N_1} \tag{14}$$

and

$$\frac{\mu_2}{\tau_2} = \frac{1}{\tau_2}\frac{\partial U_2}{\partial N_2} - \frac{\partial \sigma_2}{\partial N_2}. \tag{15}$$

Subtracting (14) from (15) and rearranging, we have

$$\frac{\mu_2}{\tau_2} - \frac{\mu_1}{\tau_1} - \frac{1}{\tau_2}\frac{\partial U_2}{\partial N_2} + \frac{1}{\tau_1}\frac{\partial U_1}{\partial N_1} = \frac{\partial \sigma_1}{\partial N_1} - \frac{\partial \sigma_2}{\partial N_2}. \tag{16}$$

Note that the right side of (16) is identical to the rightmost parentheses of (9). Substituting the left side of (16) into (9), we obtain

$$\left(\frac{\partial \sigma_1}{\partial U_1} - \frac{\partial \sigma_2}{\partial U_2}\right) dU_1 + \left(\frac{\mu_2}{\tau_2} - \frac{\mu_1}{\tau_1} - \frac{1}{\tau_2}\frac{\partial U_2}{\partial N_2} + \frac{1}{\tau_1}\frac{\partial U_1}{\partial N_1}\right) dN_1 = 0. \tag{17}$$

Now, dividing through by dN_1 we have

$$\left(\frac{1}{\tau_1} - \frac{1}{\tau_2}\right)\frac{\partial U_1}{\partial N_1} + \left(\frac{\mu_2}{\tau_2} - \frac{\mu_1}{\tau_1} - \frac{1}{\tau_2}\frac{\partial U_2}{\partial N_2} + \frac{1}{\tau_1}\frac{\partial U_1}{\partial N_1}\right) = 0. \tag{18}$$

Multiplying through by t_1t_2 we obtain

$$(\tau_2 - \tau_1)\frac{\partial U_1}{\partial N_1} + \left(\mu_2\tau_1 - \mu_1\tau_2 - \tau_1\frac{\partial U_2}{\partial N_2} + \tau_2\frac{\partial U_1}{\partial N_1}\right) = 0. \tag{19}$$

Rearranging, this becomes

$$\tau_2\left(2\frac{dU_1}{dN_1} - \mu_1\right) = \tau_1\left(\frac{\partial U_1}{\partial N_1} - \mu_2 + \frac{\partial U_2}{\partial N_2}\right) \tag{20}$$

which takes the final form

$$\tau_2 = \tau_1 \frac{\left(\mu_2 - \frac{\partial U_1}{\partial N_1} - \frac{\partial U_2}{\partial N_2}\right)}{\left(\mu_1 - 2\frac{\partial U_1}{\partial N_1}\right)} = \tau_1 \frac{\left(\mu_2 - 2\frac{\partial U_1}{\partial N_1}\right)}{\left(\mu_1 - 2\frac{\partial U_1}{\partial N_1}\right)} \tag{21}$$

since

$$\frac{\partial U_2}{\partial N_2} = \frac{\partial U_1}{\partial N_1}.$$

Equation (21) is telling us that if $m_1=m_2$ then the temperatures will equilibrate at the same value and $t_1-t_2=0$, However, if $m_1>m_2$ then $t_1>t_2$ and if $m_1<m_2$ then $t_1<t_2$. I.e., differing chemical potentials generate differing equilibrium temperatures.

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DEVELOPING A GREEN METRIC MECHANISM VERSUS LEED FOR TALL BUILDINGS IN QATAR: EVALUATION-BEASED CASE STUDY

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SUMMARY

The paper developed a new point and credit system with a different weight more adaptable to Qatar environment as an approach for developing a Green Metric System for tall buildings in Qatar. The credits were distributed based on the condition of Qatar in terms of the availability of materials, the indoor thermal comfort, the value of the reservation and the site impact, the energy consumption in relation to resources, the innovation in design and the water management.

The paper studied Tornado tower as one of the significant tall building in Qatar, the results of this study were analyzed in terms of qualifying green by developing a questionnaire that distributed to the experts in the field of Green Architecture as an approach for evaluating the developed scheme.

The re-weighted green variables were applied on the evaluation process. The author used the main criteria and credits of LEED as a reference for the developing of the new Green Metric for Doha tall buildings.

Keywords: Green architecture, tall buildings, Qatar, tornado tower, LEED, green assessment tools

1. Research Objective:

Despite of its small size, Qatar has one of the largest growing economies in the world. According to Business Monitor International[1], Qatar's construction sector is set to reach 33 billion Qatari Riyals ($9.06 billion) by year 2012; the market has identified Qatar as one of the busiest construction areas in the world. In line with this, tall buildings have arisen in Doha city-capital of Qatar because of economic necessity, developments of tall buildings go up almost daily in Doha's business downtown area, and most of them are still under construction, while to the north entire new cities and man-made islands are being developed, accordingly, government officials have revealed that Qatar will see the rise of about 800 tall buildings by year 2016. With the materialization of such tall building construction projects in Qatar, which address the massive demand for office spaces, and life style properties, the paper addresses the needs of developing rigorous metrics and tools for assessing environmental performance of tall buildings in Qatar, which enables local authorities, investors, engineers, and even the residents to evaluate the green performance of such type of buildings.

2. Green Architecture:

2.1 Definition:

(Frej, 2005) defined green architecture as the method in which the building takes a good advantages of using resources by efficient way. Such resources are specified as: Energy, Water

[1]http://store.businessmonitor.com/banking/qatar_commercial_banking_report/ (last access 29th March, 2011)

and Materials. Adding to that, this method emphasizes reducing the impacts of buildings on the environment and human health during the building's life cycle. This is accomplished through better building's sitting, designing, construction, operation, maintenance and finally removal. This is achieved by competently using the resources previously mentioned.

Also *(Richardson P., 2007)* concluded that green architecture is how to conserve space and help save the environment, to harmonize the building with the site, to use natural heating and cooling techniques, and, above all, to combine aesthetic beauty with ecological sensitivity. *(Kibert C. J., 2008)* looked at green buildings as virtually always make economic sense on a life-cycle cost (LCC) basis, though they may be more expensive on a capital, or first-cost basis, sophisticated energy-conserving lighting and air-conditioning systems with an exceptional response to interior and exterior climates will cost more than their conventional.

In general, green architecture accomplished by meeting long-term human needs is inapplicable unless the natural physical, chemical, and biological systems of the earth are conserved[2]. Green building also concluded to serve the needs of the people who inhabit it. It supports and nurtures their health, satisfaction, productivity, and spirit. It requires the careful application of the acknowledged strategies of sustainable architecture nontoxic construction, the use of durable, natural, resource efficient materials, and reliance on the sun for day lighting, thermal and electric power, and recycling of wastes into nutrients. An elegant architectural integration of these strategies produces a building which honors the aspirations of those who use it and engages the natural world[3].

<u>2.2 Analysis of Leadership in Energy and Environmental Design (LEED):</u>
Many green building rating tools have been devolved due to rising need to prompt developers and organizations to be more conscious oriented in dealing with the building as a part of the environment. One of these rating tools is (LEED).

(Bosch, 2000) concluded that Leadership in Energy and Environmental Design (LEED), developed by the U.S. Green Building Council (USGBC) in 1993, is accepted as the national rating tool. There are five categories, in which a building can receive credits under the LEED program, including: site, water, energy, materials, and indoor environmental quality. By earning specified numbers of points within these credits, a building can become LEED-certified, or receive a silver, gold, or platinum rating for earning additional points.

As a method of rating the environmental and economic performance of buildings using established and/or advanced industry principles, practices, materials and standards, this rating system along with the possible credit points are listed in the table 1[4].

Green building rating systems in general focus on five categories of building design and life cycle performance include: Site, Water, Energy, Materials, and Indoor Environment. There is 5 points extra can be given by LEED for the Innovation and Design Process.

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[2] "Sustainable Building Technical Manual Green Building Design, Construction, and Operations", US Green Building Council, P14, 1996
[3] *ARC Design Group*, What is Green Architecture? http://www.kmitl.ac.th/~kikrisda/What%20is%20Green%20Architecture.pd, retrieved July, 26, 2009, (Last access: 29th March, 2011)
[4] "LEED reference guide, Version 2.0." 2001. U.S. Green Building Council, Washington, D.C., 2001

Table 1: The possible credit points in LEED[4]

Credit Category	Possible Point
Sustainable Site	14 Possible Points
Water Efficiency	5 Possible Points
Energy & Atmosphere	17 Possible Points
Materials & Resources	13 Possible Points
Indoor Environmental Quality	15 Possible Points
Innovation & Design Process	5 Possible Points
Project Total	69 possible Points

It is stated that for each category in LEED, a number of prerequisites and credits with specific design and performance criteria exist. Table 2 shows a breakdown of the various categories and rating points available in the LEED rating system. Projects must meet all the prerequisites to qualify for certification. Prerequisites are critical because they do not provide any credit points towards the overall score, but must be met irrespective of meeting other credit requirements.

Each of the credit requirements may be a simple design feature, whereas others may require more detailed analysis to determine the performance level. When a building design meets or exceeds the requirements for each credit category, one or more "points" can be obtained depending on the performance levels achieved, which is counted towards determining the overall rating. Depending on the total points obtained, LEED awards a label or certificate that recognizes the design as a green building. The LEED rating system has four certification levels, table 2.

Table 2: LEED certification levels (National trends and prospects for high performance green buildings, 2002).

Certification Level	Points
Certified	26 – 32
Silver	33 – 38
Gold	39 – 51
Platinum	52 - 69

3. The implementation stage-weighing the green criteria for Qatar:

This part includes information related to the natural resources, industries, future view, and the steps that the country of Qatar is performing in order to achieve a greener environment. The aim of this is to construct the weight of different variables that affect the green performance of tall buildings in Qatar as an approach for implementing Qatar's green metric mechanism for tall buildings. The methodology of this part can be concluded by studying the following four steps as shown in Fig.1.

Re-weighting Green variables in LEED versus Qatar Circumstances	→	Weighting Green Variables for Developing Green Metric Mechanism for Qatar	→	Formalization of Green Variables for Developing Green Metric Mechanism for Qatar

Fig.1: Methodology of implementing the green criteria for Qatar.

According to LEED, the variables that participate in measuring the green performance for buildings are shown in Fig. 2.

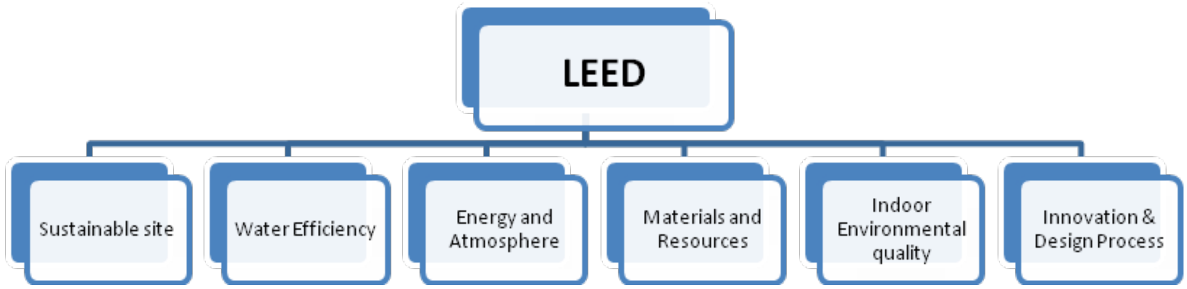

Fig. 2: Project checklist for LEED.

The previous variables are weighed in LEED, as shown in Fig. 3.

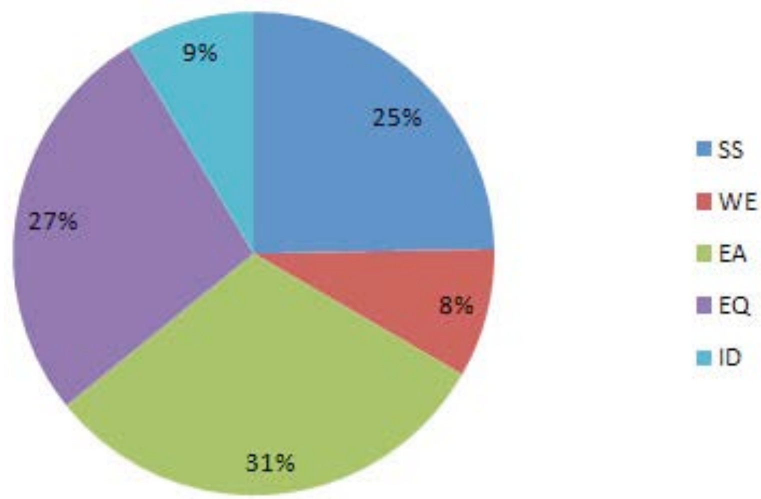

Fig. 3: The percentage of credits that is to be given for each Green variable in LEED.

3.1 Re-weighting Green Variables in LEED Versus Qatar Circumstances: Theoretical-Based Study:

The following will discuss the previous variables considered in LEED shown in figures 2 and 3, taking into account the condition of Qatar for each variable as follows:

a) Sustainable Site:

According to the LEED rating system the assessment of site sustainability is weighed as 14 points (20% of the total points "69 point"). Most of the State of Qatar is sparse or barren areas. Accordingly, more encouragement for developing the barren area of Qatar is required. Besides the ecosystem characteristic of Qatar, most of transportation at this time depends mainly on cars. The major focus of transportation research is on policies to reduce environmental and other problems caused by motor vehicles. Traffic congestion, accidents, air pollution, greenhouse gas emissions, noise and dependence on a volatile world oil market are all examples of social costs created by cars on the roads. The government of Qatar is planning to encourage other methods of transportation like railways and other public transportation that are to be functional within 20 years, so other routes for accessibility should to be considered in future designs.

According to the previous, more weight might be considered during the implementation and developing of the Qatar green metric for tall buildings to encourage the qualifying of the variables of sustainable sites such as site selection, urban redevelopment, alternative transportation, storm water management. For this reason, the percentage of evaluation to be given to sustainable sites is set be higher than the percentage of LEED.

b) Water Efficiency:
According to the LEED rating system the assessment of the water efficiency is 5 points (7% points of the total points "69 points").

Rainfall varies in Qatar from 50 mm to 100 mm per year with an average of 70 mm. Until 1953 ground water was the main source of water in the country. However, during that year a small desalination plant was installed which could produce 680m^3/d. As a result of the continuously increasing demand for water more powerful desalination plants were introduced together with ambitious programs for the treatment and re-use of municipal wastewater. According to a recent report from "Population Action Plan", the per capita annual share of a Qatari citizen of renewable fresh water resources has dropped from 1429m^3 in 1955 to 103m^3 in 1990 and could drop to as little as 59m^3 in the year 2025[5]. *(Hajiamiri et al, 2008)* concluded that increasing water efficiency is an important component of prudent water management for regions of growing water demand, water efficiency can offset demand growth that would otherwise occur in expanding urban regions, and this moderated demand can reduce the need to develop or acquire new supplies. Further, water desalination requires significant amounts of fossil fuel or waste energy to produce and this in turn contributes to increasing levels of greenhouse gas in the atmosphere. There is also a need to find solutions to the large build up of mineralized salt generated during this process. Therefore, reducing overall water use, and reusing potable water as many times as possible will provide a double benefit to the region. According to this, the evaluation of water efficiency in dry countries, like Qatar, should be given higher consideration to meet Qatar's situation, and limiting the use of potable water for landscape irrigation, reducing the generation of wastewater and potable water demand, while increasing the local aquifer recharge, maximizing water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.

c) Energy and Atmosphere:
According to the LEED rating system the assessment of the energy consumption and conservation is to have 17 points (25% of the total points of LEED "69 points"). Energy and atmosphere is the highest variable weight in LEED related to other variables.

Although Qatar has abundant oil reserves, its leaders recognize that fossil fuels are a finite resource that should be conserved to the greatest extent practicable. In order to achieve this vision, the country should embrace renewable energy sources in anticipation of a time when fossil fuel fed energy systems are no longer an option. Consumption of energy in Qatar is increasing year after year, and the oil and natural gas are the major sources of energy consumed, while the other renewable sources are not available. Qatar depends heavily on natural gas to meet over 50% of its energy requirements. In 2009, Qatar consumed approximately 147,000 bbl/d of petroleum. Although still relatively small compared to total production levels, consumption has more than tripled since 2000. Qatar's oil product consumption is expected to grow at an average annual rate of about five percent between 2010 and 2015. Qatar's increased petroleum consumption rates are due to its rapidly growing economy, particularly the associated growth of

[5]http://webworld.unesco.org/water/ihp/publications/waterway/wat7/Wat7_Feature.html, (Last access: 25th March, 2011)

transportation sector demand.[6] In the line of the previous, the energy and atmosphere is set to be higher percentage compared with LEED.

d) Materials & Resources:
According to the LEED rating system the assessment of the materials and resources are weighed by 13 points (19% of the total points).

It is well known that green products and materials have inherent environmental advantages in terms of lower upstream or downstream impacts; accordingly it is important to encourage green materials and resources early in the design process. *(Clakins M., 2009)* concluded that Site construction materials of the twenty-first century must respond to an entirely different set of forces global climate change, air pollution, rising fuel costs, ecological destruction, and loss of biodiversity. These forces are shaping the site and building construction industry through the rapidly growing sustainable development movement.

In fact, green building materials and resources are considered as products that avoid toxic or other emissions, save energy or water, reduce heating and cooling loads, and contribute to a safe, healthy built environment. For Qatar, if green materials and resources are considered in connection with the other green variables such as energy and atmosphere, the value of 18 points of the total 69 is a reasonable weight for this variable for developing the green metric of tall buildings in Qatar.

e) Indoor Environmental Quality:
According to the LEED rating system the assessment of the indoor environmental quality is 22% of other variables (15 points of 69 points).

The aim of this variable is to establish minimum indoor air quality (IAQ) performance to prevent the development of indoor air quality problems in buildings and maintain the health and well being of the occupants. *(Burroughs and Hansen, 2004)* state that reducing the intake of outside air, pollutants that were already there have been concentrated and their effects on humans have become more obvious. Energy cost has remained a significant driver of Indoor Air Quality. This variable could be considered by designing the HVAC system to meet the ventilation requirements of the reference standard, identifying potential IAQ problems on the site, and locating air intakes away from contaminant sources. Indoor environmental quality also contributes to enhancing the energy efficiency of the building envelope. *(Raymer , 2010)* concluded that the reason not to use a mechanical ventilation system would be if the air changes frequently enough naturally, natural or passive ventilation strategies can work with the right designs in the right locations in the right condition.

The energy efficiency of the building envelope already assigned a greater weight in the Qatar metric than in the LEED standard as explained before, reducing operational energy use, as well as reducing condensation-related moisture issues. As already discussed before, both energy

[6] Qatar Energy Data, Country Analysis Briefs, Energy Information Administration, Last Updated: January 2011, www.eia.doe.gov/cabs/qatar/pdf.pdf, (Last Access 25th March, 2011)

efficiency, design construction and material have been assigned a greater weight in the Qatar metric, therefore, it can be concluded that these LEED variables, though important to consider in enhancing the indoor environmental quality, might be assigned be less weight in the green metric mechanism for the State of Qatar.

f) Innovation and Design Process:

In LEED, the Innovation and Design Process is evaluated to have 5 points of the total points (7% percentage weight). This variable is divided into 2 sub areas:

- Innovation in Design (1-4 Credits):

This credit is set to provide design teams and projects the opportunity to be awarded points for exceptional performance above requirements set by the LEED green building rating system and/or innovative performance in green building categories not specifically addressed by the LEED green building rating system such as acoustic performance, education of occupants, community development, or lifecycle analysis of material choices.

- LEED Accredited Professional (1 Credit):

This credit is set to support and encourage the design integration required by a LEED Green Building project and to streamline the application and certification process. This credit is gained if at least one principal participant of the project team has successfully completed the LEED Accredited Professional exam.

Qatar has started to take similar steps by encouraging contractors, designers and government institutions and promote awareness of the need of such green building initiatives. Accordingly, the other variables of the developed metric are having a priority for innovation and design process, which if they considered it will satisfied the innovation of conserving the nature resources and limiting the impact of the tall buildings on the environment. For this reason, this variable is to be assigned by less weight compared to LEED.

3.2 Weighting Green Variables for Developing Green Metric Mechanism for Qatar-Hypothesis Based Study:

According to the previous, the hypothesis of weighing Green variables can be drawn by fixing the total points of LEED (69 points) as a stable measurement, while re-evaluating the different weight assigned to each of the LEED variables to meet Qatar's specific conditions. The estimated weight for each variable is represented in table 3.

Table 3: Weighing green metric for Qatar against the value of LEED's variables.

Credit Category	Possible Point - percentage (LEED)	Categories Evaluation (Qatar Compared With LEED)			Possible Point/percentage (Qatar)
		More	Same	Less	
Sustainable Site	14 - 20%	▨			17 – 24.5%
Water Efficiency	5 – 7%	▨			8 – 11.5%
Energy & Atmosphere	17 – 25%	▨			19 – 27.5%
Materials & Resources	13 – 19%		▨		13 – 19%
Indoor Environmental Quality	15 – 22%			▨	10 – 14.5%
Innovation & Design Process	5 – 7%			▨	2 – 3%
Project Total	69				69

The sustainable site variable is increased from 14 points in the LEED metric to 17 points in the proposed Qatar metric, an overall increase from 20% to 24.5%. The water efficiency variable, likewise, is increased from 5 points in the LEED metric to 8 points in the Qatar metric, an overall increase from 7% to11%. The value of Energy & Atmosphere is increased from 17 points in LEED to 19 points in Qatar metric, an overall increase from 25% to 27.5%. The material & Resources is to be the same weight 13 points makes 19%.

The previous increased value for the previous variables in Qatar metric are compensated by reassigning the weight of the lesser required variables for Indoor Environmental Quality, and Innovation & Design process.

The suggested weight of the different criteria for Qatar that is shown in table 3 is considered as the key to developing the metric mechanism for Qatar. After developing the mechanism, a refinement of data will be concluded to evaluate the validity of the assigned weight.

3.3 Formalization of Green Variables for Developing Green Metric Mechanism for Qatar:
The main purpose for this stage is to give an evaluation of the theoretically developed green metric mechanism for tall buildings in Qatar, provide an evidence for the effectiveness of the estimated variables' weight, and allowing the necessary development for the metric if required.

The evaluation is done by a personal contact with the field's expert and contractors by interviewing them to collect the required technical data. Sub contractors are also interviewed in order to know specifications of materials, techniques and how the tall building will be operated. This stage is concluded to cover three basic phases as follows:

a) Questionnaire:
In this stage, a design of a questionnaire which is covered the variables of green criteria is developed according to the shown developed weight for Qatar in table 3.

The designed questionnaire is shown in figures 4 a, and 4 b. A description of the process is given to each expert prior to making the meeting, thereby maintaining the respondent's interest and minimizing inconvenience.

In addition, the expert can ask further questions and gives a feedback regarding the established green mechanism. The meetings are designed to facilitate a clear recording of the meeting. The choices of each question had been ranked according to the credit for each question in the questionnaire.

Table 4 illustrates the different answer's value for the questions related to the assigned credit. However, the weight for each credit was developed theoretically according to Qatar environment as explained before, these developed criteria is to be used at the next part, as an approach to be tested in one of the most significant tall building in Qatar (Tornado tower).

Green Metric for Doha Tall Buildings in Qatar

The aim of this questionnaire is to evaluate a developed metric for tall buildings in Qatar. The results will be implanted to establish Green Metric for Doha Tall Buildings. A metrics to be implemented by the way to, enable Qatari authority, and individuals to understand the degree of green progress being made toward any tall buildings in Doha-Qatar.

A. Sustainable Sites (17 points)

1. Site selection: Evaluate the tower location in term of reducing the environmental impact on the site?(2point)

O Good	O Fair	O Poor

Comments:..........

2. Urban redevelopment: Does the tower is connected with the development of urban areas with existing infrastructures, protecting green fields and preserving habitat and natural resources? (2 point)

O completely	O partially	O Not at all

Comments:..........

3 .Rehabilitate damaged sites: Do you consider the tower participated in rehabilitating damaged sites where development is complicated?(1point)

O Yes	O No	O Uncertain

4. Alternative Transportation: Does the tower participate in reducing pollution and land development impacts from automobile use?(4points)

O Completely	O partially	O Not at all

Comments:..........

5. Reduced Site Disturbance: Does the tower Conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity?(3points)

O Yes	O No	O Uncertain

6. Storm water management: Does the site limit the disruption of natural water flows by minimizing stormwater runoff, increasing on-site infiltration and reducing contaminants?(2point)

O Yes	O No	O Uncertain

7. Landscape and exterior design to reduce heat islands: Does the tower reduce heat islands between developed and undeveloped areas to minimize impact on microclimate?(2points)

O Yes	O No

Comments:..........

8. Light pollution reduction: Does the tower eliminate light trespass from the building site and improve night sky access?(1point)

O completely	O partially	O Not at all

B. Water Efficiency (8 points)

9. Is the tower designed to Limit or eliminates the use of potable water for landscape irrigation (Water Efficient Landscaping)?(3 points)

O Completely	O partially	O Not at all

Comments:..........

10. Is the tower designed to reduce the use of municipally provided potable water for building sewage conveyance OR, treat wastewater on site to tertiary standards?(2point)

O Completely	O partially	O Not at all

11. Is the tower designed to maximize water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems?(3 points)

O Completely	O partially	O Not at all

Comments:..........

C. Energy and Atmosphere (19 points)

12. Optimize Energy Performance: Is the tower achieves increasing levels of energy performance to reduce environmental impacts associated with excessive energy use?(9points)

O Completely	O partially	O Not at all

13. Renewable Energy: to what extend does the tower encourage and recognize increasing levels of self-supply through renewable technologies to reduce environmental impacts associated with fossil fuel energy use?(3points)

O Completely	O partially	O Not at all

Comments:..........

14. Additional Commissioning: does the tower ensure that the entire building is designed, constructed, and calibrated to operate as intended?(2points)

O Yes	O No	O Uncertain

Comments:..........

15. Ozone Depletion: Does the design consider the protection of Ozone through refrigerant management?(2points)

O Yes	O No	O Uncertain

Comments:..........

16. Measurement & Verification: Does the tower provide for the ongoing accountability and optimization of building energy and water consumption performance over time?(2points)

O Completely	O partially	O Not at all

17. Green Power: To what extend does the tower encourage the development and use of grid-source energy technologies on a net zero pollution basis? (1point)

O Completely	O partially	O Not at all

D. Materials & Resources (13 points)

18. Building Reuse: Does the tower Extend the life cycle of stock, conserve resources, retain cultural resources, reduce waste, and reduce environmental impacts as they relate to materials manufacturing and transport?(2 points)

25 %	50 %	75%	100%	Not applicable

19. Construction Waste Management: Evaluate the tower Divert construction, demolition, and land clearing debris from landfill disposal. Redirect recyclable material back to the manufacturing process.? (2points)

O Good	O Fair	O Poor

Fig. 4 a: The developed questionnaire for evaluating tall buildings in Qatar – page (1)

20. Resource Reuse: Does reducing environmental impacts related to materials manufacturing and transport extend the life cycle of the towers' materials? (2points)

O Completely	O partially	O Not at all

21. Recycled Content: Does the tower increase the demand of tower products that have incorporated recycled content materials? (3points)

O Completely	O partially	O Not at all

22. Local/Regional Materials: Does the tower products increase the demand of materials manufactured locally? (2points)

O Yes	O No	O Uncertain

Comments:..........

23. Rapidly Renewable Materials: Does the tower Reduce the use and depletion of finite raw and long-cycle renewable materials by replacing them with rapidly renewable materials? (1point)

O Completely	O partially	O Not at all

Comments:..........

24. Does the tower use a minimum of 50% of wood for wood building components including structural framing and general dimensional framing, flooring, finishes, furnishings,? (1point)

O Yes	O No

Comments:..........

E. Indoor Environmental Quality (10 POINTS)

25. Carbon Dioxide (CO2) Monitoring: Does the tower provide capacity for indoor air quality (IAQ) monitoring to sustain long-term occupant health and comfort? (1point)

O Yes	O No	O Uncertain

Comments:..........

26. Increase Ventilation Effectiveness: to what extend does the tower Provide for the effective delivery and mixing of fresh air to support the health, safety, and comfort of building occupants? (1point)

O Completely	O partially	O Not at all

Comments:..........

27. Construction IAQ Management Plan: Does the tower prevent indoor air quality problems resulting from the construction/renovation process, to sustain long-term installer and occupant health and comfort? (1point)

O Completely	O partially	O Not at all

Comments:..........

28. #*Low-Emitting Materials: Does the tower reduce the quantity of indoor air contaminants that are odorous or potentially irritating to provide installer and occupant health and comfort?* (1point)

O Yes	O No	O Uncertain

Comments:..........

29. #*Indoor Chemical & Pollutant Source Control: Does the tower avoid exposure of tower occupants to potentially hazardous chemicals that adversely impact air quality?*(1point)

O Completely	O partially	O Not at all

30. #*Controllability of Systems: Does the tower provide a high level of individual occupant control of thermal, ventilation, and lighting systems to support optimum health, productivity, and comfort conditions?*(1point)

O Completely	O partially	O Not at all

31. #*Thermal Comfort: Does the tower provide for a thermally comfortable environment that supports the productive and healthy performance of the tower occupants?* (2points)

O Completely	O partially	O Not at all

32. #*Daylight & Views: Does the tower Provide a connection between indoor spaces and outdoor environments through the introduction of sunlight and views into the occupied areas of the building?(2points)*

O Completely	O partially	O Not at all

F. Innovation & Design Process (2 points)

33. #*Is the tower substantially had special consideration related to Green performance such as energy performance or water efficiency or as acoustic performance, education of occupants, community development, cultural identity or lifecycle analysis of material choices? ?*(1points)

O Yes	O No	O Uncertain

Comments:..........

34. Is there any principal participant of the project team has successfully completed any Green Accredited Professional exam? ?(1point)

O Yes	O No	O Uncertain

Fig. 4 b: The developed questionnaire for evaluating the tall buildings in Qatar-page (2)

Table 4: The different answer's values for the different questions related to the assigned credit.

Answers' variables	Good		Fair	Poor	
Credited points	100 % of the credit		50 % of the credit	10 % of the credit	
Answers' variables	Completely		Partially	Not at all	
Credited points	100 % of the credit		50 % of the credit	ZERO of the credit	
Answers' variables	Yes		No	Uncertain	
Credited points	100 % of the credit		50 % of the credit	ZERO of the credit	
Answers' variables	25 %	50%	75%	100%	Not applicable
Credited points	25% of the credit	50 % of the credit	75 % of the credit	100 % of the credit	ZERO of the credit

After conducting the study of the tower, the rank that related to how the tower meets the green criteria is given according to same categories as LEED as shown in table 5.

Table 5: The different ranks for the developed mechanism "LEED rankes".

Certificate type	Credited points
Platinum	52- 69 points
Gold	39-51 points
Silver	33-38 points

b) Local Region Tall Building Analysis-Tornado Tower:

The Tornado tower is a 52 storey office building that is located in the west bay in Doha-Qatar, Fig. 5. This building received the the Council on Tall Buildings & Urban Habitat (CBTUH) award as the best tall building in the Middle East for the year 2009[7]. The general Information about the tower is as follow[8]:

Location: *Doha, Qatar;*
Client: *Qipco Company;*
Building type: *Office;*
Date of completion: *December 2008;*
Total height / floors: *200 m;*
Architect: *CICO Consulting Architects.*

Fig. 5: Tornado tower in Doha-Qatar

[7] http://www.ctbuh.org , last access 2nd March, 2011)
[8] http://www.emporis.com/application/?nav=building&lng=3&id=qipcotower-doha-qatar, (last access 18th March, 2011).

The concept of the tower centers on the theme of a tornado in the desert swirling into the sky. The broad goal of the design was to create a prominent and eye-catching tower on the Doha skyline while maximizing interior space and functionality. With the current layout and structural design, the tower boasts column free office space allowing the maximum flexibility to arrange the space to meet tenants' needs. This goes to show that design does not have to substitute functionality by any means. There is also a great deal of flexibility in overall leasing options in terms of floors, as the project is being leased on a floor -by-floor basis[9].

c) Tornado Tower Evaluation According To the Developed Qatari Green Mechanism:
The Tornado tower is evaluated according to the expert answers to the developed green criteria for Qatar that shown in figures 4 (a, and b). The answer of each question has been analyzed, and the results are according to the figures from 6 to 11.

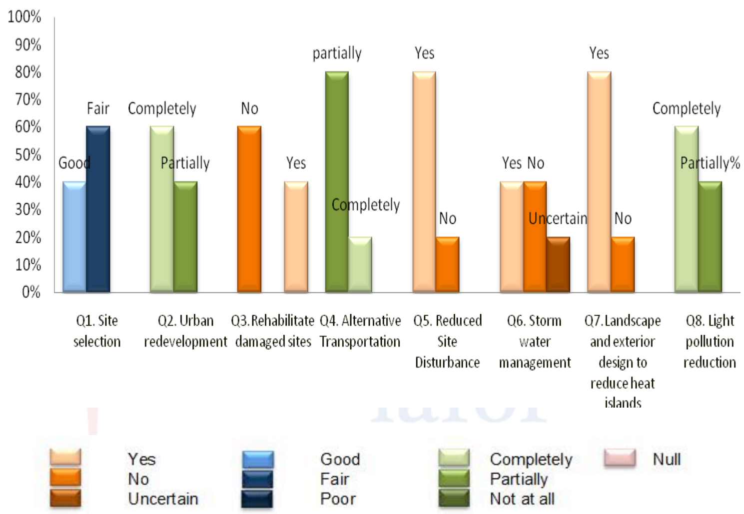

Fig. 6: Sustainable Site questionnaire results.

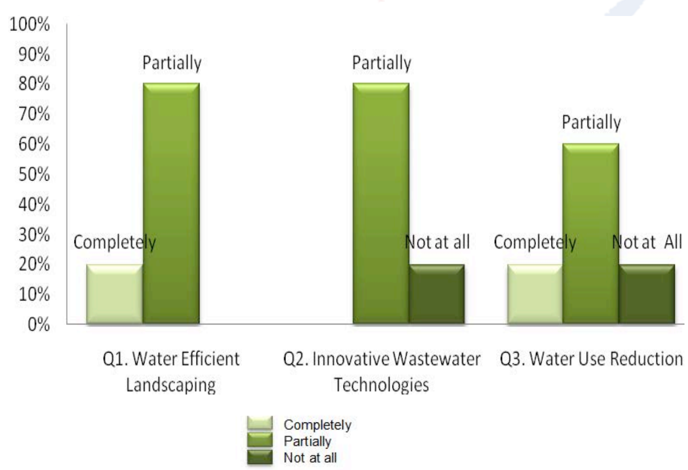

Fig. 7: Water Efficiency questionnaire results.

[9]http://www.constructionupdate.com/products/cwgulf/2008/july2008/008.html, last access 31st March, 2011)

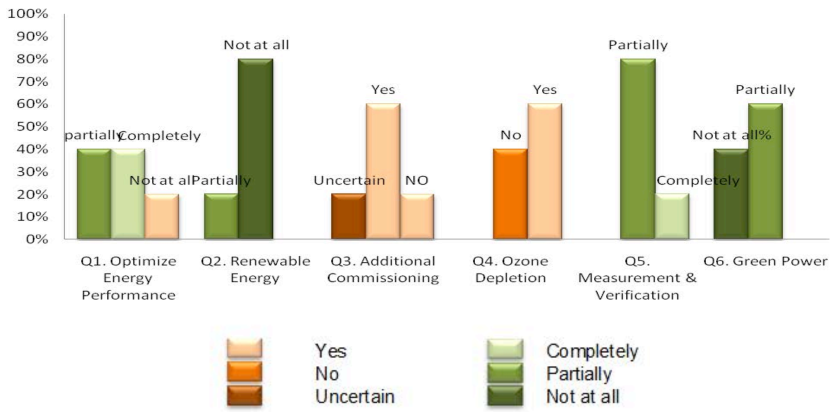

Fig. 8: Energy and Atmosphere questionnaire results.

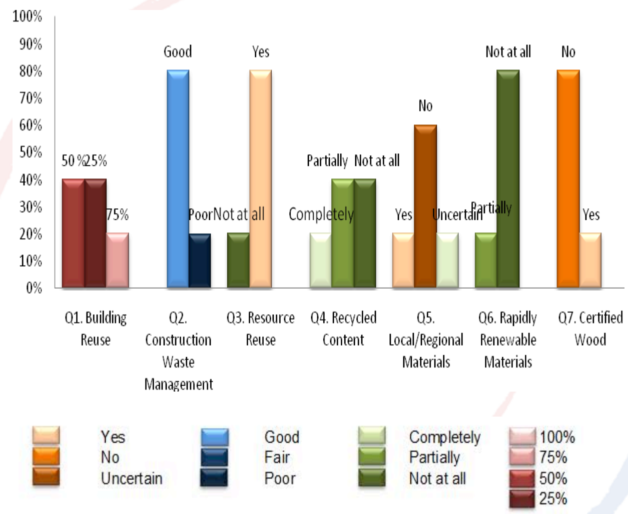

Fig. 9: Materials and Resources questionnaire results.

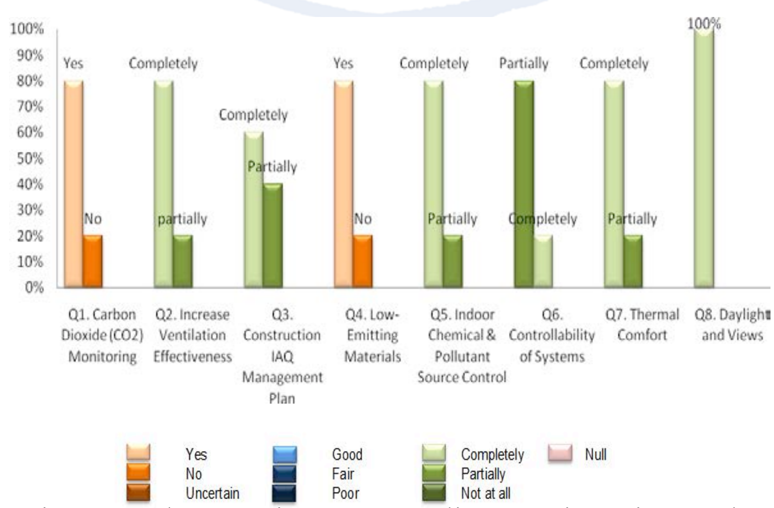

Fig. 10: Indoor Environment quality questionnaire results.

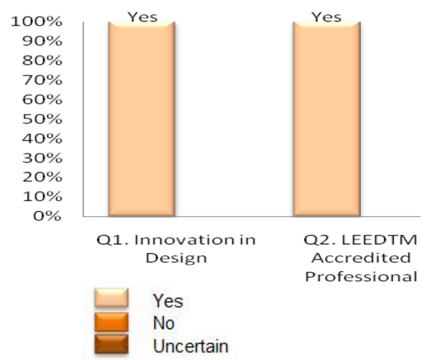

Fig. 11: Innovation Design Process questionnaire results

According to the previous analysis, the Tornado tower evaluation using Qatari rating system is listed below in table 6 with a comparison with the LEED system. In this comparison, the author applied LEED by using same questions applying LEED's weight to get the total gained points according to LEED.

Table 6: The gained points for Tornado tower according to LEED and the Qatari developed mechanism.

Criteria	Qatari Metric System	LEED Metric System
Sustainable Sites	11.8/16	11.1/14
Water Efficiency	4.1/7	2.6/5
Energy and Atmosphere	9.7/19	8.8/17
Materials & Resources	6.7/15	5.67/13
Indoor Environment Quality	6.5/10	12.9/15
Innovation Design Process	2/2	5/5
Total	40.8	46.1

As shown in table 6, the Tornado tower scored according to the Qatari Green Metric system 40.8 points giving it a Golden Certificate, however according to LEED Green Metric it scored 46.1 giving it also a Golden Certification. The tower scored the highest point in the "Innovation Design Process" whereas the lowest score was given to "Materials & Resources" and "Energy and Atmosphere" categories.

4. Conclusion and Future Work:

4.1 Conclusion:

The paper addresses the various aspects of Green architecture, and worldwide and finally a development of Green Metric for Doha tall buildings as a step towards Qatar eco-city advocacy and a more local environmental conscious design guide. Green architecture is defined as the method in which the building takes a good advantage of using resources by efficient way. Green development concepts applied to the design, construction, and operation of buildings can enhance both the economic well-being and environmental health of communities. These enhancements are achieved by meeting resources requirement which are specified as: Energy, Water and Materials. Adding to that, this method emphasizes reducing the impacts of buildings on the environment and human health during the building's life cycle. The Leadership in Energy and Environmental Design (LEED) was chosen to be studied and analyzed as an approach to be taken as the main reference for establishment the new Green Metric for Doha tall buildings. A theoretical study about Qatar including information about the country natural resources, industries, future view, and the steps that the country performs in order to achieve greener environment was conducted as a main tool for understanding and establishing the new green system. It helped in concluding the different green variables that affects Qatar.

The acquired knowledge that related to the state of Qatar were compared in relevance of the LEED criteria and credits and a decision methodology was developed to relate Qatar's nature to identifying the basics of the Green Metric for Doha tall buildings. The paper re-established a new point and credit system with a different weight more adaptable to Qatar environment as an approach for developing a Green Metric System for Doha tall buildings.

The green credits were distributed based on the availability of materials, the significance of the indoor thermal comfort, the value of the reservation and the site impact, the energy consumption in relation to resources, the innovation in design and the water management in an environment.

The paper developed a questionnaire that distributed to the experts in the field of Green Architecture regarding the case study " Tornado Tower' as an approach for evaluating the developed scheme versus LEED; the author used the main criteria's and credits of LEED as a reference for comparison and for the development of the new Green Metric for Doha tall buildings. The results of this survey were then analyzed and credit points were distributed to give a total credit and certification. The comparison approved for the need of the new Green Metric for Doha tall buildings. As the granted certification of the survey results were different from those – certifications- of LEED, it becomes obvious that LEED is not always applicable in every region and the Green Metric for Doha tall buildings was in fact needed to be adapted to the local environment of Qatar.

4.2 Recommendation and future work:

The outcome of this paper is considered as a milestone for more in depth studies for green architecture development in state of Qatar. For instance, developments can be conducted on this research in Future work, applications and academic research can be accomplished from the results that had been achieved in this research by adopting and developing the Qatari tall building metric mechanism in different methodology by governmental authorities and the different architectural firms. Also the government can form special agency that specifically works in the design process and evaluation of Doha tall buildings.

The Qatari government must enhance and encourage the green criteria for tall building and implement it as an example by using artificial intelligence technique to give a real evaluation of the tower, and at the end a certificate that shows how much the tall building is green and efficient according to Qatar. This artificial intelligence technique can also be used to integrate many opinions in the design and decisions such as the users' opinions about the energy efficiency for the evaluated tall building. The engineers can also give their opinions, which will be taken into consideration in the evaluation process. The LEED criteria for tall building in Qatar were explored and analyzed to give the outlines knowledge that can be developed in future.

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Acknowledgment:

"This publication was made possible by a grant from the Qatar National Research Fund under its Undergraduate Research Experience Program. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Qatar National Research Fund."

The Importance of Ecological and Spiritual Approach in Chemical Engineering towards Practical Conception of Sustainable Development.

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The Importance of Ecological and Spiritual Approach in Chemical Engineering towards Practical Conception of Sustainable Development.

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Abstract

The issues in sustainable development are of two kinds; the interdependent of three principle pillars of sustainable development-environment, social, and economy development and human spiritual development. The main objective of this paper is to discuss on the importance of spiritual enhancement and ecological approach in chemical engineering to develop a notion of conception for sustainability. We elaborate and discuss contemporary Islamic principle named "Jurisprudence of Priorities" (*Fiqh Al-Aulawiyyat*) and what it suggests for sustainability and concurrently delineate the need for ecological approach in chemical engineering. The study was conducted based on available published articles from books, handbooks, journals, and other on-line reliable sources related to environment and sustainability. The study concentrates on both Islamic jurisprudence principle in conserving the nature and ecological approach in chemical engineering. The examples presented in this article provide new information on the importance of spiritual development and ecological considerate in chemical engineering towards successful sustainable development. This study is perhaps one of the first to address the incorporation of spiritual enhancement (Islamic principle) and ecological approach in chemical engineering to create environmental awareness among world community.

Keywords: Environment, Islamic jurisprudence, spirituality, sustainability.

1. Introduction

The issue on environmental pollution is becoming a recent concern since it involves the complexity in ecological aspects, and this awaking everybody to look upon this issue seriously. For the past few decades we have witnessed significant indiscriminate utilization of natural resources in the name of development and industrialization. Although there are a lot of programs being organized and conducted on the platforms of academic and political discussion, and also international conferences but the ultimate consensus is yet to be achieved unanimously and to certain extent, it invokes numerous debates among developed and developing countries. The need for continued economic growth and societal development has led to activities that should inline with both objectives. Since preservation of earth's ecology grasps an intention of world community and come into dispute, the process to reach the need of both economic growth and societal development remains within a boundary of uncertainty.

Holmes Rolston (2006) argues that escalating population and development as well as the issues of peace and environment are four critical items that hindering human agenda and require global attention. These items are interdependent and the first three influence a lot to the performance of nature. It is not possible to decouple population growth and development from its consequences to nature since both agendas utilize environment equities. Some people even don't realize that peace is one of the equity that leads indirectly to environmental sustainability on a difference platform. It is also apparent that development will create obvious consequences to deteriorating the environment, if not being incorporated in sustainability agenda. In the early twenty-first century, the earth supports a human population that is more numerous and at the same time, there is an unprecedented events that associated with the huge fatalities and tremendous destruction caused by what so-called the "natural" disasters. In addition to natural disasters, emphasis is also need to be placed on "man-made" industrial and technological disasters that create an anxiety among world community (Keith Smith and David N.Petley, 1991). Industrial and technological disasters seem to create unprecedented modern catastrophe than that of natural disasters. Recent catastrophe likely to be more significant and technology-induced was regarded to be a catalyst for their occurrences.

K.-H Robert *et al* (2002) introduces the five interdependent-level hierarchical system to resolve the confliction of various tools for management and monitoring of sustainable development and suggests four systems condition that need to be emphasized in order to ascertain the success of sustainable development. Those systems are; the elimination of concentration of substances from the Earth's crust and societal production, eliminate the physical degradation and fourthly, contribute as much as we can to meeting human needs, for example using all of our resources efficiently, fairly and responsibly. The mushrooming development and industrialization which come from technological input has been applied worldwide at a very speed. In the meantime, coupling the technological innovation with business expansion may accelerate the unpredictable environmental consequences if not being dealt ethically and in-depth integrity with accordance to values and faith. World communities have to make value judgments to focus on sustaining economy and societal development in balance with environmental needs. However, there are yet numerous conflicts to be answered and it remains in debate among business players and nature lovers. Issues such as how much original nature we wish to restore and how much technologically modified or physical degraded nature we want. Eventually the conflict will remain on two underlying issues; on giving a priority to sustainable development or to emphasize on a sustainable biosphere. It is obvious that business players and technology developers are more concern about creating wealth rather than preserving the nature and to be fair, they are actually sitting on the right platform because they contribute to meeting human needs; human affluence and well-being. On the other side of the coin, environmental needs are also should be put into account because of their role in balancing the cycle to prevent unprecedented events due to overwhelming utilization and degradation. Y. Jin *et.al* (2004) argues that human activities relative to the earth's ecology have two important stands on sustainability whereas the mainstream is a stand for continued economic growth and the second stand is environmental sustainability. They also highlighted that engineering issues that involve the ecology are complex because they depend on the notions of value and justice of a person. However, both important stands require values that have an ability to direct sustainability process to the apex of human civilization. Any system may have a difficulties and barriers to reach the objective unless there is a mechanism that will enable the players play their role to achieve the targets. Indeed, these so-called environmental conflicts (or dilemmas) are remaining unsolved because of its complexity and none of the solutions being reached to satisfy all parties.

Regardless of whether giving a priority to societal improvement, economic growth or nature conservation, balancing spiritual development with these three principle pillars of sustainable development is of paramount important. The ecosystem must be managed with accordance to godly guidelines towards human sustainability. Sustainable economy and sustainable environment are tools to reach the apex of human civilization and eventually, man is the one who will benefit from this glorious achievement. The failure of achieving them indicates a weakness of humankind managing the globe and we should be accountable for. The needs for godly guidelines therefore lead humankind to sustain their life with the nature harmoniously. Strengthening spiritual values is not only essential in term of sustainability but it is also encouraging mankind to appreciate other God's creatures and treat them accordingly and respectfully.

R.Clift (1998) refers to Brundland statement and come to conclusion that the role of the new model engineer is closely associated with the concept of sustainability which he prefer this term to sustainable development. Incorporating spiritual development into good engineering practice could stimulate new paradigm shift for practically sustainable development. Hence, the presence of this value will reflect to the importance of developing a strong connection between human and the Creator, through enhancement of this value and understanding our ultimate responsibility and accountability (trusteeship).

1.1 "2Es + 1S" for sustainability

The hotly debated topic, sustainable development has been discussed for so many years. The word "sustainable development" has became popular recently; even some have questioned the motive behind this popularity (Bawden R., 1997), and the main catalyst for its popularity was the Rio de Janeiro Earth Summit held in 1992. The Rio Summit agreed a set of action points for sustainable development, collectively refer to a blueprint named Agenda21 (Simon Bell and Stephen Morse, 1999). The most cited principle of sustainable development is about sustaining the economy, society and nature or environment for the sake of inter and intra-generational equities. Sustainable development becomes our national agenda and the commitment showed by our government is obvious and practical. It is an important aspect for all countries to make development sustainable and it based on the assumption that societies need to manage these three types of capitals. The capitals may be non-substitutable and whose consumption might be irreversible, and of course, consideration to sustain inter-generational and intra-generational equities must be taken into account. In fact natural capital, social capital and economic capital are often complementarities. Even there is an attempt to replace some natural resources but it is much unlikely that they will ever be able to replace services that provided by ecosystem. Because of multi-functionality of many natural resources, substitute other service with others is likely not possible. Consumption of natural and social capital may have no observable impact but the consequences may appear after certain period of time or until a certain threshold is reached.

Business and economy therefore hinges upon good practices to stay sustain. Hence, it is often said that good and effective business practice is sustainable development in business (Ghazali Mohd Yusoff, 2008). However, in order to ensure the success of this agenda, we have to face a few challenges that mainly in the areas of awareness (public and business domains), strengthen the government and private agencies and establishment of monitoring or data collection system to gauge the success of this vision. There are more else factors that hinder this objective but most of them are physically oriented and require technical solution. However, the essence of the success of sustainable development is still subject to development of strong spirituality and comprehension on our role over all creatures.

2. Methodology

The study was conducted based on available articles collected from journals, books, handbooks and other reliable resources related to environment and sustainability and . The emphasis was placed in the Islamic perspective of sustainability with accordance to the "Jurisprudence of Priorities" (Arabic: *Fiqh Al-Aulawiyyat*). The logical views outlined by this jurisprudence towards spiritual enhancement with accordance to Islamic principle for sustainable development is of paramount important to ascertain the success of this objective. In addition to this, the ecological approach in chemical engineering is also discussed.

3. Results and discussion

3.1 Spirituality and sustainability

According to Keith Smith and David N.Petley (1991), environmental hazards exist between the natural events system and human use system. Hazards and human response to them can influence global change and here the concept of sustainable development has came into attention. Environmental hazards also linked to ongoing global environmental change that includes many factors and those factors will interact to each other to determine the prospects, failures and success for sustainable development. In fact, human actions contribute to hazardous processes and disaster outcomes are obvious and due to the greater complexity of human society and discovery of mega-advanced technologies, many say that future disasters are likely to be larger in scale than in the past if no comprehensive measures being implemented and no explicit directions being made.

The unprecedented disasters are unpredictable and serious attention need to be paid to deter tremendous loss of properties and fatalities. Since nature and society are interconnected, any changes in one have the potential to affect other. Such relationships are increasingly important for those human actions that over-exploit and degrade natural resources through "man-made" activities and consequently amplify the risk from natural hazards. Our understanding of hazards and disasters has to be changed since the chances of facing the catastrophes are always unpredictable. The great catastrophes have to be seen as "Acts of God" due to "Man wrongdoings". This perspective viewed damaging events as a divine punishment for consequence of human use of the earth rather than mere "natural disasters" (Figure 1). We therefore, need to act accordingly and manage the entire world with respect and responsible as guided by the Creator.

"*Mislead has appeared on land and sea because of (the meed) that the hands of men have earned, that (Allah) may give them a taste of some of their deeds: in order that they may turn back (from Evil)*" (Surah Ar-Rum (The Romans), Verse 41)

The issue on man-destructive acts upon nature is not an assumption, and the Koran has revealed clearly the connection between man-made activities (anthropogenic) and its consequences to the environment in verse 41, Surah Ar-Rum. In other word, if the activities are not in accordance with ethical (based on Islamic attribute) and godly manners, man will suffer the "punishment" for what they have done to the nature.

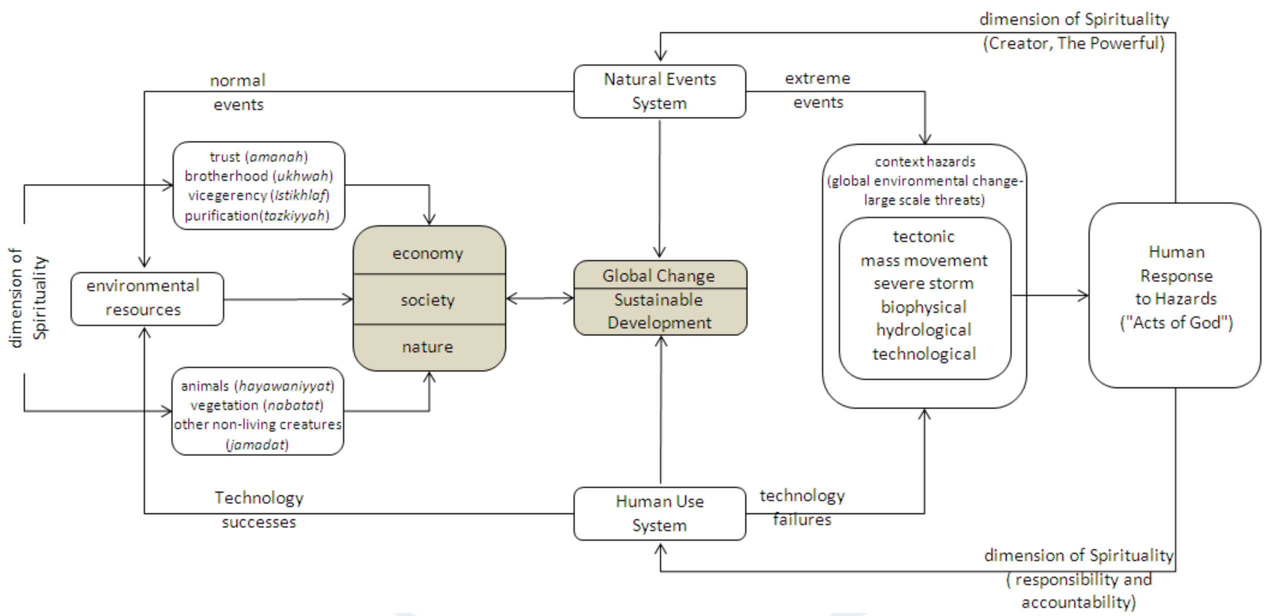

Figure 1: Environmental hazards and spiritual values (adapted from Burton *et. al.* (1993), Keith Smith and David N.Petley (2009))

R. Kamla *et al* (2006) cited that the rapid deterioration of the environment can be closely connected to a crisis of values. The values here might be defined as a belief in God and practice integrity as God wishes. Figure 2 shows the sustainable development concept with multidimensional elements which involving no less than three dimensions (as most cited; economy, social and nature) and spiritual development plays as an essence towards the centric goal. It is viewed as the mutual beneficial interaction between all dimensions whereby the linkage to inner faith is at the apex. Difference than other visible dimensions, spiritual development is a dimension that perfectly forms the ultimate sustainable development philosophy. Having this spiritual development is putting us close to the success for sustainability. Strengthening our relationship to Creator and understanding our role to establish harmonious development is a pre-requisite towards the goal of sustainability. The failure and success of sustainable development relies on how human faith and depth spirituality lead to its outcomes.

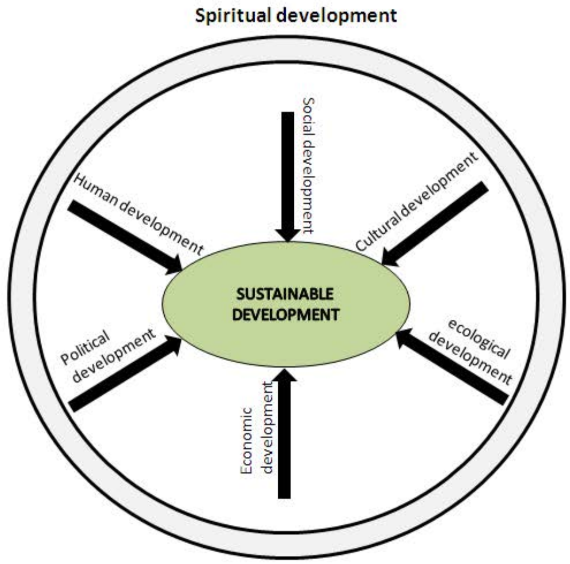

Figure 2: New pattern of "sustainable development" by incorporating "spiritual development" as an essence.

The most cited controversial article written by Lynn White (1967) has opened the world eye to see religion as something that being misunderstood. Lynn White concluded that the Christians emphasis on a transcendent deity who is exterior to and above nature was a major root of techno-industrial culture's disregard for the nature. He argues that the religious teaching was regarded to provide permission to utilize and exploit natural resources for the benefits of mankind. His controversial viewpoint awoke intellectual and community leaders of all the world's religions to articulate ethical and cosmological rationales for better environmental care (Susan Power Bratton, 1990)

In fact, the world's religions have historically appreciates the nature as a part of religious rituals. Susan Power Bratton (1990) also reported that world's religions have served as important cultural reservoirs of ecological understanding and in addition, it valuing nature preservation. The Koran, the Hebrew Scriptures (Torah), the Bibles, the Bhagavad Gita and Buddhist doctrine of *pratitysamutpada* discuss about ecology issues and the way we exploit and utilize them in a very ethical.

According to Harold Coward (2003), Hindu texts speak about ecology is closely related to righteousness or *dharma* and even the key Hindu text, *Bhagavad Gita* has said that a vision of universe as the body of God which every single Hindus has to respect and treat them harmoniously. According to him, in Hindu, destruction of forest is condemned and planting of trees encouraged. He also roused out an example of a temple in *Tirumala Tirupati* in South India that establishing large nursery forest. Other than forest, the Hindus also believe water as a powerful media of purification and as a source of energy. O.P Dwivedi (1990) said that according to Manu (*Manusmrti IV : 56*):

"*One should not cause urine, stool, cough in the water. Anything which is mixed with these impious objects, blood and poison should not be thrown into water*".

The respectfulness to the nature is not only taught in Hindu, the Buddhist doctrine of *pratitysamutpada* sees the world as a single whole. They share a holistic paradigm of nature with the environmental science (Ronald Y.Nakasone, 2003). Noise is recognised as a serious environmental pollutant and in Buddhist the element of silence is a part of their ritual condition. The Buddha and his followers revelled in the silent solitary natural habitats unencumbered by human activity and even the choice of monasteries also seriously concern about the quality of silenceness (Lily De Silva, 1987) such as the Shoalin Temple and others. The Hindus and Buddhist are among the many examples that prove the relationship between religions and nature.

3.2 Islamic Jurisprudence and Environmental Conservation

Islamic principles are suggestive of a variety of implications for governance and reflecting upon Islamic principles, we here engage with the notion of Islamic jurisprudence for the environment. In general, Islamic laws that govern human activities are divided into *ibadah (*religious rituals*)* and *muamalah (*relationship between man-to-man and man-to-surrounding*)*. The practice of both *ibadah* and *muamalah* should be guided and governed in accordance to Islamic laws. Hence, environmental management and the process of establishing sustainable development (considered as *muamalah*) also should be in line with Islamic laws principle.

One of the unique characteristics of Islamic teaching is its concept of flexibility and mandatory. The sacred text of Koran, as the highest source of jurisprudence has underlined laws in general. It also outlined the main principles of Islamic teachings. The laws and principles that had been underlined in the Quran are mandatory and should not be argued. Literally, these laws are related to *ibadah* and as for *muamalah*, Koran merely outlined the basic principles and we are allowed to practice it as long as they are not against the basic principles.

Furthermore, from the view of Islamic jurisprudence philosophy, the laws of Allah have their objectives as included in Shariah Objectives ("*Maqasid al Shariah*"). The Shariah was revealed to realize human interest and wellbeing and its objectives are to safeguard faith/religion (*din*), life (*nafs*), reason (*aql*), posterity (*nasl*), and property (*mal*). The main objective of Shariah is to preserve public good (*maslahah*) and prevent harm (*dar' al mafasid*). *Maslahah* can be classified into three categories: *daruriyat* (the essentials), *hajiyat* (the complementary), and *tahsiniyat* (the embellishments) (Asyraf Wajdi Dusuki and Nurdianawati Irwani Abdullah, undated).

"Jurisprudence of Priorities" or *Fiqh Al-Aulawiyyat* reflects the Shariah and offers problem-solving mechanisms to the contemporary issues. In the context of environment conservation, *fiqh Al-Aulawiyyat* suggests what so-called the art of weighing between the alternatives to opt the lesser harms and minimize the negatives impacts as well as maximize the good impacts in the long run. It is mainly concerned with finding solutions to people's problems and making their life easy. In other word, it is an art of Shariah jurisprudence to safeguard the greater benefits by the exclusion of the lesser and to remove the greater harm by acceptance of the lesser. *Fiqh Al-Aulawiyyat* offers within the following set of laws:

(i) Prioritize the necessities (*daruriyat*) above the complementary (*hajiyat*) and the embellishment (*tahsiniyat*): The things under category of *Daruriyat* in Shariah are religion(*din*), life(*nafs*), posterity(*nasl*), reason(*aql*), and property(*mal*).
(ii) Prioritize the benefits which offer obvious result upon implementing.
(iii)Balancing among benefits, prioritize the one that offers the better.
(iv)Balancing among harms, prioritize the one that offers the lesser.
(v) Balancing between benefits and harms when clashing, prioritize which one can be tolerated in achieving the long run benefits. (e.g choosing harm in return of achieving some benefits is tolerable)

In the case of sustainable development, we are under dilemma to balance the economy, social and environment needs and eventually, the process of materializing the result will become complicated. To choose the alternatives, the benefits and harms should be examined and assessed carefully in terms of their size, effects, durations, importance and urgency. As well as they also should be scrutinized in term of their degree of actuality and certainty. In an attempt to ascertain the implementation of sustainable development vis-à-vis the Shariah, one may refer to some of the principles of *fiqh Al-Aulawiyyat* which offers the art of weighing between the alternatives. Yusuf Al-Qardawi (2000) stressed that safeguarding, protecting and caring for the environment are deeply rooted in all fields of Islamic teaching and culture and when we are facing a conflict to make a desicion, the *fiqh Al-Aulawiyyat* offers the solution: balancing the priority among alternatives without compromise the basic teaching of Islam.

There are many verses in sacred text and Hadith (prophet's say) show how Islam respect and treat the nature. Below are some of the Quranic texts of many which emphasize on caring and appreciating the nature :

"*That Home of the Hereafter We shall give to those who intend not high-handedness or mischief on earth and the end is (best) for the righteous*" (Surah 28, verse 83)

"*Do you not observe that God sends down the rain from the sky, so that in the morning the earth becomes green*" (Surah 22, verse 63)

"*There is not an animal in the earth, nor a creature flying on two wings, but there are nations like you*" (Surah 6, verse 38)

"*Eat and drink but waste not by excess: Verily He loves not the excessive*" (Surah 7, verse 31).

"*Such as remember Allah, standing, sitting, and reclining, and consider the creation of the heavens and earths, (and say): Our Lord!, Thou createdst not this in vain. Glory be Thee!*" (Surah 3, verse 191)

"*They hasten about the Earth, to do mischief there, and God loves not the workers of mischief*" (Surah 5, verse 64)

The practical example of environment-conscious in Islam is the concept of "*hima"*as cited by Mawil Y. Izzi Deen (1990). In Islam, *hima* comes out with a regulation on the management on unowned lands whereby it must be conserved for common use. Historically, the "*harim"* is another ancient institution that manages the ecosystem. *Harim* is usually found in association with wells, natural springs, underground water channels, river and tree planted on barren land and the *harim* zones based on the practice of Prophet Muhammad p.b.h and the precedent of his companions. In addition, the element of respectfulness to other creatures is a apart of Islamic teaching (Figure 3). Thus, this is our responsibility to treat them ethically. Man is not created as a master to conquer the world but as a "*khalifah*" (vicegerent) to manage it with accordance to godly guidelines (sacred text, Koran and Al-Hadis).

"*It is He has appointed you as regents in the earth*" (Surah 35, verse 39)

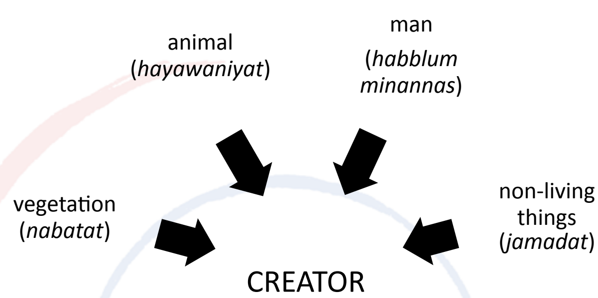

Figure 3 Human relationships with other creatures

3.3 Chemical engineering and sustainability

The chemical based industries have been long known to be the major contributor for many types of pollutions and ecological disturbances, in which it simulate the best example of how human consume natural resources and produces toxic waste as the by product. The chemical engineering practices have undergoes series of evolution to address these issues, starting from pollution control to pollution prevention, green engineering and the latest development was towards sustainability.

Having gone through rapid development during industrial revolution and the emerging environmental awareness, the international scientific community was started to embraced the idea of sustainable development after the publication of a report entitled 'Our Common Future' by the Brundtland Commission in 1987 (J. Garcia-Serna et al., 2007). As far as the chemical industry is concern, the major issues concerning sustainability are the environmental related problems. For example, the carbon emission which leads to the Green House Effect was significantly contributed by the burning of fossil fuels, which is the prime product and core business of the chemical industries. In general, total share of world carbon emission is estimated to increase from 21,518 Million Metric Tons in 1990 to 40,178 Million Metric Tons in year 2030 (Figure 4). This data surely reflect the needs for pre emptive action to be taken in order to minimize the projected impact. If we analyze the data further, we could see that the industrial sector and energy generation are the major contributors for carbon emission.

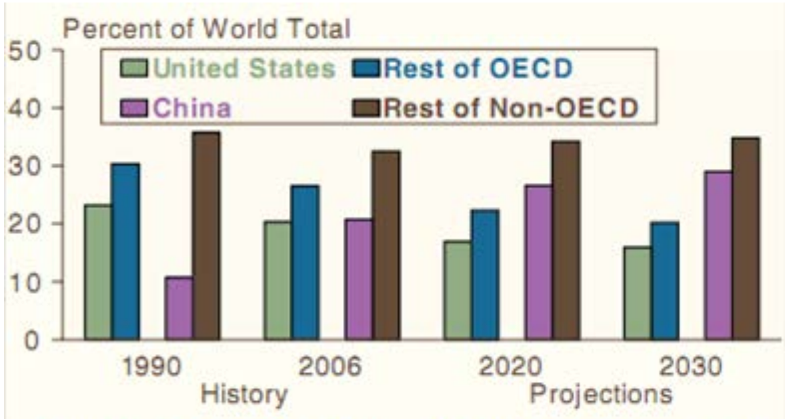

Figure 4: Regional Shares of World Carbon Dioxide Emissions, 1990, 2006, 2020, and 2030 (Source: Article on Emissions of green house gases in the United States 2008, p8)

With more arising environmental global issues other than carbon emission, such as acid rain phenomena, water pollution and industrial disasters, many chemical corporations responded by becoming more environmental friendly and committed to minimize waste emission. On the other hand, it created vast opportunities for the current chemical engineers to take the leading role in promoting and implementing sustainable development.

3.3.1 Current Scenario

In engineering practice, there are four aspects concerning sustainability: the environment, technology, economy, and societal organization (H. Tony Bi, 2005). The traditional approach for most of chemical engineering schools was to produce chemical engineers equipped with sufficient knowledge on technology development and economic analysis, less priority were given on the societal organization and the environmental considerations towards holistic approach of sustainability development. However, due to the increasing awareness of the needs, the modern approach of chemical engineering teachings has incorporated the element of environmental and social obligations into the curriculum structure. R.J Batterham (2006) has suggested a sustainability scorecard to be developed based on the respective areas, shown in Table 1 below. This will enable chemical engineers to identify critical factors in their design considerations towards sustainable development.

Table 1: Critical Elements in Sustainability Scorecard (R.J Batterham, 2006)

Economic	Environmental	Societal
Direct	Material consumption	Quality of life-cycle
Raw material costs	Products & packaging mass	Breadth of products or service availability
Labor costs	Useful product lifetime	
Capital costs	Hazardous materials used	Knowledge enhancement
Operating costs	Eco-efficiency	Employee satisfaction
Potential hidden	Energy consumption	Peace of mind
Recycling revenue	Life-cycle energy	Perceived risks
Product disposition costs	Power in use operation	Community trust

Contingency	Local impacts	Illness & disease reduction
Employee injury costs	Product recyclability	Illness avoided
Customer warranty cost	Run-off to surface water	Mortality reduced
Relationship	Regional impacts	Safety improvement
Customer retention	Smog creation	Lost-time injuries
Business interruption due to stakeholder intervention	Acid rain precursors	Reportable releases
	Biodiversity reduction	Number of accidents
Externalities	Global impacts	Health & wellness
Ecosystem productivity loss	Global warming emissions	Nutritional value provided
Resource depletion	Ozone depletion	Subsistence costs

For current practice particularly in Malaysia, the Malaysian Government through the Engineering Accreditation Council, Board of Engineers Malaysia has responded to this issue by introducing integration between the technical and technological knowledge with the elements of environmental and social obligations as part of the element that need to be address in the curriculum structure of all Malaysian chemical engineering schools. As an example, the Faculty of Chemical & Natural Resources Engineering, University Malaysia Pahang has outlined 10 Program Outcomes (PO) to be achieved by its graduates. As can be seen from Table 2 below, at least 4 out the 10 POs are addressing the elements related to sustainability, in which PO6 deals specifically with understanding the principles of design for sustainable development.

Table 2: Programs Objectives for Faculty of Chemical & Natural Resources Engineering, Universiti Malaysia Pahang, Malaysia

No	Programs Objectives
1	Ability to acquire and apply knowledge of science and engineering fundamentals in chemical engineering and related areas.
2	Ability to communicate effectively, in verbal and written forms, with both technical and non-technical groups.
3	Acquire in-depth technical competence in chemical engineering and related discipline
4	Ability to identify, formulate and solve chemical engineering and related problems
5	Ability to utilize systems approach to design and evaluate operational performance
6	Understanding of the principles of design for sustainable development
7	Understanding of professional, ethical and safety issues in engineering practices, the responsibilities and commitment to them
8	Ability to function effectively as an individual and in a group with the capacity to be a leader or manager
9	Understanding and responsive to the social, cultural, global and environmental responsibilities of a professional engineer
10	Ability to recognize the need for and engage in lifelong learning

Such proactive actions taken by chemical engineering academia to inculcate sustainability was a major contribution towards sustainability development. The importance should be recognized by the society and university's stakeholders by providing support and assistance needed.

3.3.2 New Trends for Sustainability in Chemical Engineering

As discussed earlier, the approach of chemical engineers to address the environmental related issues of the chemical industries has gone an evolution stages. Being the contemporary approach, sustainability development requires chemical engineering students to have a strong fundamental of the underlying philosophy of it. Therefore the knowledge of pollution control, pollution prevention and green engineering becomes a crucial competence that need to be mastered by the current chemical engineers. J. Garcia-Serna *et al.* (2007) have even concluded that the education in Green Engineering is the key weapon to tackle the current needs.

The trend of implementing sustainability in chemical engineering can be observed in two ways, the preventive and reactive approach. The first approach is mainly related to the task for academicians through proper refine of education in the chemical engineering schools. It is through education that we are able to 'organically' produce graduates of chemical engineers with sustainability at heart. The curriculum need to be designed to incorporate the element of sustainability especially in the core chemical engineering subjects such as material and energy balances, unit operations, chemical reactions, heat transfer, thermodynamics, process controls, process plant design and perhaps even in the elective subjects. The approach should be holistic and involvement of private chemical corporations in the process is highly recommended. In this way, it will enables student to really comprehend the real problems face by the industries. Through proper education, the sustainability awareness among future chemical engineers will last longer and they will able to materialize the philosophy when they become the people who will do design and make decision later.

Through the reactive approach, it involves introductions of structured legal framework and regulation related to sustainability. It is the part played mainly by the authoritative body such as the government and the Institution of Chemical Engineers. The developed system must not necessarily that become guidelines for the practical chemical engineers, but it may also comes with the reward and punishment system. The recent example was the concept of Carbon Credit which was brilliantly design to allow the trading of carbon emission. Introducing the economic factor will surely attract the private corporation to positively respond to the call and becomes the motivation factors to reduce carbon emission.

4. Conclusions and discussions

All of all, the integration of working framework for sustainability in chemical engineering are based on two standpoints;- understanding a basis of Shariah as guided in *Fiqh Al-Aulawiyyat* and incorporating ecological principle. Application of *fiqh Al-Aulawiyyat* in decision-making will guide to sustainable outcomes and incorporation of "green" ideas is in-line with the Islamic principle as guided in Shariah. All chemical engineers, particularly Muslim engineers should be equipped with depth-understanding on *fiqh Al-Aulawiyyat* concept and practice "green" approach while handling any issues related to their discipline. The goals of sustainable development can be resulted in success if both spiritual strength and "green" approach come in parallel. Lacking in these values will be a barricade to the success of practical sustainable development.

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“Renovating the industry through energy efficiency projects: A case study of Iranian brick industry.”

By:

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Key words: energy efficiency, financial appraisal, CER, ESCO, industry renovation

JEL code: Q40, Q48, Q51

Abstract

The energy intensity index in Iran is almost the worst in the world and the 100-billion-dollar of energy consumed, is not in accordance with other economic indices in the country. Although the very low energy carrier prices in Iran do not let energy efficiency projects be profitable, regarding the regional prices they are economically lucrative.

This paper has been derived out of a research studying how we can conserve energy in brick industry in Iran. The results show, assuming free access to a regional market to sell the conserved amount of energy, it is economically feasible and attractively profitable.

1. Energy consumption in Iranian industries

Very high energy and more specifically fossil energy consumption has long been an economic and at times political problem in Iran. The amount of energy consumed in Iran in terms of crude oil is about 797.7 million barrels a year, from which 29% is pumped into the industries. On the other hand the energy intensity is twice as much as the world average. In the chart below the amount and value of the yearly consumed energy in Iran is respectively shown.

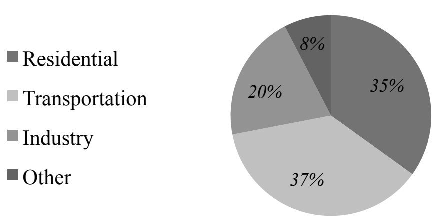

Chart 1. Share of energy consumption in different sectors of the Iran's economy – strategic plan of brick industry (2006)

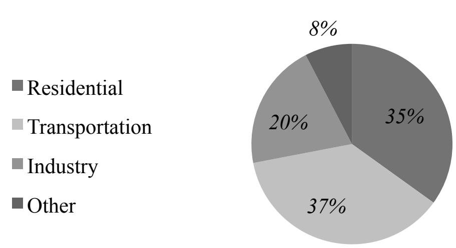

Chart 2. The value of energy consumption in different sectors of the Iran's economy – strategic plan of brick industry (2006)

... ume ... sents only ... ener ... why the energy intensity is this high in Iran, two main reasons can well indicate it:

- Extremely old technology
- Deviated energy carriers prices

The first might as well be the problem in many other developing countries and could not be solved unless a huge amount of investment is directed towards the renovation of the industrial section.

But the second is due to a government policy to support the poor. Subsidies have for decades deviated the consumers' price from the market price. It didn't use to be noticed as a problem until the oil shocks and successive jumps in all fossil energy carriers increased the gap dramatically. Still the consumers were not under pressure but the government was, and this of course was possible only at the cost of ignoring construction projects to finance the yearly increasing subsidies budget.

These frozen prices had lost their role as important signals to make consumers review their consumption pattern and take action to adjust it.

2. Solving the energy problem in Iran

This problem could be solved through two different approaches:

2.1. Price policies

These policies focus on price adjustment and assume as soon as the prices are freed all agents interacting in the economy will have to adjust themselves to the new prices, optimizing their level of consumption and necessarily acting more prudent.

It seems to be rational, but the social consequences advise a second thought. Although the market represents the true value of energy carriers the controversy is wither it can be a short term policy. Agents need time to adjust themselves and it does not happen after an abrupt price freemen and without social unrest.

2.2. Non price policies

These policies focus on how we can lower the level of energy consumption via measures such as renovating the industries. New technologies are supposed to be more efficient. But as long as the prices are so low, there is no incentive to invest on it.

3. ESCOs[1] as a non price solution to a price problem

[1] Energy Services Companies

To get out of this problem we have to think of a new framework which can solve this problem, and lower the energy consumption with no need to free the prices in a midterm outlook.

After the first and second oil shocks a new opportunity was captured in the world to optimize the energy consumption in different sections of the economy. The point is you can lower energy consumption and compensate the expenses using the market value of the margin conserved.

Energy Saving Companies emerged in 1980s and in North America soon spreading the idea through to East Asia. All they do is an energy audit then contracting you using a performance contract.

In this paper the ESCO framework is used to study the feasibility of brick industry renovation in Iran as a case.

4. Brick industry in Iran

As part of the industrial section the brick industry is technologically very old and the energy intensity in this industry is very high. 7000 scattered units produce different types of brick in Iran and the whole industry consumes 36% of the total energy consumption in the industrial section. Very few of the manufacturers are equipped with new technologies and the rest produce low quality expensive brick in comparison with foreign products.

As the bar chart below represents, to produce a kilo of brick in Iran you will need twice as much as energy as you need in European countries.

5. Renovating the industry, the only solution

Producing brick is not as complicated as production in other industries. It's all about drying and then heating the formed mixture of clay and water. This happens in a furnace which is fueled by fossil energy.

Table 1 presents the number of furnaces used in Iran to produce yearly 23 million tons of brick to feed construction projects.

Type of furnace	Number	Production (Million Tons)	Share of production

Hoffman	1500	21	91.3%
Tunnel	18	2	8.7%

Table 1: brick production in Iran in terms of furnaces types- strategic plan of Iran brick industry (2006)

Hoffman furnaces which account for more than 90% of production, are supported by a very old, non efficient technology. On the other hand more efficient Tunnel furnaces need half as much fuel as is burned in Hoffman ones to produce the same amount of brick.

Table 2 compares these two technologies, as is shown, to produce one ton of brick you'll need 118.4 liters of fuel oil in a Hoffman furnace and 56.4 liters of fuel oil in a Tunnel furnace. It is a plausible difference, but as long as the government provides the manufacturers with subsided prices- 17 cents for a liter of fuel oil, there would be no production cost pressure to make the producers enhance the technology and increase energy efficiency.

	Furnace energy use (liter/ fuel oil)	Dryer energy use (liter/ fuel oil)	Reused energy ((liter/ fuel oil))	Total energy use (liter/ fuel oil)
Hoffman	90.2	28.2	0	118.4
Tunnel	45.1	28.2	16.9	56.4

Table 2. Comparing two technologies - strategic plan of Iran brick industry (2006)

Nothing can be done to ameliorate the existing technology and the only solution is to replace the old Hoffman furnace technology with the new Tunnel furnace.

5.1. Assumptions:

To simplify the study of what would happen if all the brick demand in Iran were met through producing it in Tunnel furnaces, some assumptions are needed to be made:

1- The new technology has to be imported
2- The amount of energy needed to produce brick in Iran, is equal in different provinces of the country
3- A furnace can be used for 25 years
4- The carbon emission reduction due to renovating the industry can be traded
5- The actual yearly production of brick in Iran is 21 million tons which is a basis for the calculations

6- The average carbon emission due to burned a liter of fuel oil is the same in different parts of the country.

5.2. Cost and benefit variables

To renovate the whole industry the expenses would be:

- Tunnel Furnaces
- Dryers
- Site preparation and installation

According to the currently accessible markets[2], a furnace can be bought for 1.4 million Euros and a dryer would be .9 million Euros. The nominal capacity of such furnace is 120 tons a year.

To produce 21 million tons of brick in Iran, 175 furnaces would be needed. Besides, site preparation and installation comes to 20 billion Rials for each furnace.

The revenue side includes:

- Saved energy
- Carbon Emission Reduction (CRE)

The amount of the saved energy after installing Tunnel furnaces is about 1.28 billion liters of fuel oil a year. Regarding the average fuel oil price in 2008, it would be .5 dollar a liter (Persian Gulf FOB price)

Carbon emission reduction can now be traded based on the Kyoto Protocol, and each CER has been traded for about 12 Euros. The future prices are also available and for each farther year a Euro is added to the base price.

5.3. Sources of finance

- Iranian banks
- Foreign banks

It is assumed the Iranian banks provide the industry with 12% interest rate loans covering the site preparation and installation expenses and foreign banks such as WB provide 6% interest rate loans covering the furnace and dryer purchase expenses.

The repayment period is set to be 10 years.

6. Methodology

As a financial feasibility study the cashflows are calculated to find the following indices: NPV, IRR, ROI and payback period.

[2] Iranian Fuel Conservation Company

NPV, or net present value is the accumulation of discounted net flow of the project over its life. The formula below is used to calculate it:

$$R_i\text{-}C_i)/(1+r)^i] \qquad)[\sum \quad NPV=$$

In which R_i is the revenue in the ith year, C_i is the cost in the ith year, r is the discount rate. i starts at zero.IRR, the internal rate of return, is the discount rate at which the NPV equates zero. ROI is the net present value per unit of initial investment, and payback period is the time the project needs for the accumulated discounted net cashflow to be zero.

7. Calculations:

Based on the provided data, the following tables present the results:

68.25%	IRR
3.40	NPV(Billion USDs)
4.16	ROI
2.66	Payback Period (years)

Table 3 Financial results – the authors' calculations

Since the oil prices fluctuate due to numerous reasons, it is possible the results are negatively affected. Through a conducted sensitivity analysis, even if the fuel oil price drops 50%, the IRR would be 34.6% which still is far more than the threshold we expect.

The following table also modifies the results for when the CER in omitted as a revenue variable:

IRR	-50
NPV (Billion USDs)	3.32
ROI	4.08
Payback period	2.83

Table 4 Financial results excluding CER – the authors' calculations

These calculations are based on an assumption, which states the conserved energy can be traded at FOB Persian Gulf prices, and that the government facilitates the process. Otherwise at local prices (less than 2 cents!) the result would be as table 3 displays:

NPV (Billion USDs)	-.577
ROI	-0.71

Table 5 Financial results at local energy prices – the authors' calculations

8. Conclusion

Although unreal prices are certainly a problem in Iranian industries, there are still non price solutions to solve this price problem. ESCOs framework lets Iranian industries get renovated and simultaneously leads to considerable energy conservation which itself, finances the project provided that the path to trade the conserved amount at regional prices is paved by the government.

However it is not a long term resolution, in the short term it prepares the industries to tolerate the real prices by decreasing their dependency on fossil energy.

This paper is just one case out of hundreds which illustrates the vital need to taking new approaches towards energy efficiency problem in Iran.

On the other hand these projects can be labeled "green" due to the emission reduction which is a by-product after the industry is renovated.

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Explaining the Adoption of Sustainable Agricultural Practices: An Improved Integrative Agent-Based Framework

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ABSTRACT

Despite the need to improve the sustainability of agricultural systems, adoption of sustainable agricultural practices (SAPs) has been disappointedly less prevalent. By ignoring interaction and feedback between and within system components, relevant past studies which used reductionist approaches have offered limited knowledge in explaining why farmers have either adopted or have not adopted SAPs. To fill this research gap, this paper proposes an improved integrative agent-based (IAB) framework, which is built on recent work in ecological economics. It is envisaged that this will assist future research on the adoption of SAPs. Responding to requirements of effective research on the issue, the general system theory (GST), the theory of interpersonal behavior (TIB), and the theory of diffusion of innovation (DOI) are integrated on a platform of agent-based framework. As a whole, the TIB emphasizes psychological and social factors in shaping behavior; the DOI theory enhances the TIB by considering mental persuasion and information; and the GST captures behavioral input-output feedback cycles, social-ecological interlinks, and social interactions. This improved IAB framework will be tested in our impending investigation on the adoption of SAPs within complex agricultural systems. We hope to demonstrate conclusively that this framework can be used to advance a better understanding of the adoption of sustainable agricultural innovations.

Keywords: adoption, sustainable agricultural practices, integrative agent-based framework

1. Introduction

Realization of unintended externalities has led to the emergence of widespread promotion of sustainable agricultural practices (SAPs) in individual countries. SAPs, as defined by the Food and Agriculture Organization (FAO) of the United Nations, are environmentally non-degrading, resource conserving (of land, water, plant and animal genetic resources)[2], socially acceptable, technically appropriate, and economically viable (Loftas, 1995). However, the adoption of SAPs

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[2] Given that resource conservation is a subset of SAPs, we recognize conservation technologies as SAPs in this paper.

has been less prevalent across developed countries (Caswell et al., 2001; Horrigan et al., 2002) and developing countries (Barrow et al., 2010; Li et al., 2010).

In explaining why farmers have either adopted or not adopted SAPs, the current state of the research frameworks is fragmented (Karami and Keshavarz, 2010). Relevant past studies have been locked into using reductionist approaches. These reductionist approaches dissect their subjects into smaller and specialized parts (Lewis et al., 1997), assuming that interactions and feedback between and within system components are negligible (von Bertalanffy, 1968). These omissions are neither adequate to explain the difference in farmer behavior (Galt, 2008) nor sufficient to generate operational knowledge for policymakers (Dent et al., 1995).

Limitations offered by reductionist approaches have led to empirical question of their importance as research tools (Burton, 2004). New methods must be devised to advance understanding of the adoption of SAPs (Costanza et al., 1993). To fill these gaps, this paper proposes an improved integrative agent-based (IAB) framework for future research on the adoption of SAPs. This framework is built on Feola and Binder's (2010a) recent work in ecological economics. This paper also responds to various empirical calls for employing an integrative approach (e.g. Barrios and Sarte, 2008; Gliessman, 2005; Karami and Keshavarz, 2010; van der Fliert and Braun, 2002), which has not been well-developed and towards attaining a refined understanding of the phenomenon.

2. Requirements for effective research on the adoption of SAPs

Under voluntary schemes, understanding of the adoption of SAPs needs to be subscribed differently from technology adoption (Saltiel et al., 1994; Vanclay and Lawrence, 1994). Policies of SAPs, by and large, are responses to detrimental changes in agricultural systems. Their ultimate objectives are to yield behavioral changes to adopt recommended SAPs. Given their peculiarities, Karami & Keshavarz (2010) suggest that effective research on the adoption requires an understanding of agricultural systems, farmer behavior, diffusion, and integration.

2.1 Agricultural systems

Agricultural systems are formed by interdependent ecological subsystems and socio-economic subsystems (Alrøe and Kristensen, 2002; Conway, 1987; Dent et al., 1995; Folke et al., 2005; Spedding, 1988). The sustainability of agricultural systems is inexorably linked with dynamic feedback processes within and between ecological and socio-economic subsystems (Park and Seaton, 1996).

Feedback processes within ecological subsystems involve observations of changes in a variety of biological, chemical, and physical stimulus (Simmons, 1996). Slightly different, feedback within socio-economic subsystems is transmitted through communications, observations, and actions among social members and institutions (Sundkvist et al., 2005).

The relationships between ecological and socio-economic subsystems can be understood as agricultural activities depend on the health of ecologies, and the health of ecologies depends upon respectful agricultural activities (Conway, 1990). Their interdependence is described by their relationship and feedback processes from outputs to its source of inputs. They interact with each other (Benveuti, 1975; Noe and Alrøe, 2003) and co-evolve (Norgaard, 1984; Waring, 2010).

Humans are regarded as the integral part of ecosystems (Karami and Keshavarz, 2010; Matthews and Selman, 2006; McDonnell and Pickett, 1993; Vitousek et al., 1997). Improvement in sustainability is possible with enhanced ecological and socio-economic feedbacks to the actors (Lewis et al., 1997). These feedbacks, as consequences or messages, convey information about the outcomes of their activities back their sources (actors) (Capra, 1996). Subsequently, actors are influenced indirectly by the changes they have induced (Sundkvist et al., 2005).

2.2 Farmer behavior

The aforementioned discussion reveals that farmers are the key actors, therefore, there is a need to acquire a step-up understanding of their behavior within agricultural systems (Edwards-Jones, 2006; McGregor et al., 2001; Pearson, 2003). "Behavior" refers to the actual physical act of using or performing SAPs. Adapting Rogers' (2003) definition, behavioral change in the form of adoption is a decision of a farmer to apply SAPs as the practices are readily available in agricultural systems.

Typical understanding of farmer behavior depends on attitudes, normative beliefs, subjective norms and cognitive controls. Attitudes are the central disposition to respond favorably or unfavorably to SAPs which results from an agent's beliefs (evaluations) of particular behavior (Bayard and Jolly, 2007; Karami and Mansoorabadi, 2008; Vignola et al., 2010). Normative beliefs take into account significant peer judgment and subjective norms express social group expectations in influencing an agent's perceptions concerning particular behavior (Ajzen, 1991). Behavior is better explained by incorporating cognitive controls, which reflect an agent's perceived ease or difficulty and his ability to perform a particular behavior (Bergevoet et al., 2004; Mullainathan, 2007; Tutkun et al., 2006).

In addition, humans are habit bound (Klockner et al., 2003; Tarkiainen and Sundqvist, 2009). Behavioral change requires breaking old routines and establishes new ones (Dahlstrand and Biel, 1997). Contextual forces like socio-economic factors, biophysical conditions, institutional endowments and informational influences may bolster or deter an agent's behavior.

In short, sustainable behavior is a function of an agent's attitudinal factors (attitudes and norms), capabilities, habits and contextual factors (Stern, 2000b). It is worth noting that the importance of these behavioral formation factors varies across agents, areas, and behaviors (Stern, 2000a).

2.3 Diffusion

Adoption of SAPs is the result of diffusion, which describes the communication process of an innovation through certain channels, over time, and among members of that social system (Rogers, 2003). From this definition, innovation, communication channels, time, and the social system are the main elements in diffusion. First, an innovation is a practice, product or system that is newly perceived by an agent. Perception towards its characteristics affects the adoption rate of SAPs. Second, communication channels are the means of sharing and exchanging information in relation to the innovation. Third, time is involved in the innovation-decision (adoption) process and adoption rate at any given period. Fourth, diffusion takes place, to achieve a common goal, within a set of the interrelated units of a social system.

The diffusion of SAPs involves interaction between individual farmers and their social members in sharing and exchanging related information. Because most decisions are made on the basis of inadequate information (Vallentyne, 1992), messages passed from one person to others should intuitively have significant effects on their decisions. In turn, this will result in a behavioral change at the micro level and a social change at the macro level (Valente and Rogers, 1995).

2.4 Integration

Integration is required to better understand farmer behavior in relation to sustainability in agricultural systems (Belcher et al., 2004; Park and Seaton, 1996). Given that farmer behavior is a result of multi-disciplinary considerations (Conway, 1985), integration of the abovementioned multi elements of farmer behavior within agricultural systems appears to be required (Gliessman, 2005; Renting et al., 2009).

Complexity of farmer behavior is characterized by inter-relationships, interactions, reciprocal feedbacks, and non-linear (dynamic) processes of multi-components (Galt, 2008; Rossing et al., 2007). Such complexity requires simultaneous understanding from various relevant perspectives (Mayumi and Giampietro, 2006). Failing to link these perspectives can lead to severe misperceptions and skewed policy development (Costanza, 1987).

3. Recent work in ecological economics

Studies in ecological economics (e.g. Bekele and Drake, 2003; Calkins and Thant, 2011; Galt, 2008) have integrated ecology and economics or socio-economic and ecological subsystems. Among studies of ecological economics, Feola & Binder's (2010a) IAB framework is considered a valuable adjunct to future studies.

When most research efforts have paused at theoretically conceptualizing the integrative approach (Liu et al., 2007), Feola & Binder (2010b, c) have empirically analyzed the IAC framework. The framework not only addresses the complexity of systems, but also provides insights on farmer behavior within agricultural systems. Their framework integrates socio-economic subsystems, ecological subsystems, and farmer behavior. Altogether, these components are based on the integration of agent-based Giddens' (1984) structuration theory (ST) and Triandis' (1977) theory of interpersonal behavior (TIB).

3.1 The structuration theory (ST)

According to Giddens (1984), the ST aims to balance the duality of the social system. The duality of the social system is characterized by structures, modalities, and interactions. Social structures (macro-level) anticipate certain actions by agents (micro-level). The means to translate social structures into action are known as modalities. In turn, the modalities of agents within the social system interact accumulatively to create social structures.

Giddens (1984) points out that the social structures of the ST are the reflexive monitoring of agent action in social systems. Social reflexivity represents recursive macro social reproduction, which conforms or modifies through impulsive self-regulation for intended consequences and a homeostatic loop for unintended consequences. Agent reflexivity implies a micro social reproduction that responds to changes of social structures within the specific configurations of rules and resources. Therefore, the ST is credited as allowing for non-linear equilibria of societal progress as self-modifying or self-organizing systems (Fuchs, 2003, 2006).

The ST is commonly used to investigate dynamic interactions, feedbacks, and interlinks in social-ecological studies (Binder, 2007; Binder et al., 2004; Feola and Binder, 2010b, c; Geels and Schot, 2007; Warren, 2005). However, it does not hold a strongly defined position within conceptualization and in respect to empirical application. In previous research, Pozzebon & Pinsonneault (2005) and Archer (1990) attempt to address its complexity in conceptualization, largely due to its abstract concepts and general propositions. They also recognize its difficulty in the empirical application, particularly in integrative applications with other research method(s).

3.2 The theory of interpersonal behavior (TIB)

Triandis' (1977) TIB explains mechanisms of behavior resulting from complex interpersonal encounters within and outside an agent. The agent behavior is jointly determined by facilitating conditions, habits and behavioral intentions. Behavioral intentions are influenced by normative, subjective, cognitive, and affective antecedents. Any behavior is expected to lead to outcomes in the forms of perceived consequences.

The TIB shares some similarities with Ajzen's (1985) theory of planned behavior (TPB) but there are three distinct differences between them. First, the TIB considers the facilitating conditions, habits and behavioral intentions as key determinants to behavior; whereas the TPB posits that behavior is a direct function of behavioral intentions. Among these, the TIB goes beyond the weakness of the TPB in providing for a theoretically derived inclusion of facilitating conditions. Facilitating conditions are similar to perceived behavioral control in the TPB, which considers an agent ability to perform an act. Second, the TIB takes into account social roles and the values of an action in addition to the subjective norms of the TPB in explaining partial behavioral intentions. Third, the TIB differentiates the concept of attitude. In the TPB, attitude denotes only emotional responses. Conversely, the TIB defines emotional responses as "affect" and "attitude" as expectation of the occurrence of perceived consequences.

In addition, perceived behavioral consequences serve as potential reciprocal exchange nodes in modifying the constructs, which determine behavior (Triandis, 1977). By capturing most constructs, the TIB offers a comprehensive theoretical heuristic framework that can flexibly work in different situations. In summation, the TIB is considered appropriate to the integrative investigation of agent behavior within complex systems (Jackson, 2004).

As to its applicability in social-ecological subsystems, Feola & Binder (2010a) point out that complex issues of interactions, feedbacks, and interlinks are not well considered within the TIB. Although an agent's action is restricted by contextual factors, the emergence of those factors is in turn affected by the consequences of his action. However, the latter is not considered in the TIB. Despite depicting the one-way influence of social groups on an agent's behavioral intention, the TIB does not include interactions of the consequences that are derived from his action in relation to forming social phenomenon. Within an agent's decision-making process, the TIB does not capture the feedbacks of his behavioral outcomes in modifying his expectations in attempting the repetition of an action.

3.3 The integrative agent-based (IAB) framework

To capture system dynamics, Feola & Binder (2010a) integrate the TIB with the ST. However, its application in Feola & Binder (2010b, c) has been less convincing in understanding farmer behavior within complex agricultural systems.

Recalling that the ST's intent is to integrate micro actions to construct macro social structures, it does not provide theoretical motivations to take account of dynamic processes within individual decision-making processes and between socio-economic and ecological subsystems. Therefore, it is puzzling to understand how the consequences of behavior can be linked, theoretically, to (1) changes in ecological subsystems, which in turn modify the behavior as demonstrated by Feola & Binder (2010b) and (2) phenomena in socio-economic subsystems, which subsequently induce behavioral adjustment as established by Feola & Binder (2010c).

In tandem with the identified questions of theoretical construct, using Feola & Binder's (2010a) own words, their application of ST integrated with TIB is not based on well-grounded theory. Considering these challenges, Bell (2005) suggests that the general system theory (GST) is more useful than the ST in capturing system dynamics.

4. Towards an improved integrative agent-based (IAB) framework

Even though Feola & Binder's (2010a) IAB framework suffers some deficiencies, they have underscored fundamental considerations in our interest to understand farmer behavior with regard to the adoption of SAPs within complex agricultural systems. We are cognizant that farmers are the integral agents of interacting socio-economic and ecological subsystems (Gliessman, 2005). Investigation of the adoption of SAPs must go beyond singular approaches. Future effort should integrate farmer behavior, diffusion, and their interacting socio-economic and ecological subsystems for the study of the adoption of SAPs (Karami and Keshavarz, 2010).

An integrative approach may synthesize two or more methodologies to form a pluralistic framework, despite their varied underlying assumptions (McGregor et al., 2001). Progressing from Feola & Binder (2010a), we propose retaining Triandis' (1977) TIB and integrating it with von Bertalanffy's (1950) GST and Rogers' (1962) theory of diffusion of innovation (DOI). We justify this integration since all three are built upon platform of agent-based frameworks.

4.1 The general system theory (GST)

Von Bertalanffy's (1950) GST elaborates properties, principles, laws, nature of component elements, and their interrelationships in systems. Against reductionist theories, it recognizes that each subsystem is independent, though nevertheless interlinked by relationships to form a complex whole for a common purpose (von Bertalanffy, 1965). It explores the sum of subsystems and the wholeness of systems (van Dyne and Abramsky, 1975).

The focal point of the GST is in developing systematic frameworks for describing general relationships in complex systems (Johnson et al., 1964). Through the biological principle of isomorphism, which is a structural similarity between an abstract model and an observed phenomenon, it can be applied to any system that is formed by interacting subsystems (Kissen, 1980). It can be considered as the integrator of multi-disciplines (Dent, 1975).

Although Bell (2005) suggests a more plausible use of the GST than the ST, it is important to shed some light on the GST in respect to its applicability in our interest. In open systems such as those illustrated by Skyttner (2002), subjects are self-contained in respect to both inputs and outputs. The latter interacts with environments and social groups. In turn, the subjects are dependent upon environments and social groups. In view of such peculiarities, it is able to deal with inputs and outputs, the formation of social structures, and interactions between subsystems within human-dominated systems (Chen and Stroup, 1993; Kast and Rosenzweig, 1972). It goes beyond the building of social structures, which is the main contention of the ST.

In addition, the GST is psycho-physically neutral in dealing with material and non-material phenomena (von Bertalanffy, 1967). In non-material phenomena, it accounts for the feedback processes of psychological transformation, adaptation, information, learning, motivation, and interaction as the realities of human beings (van Gigch, 1991). It has been extended to understand consumer behavior within marketing systems (Njite et al., 2008; Sirgy, 1985) and farmer behavior within social-ecological subsystems (Benveuti, 1975; Kaine and Cowan, 2011).

Examining the GST's applicability in specific contexts, including human-dominated social-ecological systems, major criticisms are leveled at its concepts. Its concepts are vague (von Bertalanffy, 1965). It lacks a structured core and is without real contents (Peery, 1972). In view of that, it is reasoned that it is principally applicable to all systems (Dubrovsky, 2004). However, the GST offers more of a philosophical conceptualization than an operational mechanization (van Dyne and Abramsky, 1975). It is difficult to quantify mechanisms based solely on the GST (Lin and Cheng, 1998). While these criticisms are not blindingly driven, the GST offers extensive flexibility for integrative investigation (Chen and Stroup, 1993; Gulyaev and Stonyer, 2002; Johnson et al., 1964; Peery, 1972; von Bertalanffy, 1972). It can be used to complement traditional approaches in understanding behavioral realms (Skyttner, 2002).

4.2 The theory of diffusion of innovation (DOI)

Based on Rogers' (1962) theory of DOI, the adoption journey is the mental process through knowledge and persuasion, to decision, facilitated by communication. These processes are not independent but rather interrelated.

In the first stage, an agent becomes aware and gains knowledge of innovations. These are made possible by interactions that expose him to innovations in accordance with his previous practices, needs, interests, and social norms. Degree of knowledge is also partially a function of socio-economic characteristics, personality variables, and communication behavior. Characteristics of the decision-making unit, then, influence his mental persuasion in the second stage. The mental persuasion occurs in the forms of subjective perceptions toward the characteristics of any innovations. However, his attitude may interpose themselves between knowledge and adoption if the information is irrelevant to his interest or if the information is inadequate to form mental persuasion (Rogers, 1995).

In retrospect, Rogers (1962) identifies communication as one of the crucial keys to the adoption of innovation. Against most related studies, which have banked on access to information, Schreinemachers et al. (2009) have decently revisited adoption. They interoperate adoption as an agent's rational decision after processing information and messages. An aggregate pattern of DOI emerges when interactions take place between agents. In particular, adoption of agricultural innovations is a complex system behavior. Therefore, adoption at micro levels and diffusion at macro levels is not independently isolated.

However, the adoption process does not necessarily follow Rogers' (1962) linear flow. Despite being a complex behavior in systems, the linear framework tends to restrict adoption to a rational and planned process (Fliegel, 1993). Consequently, the adoptive decisions are oversimplified (Baerenklau, 2005). Conversely, adoption process may not go through or follow the suggested stages.

Nevertheless, the rubric of the adoption process is not completely useless. Information, communication, and the perceived characteristics of innovations can contribute partly to the understanding of the adoptive decision-making process (Alonge and Martin, 1995). As witnessed by Jackson et al. (2006), there has been a resurgence of diffusion framework concepts in SAPs studies (e.g. Forte-Gardner et al., 2004; Neill and Lee, 2001; Parra-Lopez et al., 2007).

4.3 The improved integrative agent-based (IAB) framework

Overall, the TIB, the GST, and the theory of DOI can be integrated on the basis of their being agent-based. Their integration complements the weaknesses of single approaches. While the TIB offers a great deal towards understanding behavioral constructs, the theory of DOI enhances its robustness to cater for illustrating adoptive decisions, which is also known as behavior. The theory of DOI provides greater facilitating factors that may informatively alter the agent's behavior. Since beliefs are formed from perceptions (Pennings and Leuthold, 2000), the perceived characteristics of innovations in the theory of DOI can be fitted within the dimension of attitude formation in the TIB. The GST frames system dynamics, which are offered by neither the TIB nor the theory of DOI. The GST enables (1) feedback processes within an agent, (2) interlinks between socio-economic and ecological subsystems, and (3) interactions between micro and macro levels.

An agent is reflexive, rational, and societal. He may change his behavioral choices after (1) observing outcomes of his actions, (2) learning the impacts of his actions on the ecological subsystems, and (3) interacting with their social groups. With such conceptualizations, we posit that the TIB, the GST, and the theory of DOI can be integrated to build an improved IAB framework for probing the adoption of SAPs.

5. Theoretical concepts of the improved integrative agent-based (IAB) framework

Our proposal of the improved IAB framework is presented in Figure 1. This framework is built on an agent-based platform. The platform pre-supposes that behavior is a function of contextual factors, habits, perceptions, and intentions. Adapting Triandis' (1977) formula, it can be expressed in a model as follows:

$$B = F * (w_H * H + w_P * P + w_I * I) \quad (1)$$

where

B is the behavior;
F is the contextual factors;
H is the habits to act;
P is the perceptions;
I is the intentions; and
w_H, w_P, w_I refer to the weights of habits, intentions, and perceptions, respectively.

According to Triandis (1977), behavior (act) as a dependent variable can be measured by intensity or probability of occurrence. Among these, probability of occurrence can be appropriately used to measure the adoption of indivisible agricultural practices, like SAPs.

Contextual factors (F) are those external factors outside of agent control. They may either facilitate or constrain the agent's ability to carry out an act. Socio-economic, agro-ecological, and institutional factors are important aspects among the contextual factors. The act is further facilitated when he has knowledge (Triandis, 1977) by obtaining relevant information (Rogers, 2003).

Habits (H) represent repeated actions. Habit to act is traditionally measured by the number of times that act has already been carried out by the agent (Triandis, 1977). While frequency of carrying out indivisible agricultural practices is difficult to quantify, duration of adoption can be used as the proxy to describe the repetition level of the act.

Perceptions (P) refer to the mental persuasion of the agent. It can be predetermined by various contextual factors. Regardless of whether the agent has full or partial information of relevant agricultural practices/technologies, he rationally undergoes self-evaluation based on his perceptions. These are generally known as perceived characteristics (Rogers, 2003).

Intentions (I) imply a cognitive instruction to carry out an act (Triandis, 1977). A general intention, such as "to farm in a sustainable way" can lead "to the adoption of SAPs," as an antecedent of an act. This is determined by social factors, affect, and attitudes. Their relationship can be expressed as follows:

$$I = w_s * S + w_{AF} * AF + w_{AT} * AT \qquad (2)$$

where

I is the intentions;
S is the social factors;
AF is the affect attached to the behavior;
AT is the attitudes towards the behavior; and
w_s, w_{AF}, w_{AT} refer to the weights of social factors, affect, and attitudes, respectively.

Social factors (S) ascribe similarities and differences to what people think about social behavior (deriving from the relationship between the agent and his surrounding human systems). They include social norms, roles, and self-image.

Social norms explain the observable regularities in human environment (Skyttner, 2002). They are the established behavior patterns for members of a social system (Rogers, 2003). They form beliefs that certain behaviors are appropriate, correct, or desirable as viewed by the agent's social groups (Triandis, 1977).

Roles refer to a set of behaviors, which are appropriate, in relation to his particular position in the social systems (Triandis, 1977). In hierarchical agricultural systems, behaviors associated with the position of an opinion leader are examples of role behaviors. He faces social pressures to be innovative and is one of the first expected to adopt new practices.

Self-image reflects self-attributed traits about who he is (Triandis, 1977). If a farmer considers him as "environmentalist", he is more likely to have similar behavioral intentions to adopt SAPs.

Affect (AF) attached to the behavior refers to the agent's emotions toward a behavior (Triandis, 1977). His emotions may include positive or negative and strong or weak internal feelings. If a farmer feels that application of animal manures is disgusting, he does not have the stimulation to shape favorable behavioral intentions towards applying animal manures.

Attitudes (AT) can be understood as the expected consequences of the act (Triandis, 1977). Attitudes are the results of an agent's enduring beliefs that indirectly predispose his actions (Rogers, 2003). These beliefs are developed from his self-perceptions that have mentally evaluated characteristics of practices/technologies.

In Equations (1) and (2), weights are attributed to the different variables. Feola & Binder (2010a), assign weights as valued by the agent However, Triandis (1977) argues that these weights correspond to correlations among the variables of an equation. They can be estimated by multivariate analysis. Knowing the estimated coefficients (weights), we can predict the probability of occurrence (e.g. adoption).

It is, hopefully, clear that the improved IAB framework is dynamic. First, while social factors indirectly influence an agent's behavior, accumulative behavior at the micro level leads to social change at the macro level (Rogers, 2003). Neither an agent nor the social systems, within which he operates, are isolated. Second, outputs of an act provide feedback and generate inputs directly to an agent (von Bertalanffy, 1965). They are used for reinterpretation within his decision-making processes by modifying his intentions, affects, and habits (Triandis, 1977). Third, the consequences of the agent's behavior are associated with changes in contextual factors (von Bertalanffy, 1965). Their interconnectedness can be seen as interlinking socio-economic and ecological subsystems (Conway, 1987).

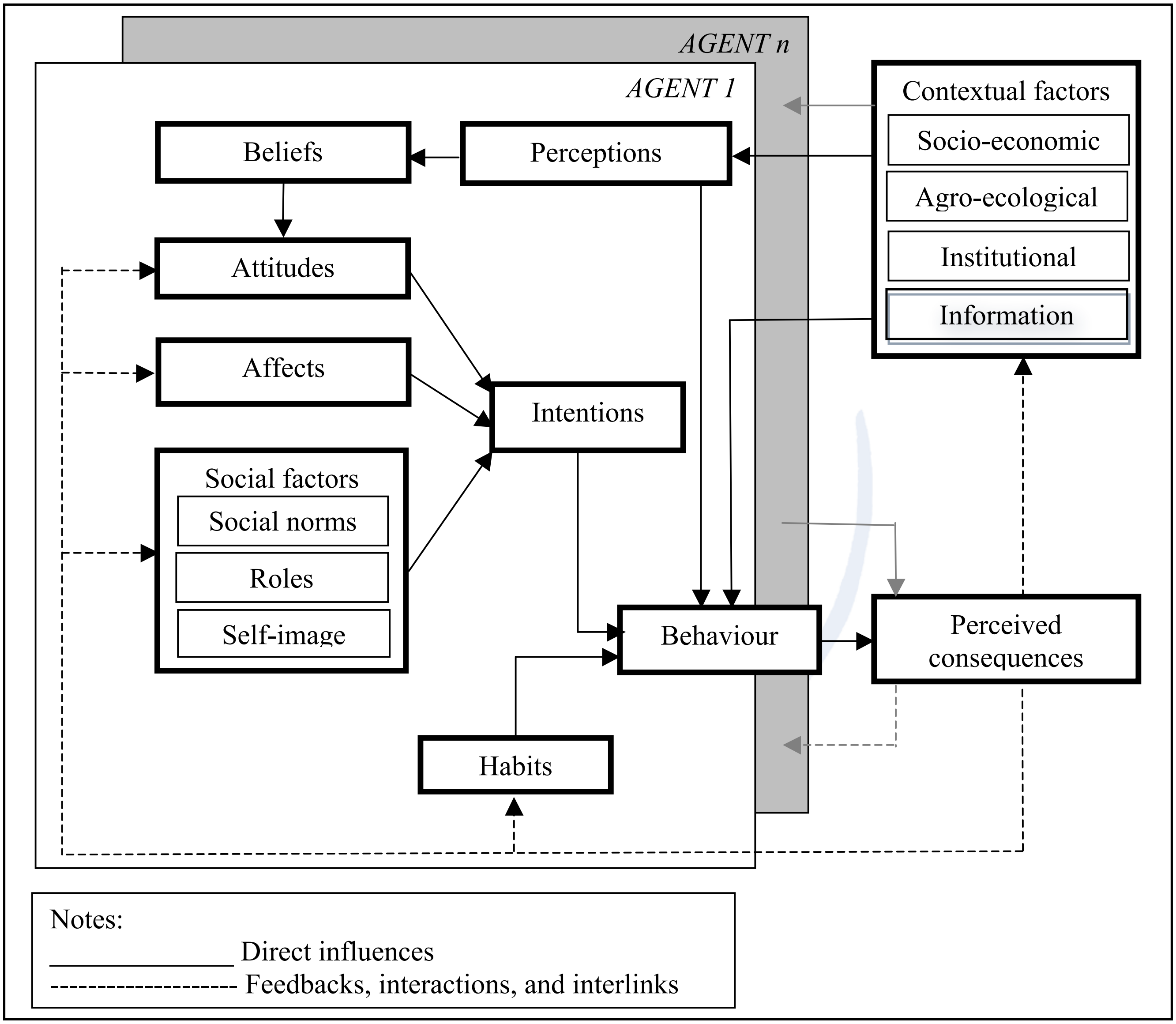

Figure 1 The improved integrative agent-based (IAB) framework (adapted from Feola & Binder (2010a))

6. Discussion

The improved IAB framework has the flexibility to support research designs and methodologies. As suggested by Feola & Binder (2010a), the integrative framework can be used to analyze its pan-model and sub-models. They can be applied to cross-sectional studies, longitudinal studies, comparative studies, and simulation studies using qualitative and/or quantitative method(s). Being preliminary work on the social-ecological systems research, cross-sectional data can be used to analyze the systems model provided that the framework is consistent with social reality (Straus, 1973).

However, application of this improved IAB framework is not without challenges. Initially, Godin (2008) argues that the TIB provides relatively hazy guidelines. Variables in the TIB are not as clearly defined as the TPB. Their measurements (e.g. type of scale) also vary across populations. Given their increasing application in literature, these issues can be overcome by referring to related successful past studies.

In addition, the robustness of a framework does not warrant its final completeness. This framework consists of an interdependent relationship: an independent variable in an equation is a dependent variable in another equation. Indeed, farmer decision-making processes are not easily modeled and estimated using econometric methods (Willock et al., 1999). Multivariate analysis is recommended to deal with such complication in complex systems (Littlejohn, 1996).

8. Conclusion

To fill research gaps limited by reductionist approaches, this paper proposes an improved IAB framework for future investigation on the adoption of SAPs. This framework is built upon recent empirical work in ecological economics. It corresponds to the suggested effective research requirements, including an understanding of agricultural systems, farmer behavior, diffusion, and integration.

Recognizing that farmers are the integral agents of adoption, the GST, the TIB, and the theory of DOI are integrated into on a platform of agent-based framework. As a whole, the TIB emphasizes psychological and social factors in shaping behavior; the theory of DOI enhances the TIB by considering mental persuasion (perceptions) and information (as an additional facilitating factor); and the GST captures behavioral input-output feedback cycles, social-ecological interlinks, and social interactions. Together, then, this framework incorporates mental, psychological, social, socio-economic, agro-ecological, institutional, and informational components.

Ultimately, the improved IAB framework will be tested in our impending investigation on the adoption of SAPs within complex agricultural systems. Through this prospective research, we seek to demonstrate conclusively that this framework can be used to advance a better understanding of innovation adoption, which, hopefully, will provide an innovation capable of planning and realizing sustainable agricultural systems.

Acknowledgement

This paper is part of a PhD research at the University of Adelaide. The realization of the research project is made possible by the Adelaide Scholarship International from the University of Adelaide to Yeong Sheng Tey. The research project is also part-funded by the Universiti Putra

Malaysia's Research University Grant Scheme. We thank Mark Brindal and Cheng Wee Tan for proofreading earlier versions of this paper.

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Title: Chemical Reaction Method to Utilize Geothermal Energy

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Chemical Reaction Method to Utilize Geothermal Energy

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Abstract

World's energy consumption is increasing drastically and the dependence on fossil fuels cannot be expected the basis for sustainable growth. Consequently, there is an inevitable need for alternate sources of energy. One of potential alternative is geothermal energy, which can be utilized in electric as well as non-electric forms.

There exist various techniques to harness geothermal energy in form of electric energy. The major disadvantage associated with these methods is that they do not work below a particular temperature range, so it is not possible to harness the geothermal energy from low temperature zone. Hence, we are not able to utilize those geothermal zones to produce electricity and it calls for a new technique to mitigate this disadvantage. The proposed technique named as 'Chemical Reaction Method' (CRM) which can theoretically work at any temperature to produce the electricity. The paper discusses the proposed method along with fundamental principle, working of plant and other features.

Keywords: Geothermal Energy, Geothermal Harness Technique, Chemical Reaction Method, Renewable Energy.

1.0 Introduction

The word geothermal is originated from Greek words 'geo' (earth) and 'therme' (heat) which means the energy contained in the interior of the Earth. As world's energy consumption has increased many folds and conventional energy sources like fossil fuels are limited so renewable energy sources like geothermal, solar, wind energy etc are attracting industries' attention. Geothermal might be one of the important sources of energy and is being utilized in electric as well as non-electric form. To put into perspective, the geothermal energy in the uppermost six miles of the Earth's crust has been identified with potential of 50,000 times the energy of all oil and gas resources in the world [1] but existing techniques are not even able to harness fraction of this vast resource.

Resources of geothermal energy range from the shallow ground to hot water and hot rock found at few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock as the temperature in the earth's interior is as high as 7000°C and decreasing to 650 - 1200°C at depth of 80km-100km [2]. Direct or non-electric utilization of geothermal energy refers to the use of the heat energy whereas electric utilization means converting it to electric energy. The type of utilization of geothermal energy depends upon temperature of reservoir and depth. For the low-to-moderate temperature range between 50° and 150°C, direct use applications are preferred but electric use of geothermal zone is economical for temperature above 150°C [4].

Various techniques have been developed to harness the geothermal energy like direct use, steam plants etc but there is still a necessity of improvement of these techniques because of low efficiency. This paper discusses major disadvantage associated with existing technique and proposes a new method to utilize geothermal energy.

The proposed method can mitigate major disadvantage of the existing techniques and is named as 'Chemical Reaction Method', which is discussed along with working of a plant that is based on this technique.

2.0 Existing techniques to utilize geothermal energy

Other then direct use, the geothermal energy is primarily used to produce electricity. The fundamental notion is to bring the earth's heat to the surface in form of steam, which is fed to gas turbine coupled with generator and electricity is produced. There exist three techniques for power plant, which are briefly mentioned below-

1. Dry Steam Plants use geothermal steam directly. Dry steam power plants use very hot (>455 °F or >235 °C) steam and little water from the geothermal reservoir. The steam goes directly through a pipe to a turbine to spin a generator that produces electricity.

2. Flash Steam Plants use high pressure hot water to produce steam when the pressure is reduced. Flash steam power plants use hot water (>360 °F or >182 °C) from the geothermal reservoir. When the water is pumped to the generator, it is released from the pressure of the deep reservoir. The sudden drop in pressure causes some of the water to vaporize to steam which spins a turbine to generate electricity. Hot water not flashed into steam is returned to the geothermal reservoir through injection wells.

3. Binary Cycle Plants which use moderate-temperature water (225 to 360 °F or 107 to 182 °C) from the geothermal reservoir. In binary systems, hot geothermal fluids are passed through one side of a heat exchanger to heat a working fluid in a separate adjacent pipe. The working fluid, usually an organic compound with a low boiling point such as Iso-butane or Iso-pentane, is vaporized and passed through a turbine to generate electricity.

The existing techniques for the power plant to generate electricity from geothermal energy has major disadvantage that they work in a particular temperature range, so these techniques fail where temperature is comparatively low and have low efficiency. Hence, it calls for a new method to eliminate these two disadvantages.

3.0 Principle of chemical reaction method (CRM)

The basic concept of CRM is transferring the heat from geothermal zone to earth surface through reversible chemical reactions based on Le Chatelier’s principle of reversible reactions. According to Le Chatelier's Principle if a system is in equilibrium and is disturbed by an outside influence (for example a change in temperature), the system will respond in such a way as to counteract and reduce the effect of the disturbance [5]. Therefore, if temperature change is applied to a reversible reaction then the equilibrium shifts to eliminate the effect of temperature change and heat will be dissipated. If we choose such a reversible reaction which gives up heat at low temperature and absorb energy at high temperature, then it can be used to transfer thermal energy from earth crust to surface.

Let’s consider a reversible reaction of reactant A and B. The reaction takes place at high temperature T_1 and absorbs heat to produce C and D. The reactants and products remain in a dynamic equilibrium and this equilibrium can be shifted forwards by increasing the temperature and backwards by decreasing it. Now, if reactants are subjected to high temperature in geothermal zone under earth surface i.e. reaction chamber, reaction will shift toward left side producing more products. As the products are in gaseous form, they’ll reach to surface and subjected to comparative low temperature T_2 in heat exchanger and then backward reaction occurs with dissipation of heat. Hence, it is possible to transfer earth’s heat from crust to surface through reversible reactions.

□(□)+□(□)+□□□□ (At T_1) □(□)+□(□) (At T_2)

Where, $T_1 > T_2$

T_1 = temperature of reaction chamber,

T_2 = temperature of heat exchanger.

The forward reaction will take place in geothermal zone by absorbing thermal heat, whereas backward reaction will take place on surface with dissipation of heat. The dissipated heat will be used to generate steam, thereafter to rotate gas turbine.

4.0 Example reactions:

Following three sample reactions are identified which could be suitable for the proposed method.

- On heating strongly above 340^{o}C, the white solid ammonium chloride thermally decomposes into a mixture of two colorless gases ammonia and hydrogen chloride.

□□4□□(□) 340□□ □□□□ □□3(□)+□□□(□)

Ammonium fluoride (>550^{o}C), ammonium bromide (>450^{o}C) and ammonium iodide (>550^{o}C), with a similar formula, all sublime in a similar physical-chemical way when heated, so the equations will be similar i.e. just swap F, Br or I for the Cl.

- Similarly, ammonium sulphate also sublimes when heated above 235^{o}C and thermally decomposes into ammonia gas and sulphuric acid vapor.

(□□4)2□□4(□) 2350□ □□□□ □□3(□)+□2□□4(□)

- Ammonium nitrate does not undergo a reversible sublimation reaction; it melts and then decomposes into nitrogen (I) oxide gas (*dinitrogen oxide*) and water vapor.

□□4□□3(□) □□□□ □2□(□)+2□2□(□)

5.0 Construction and working of the plant

The construction of the Chemical Reaction plant will similar to existing plant, except it'll be designed to sustain the used chemical reactions. The plant will consist of a reaction chamber, heat exchanger, gas turbine coupled with electric generator and condensers as shown in figure. The reversible reaction takes place at two places, one at the reaction chamber, which is situated in geothermal reservoir and second in the heat exchanger, which is on the earth surface. The function of heat exchanger is to transfer heat from product of chemical reaction to the cool water to generator steam. The turbine is rotated by the steam and electric generator produces electric power.

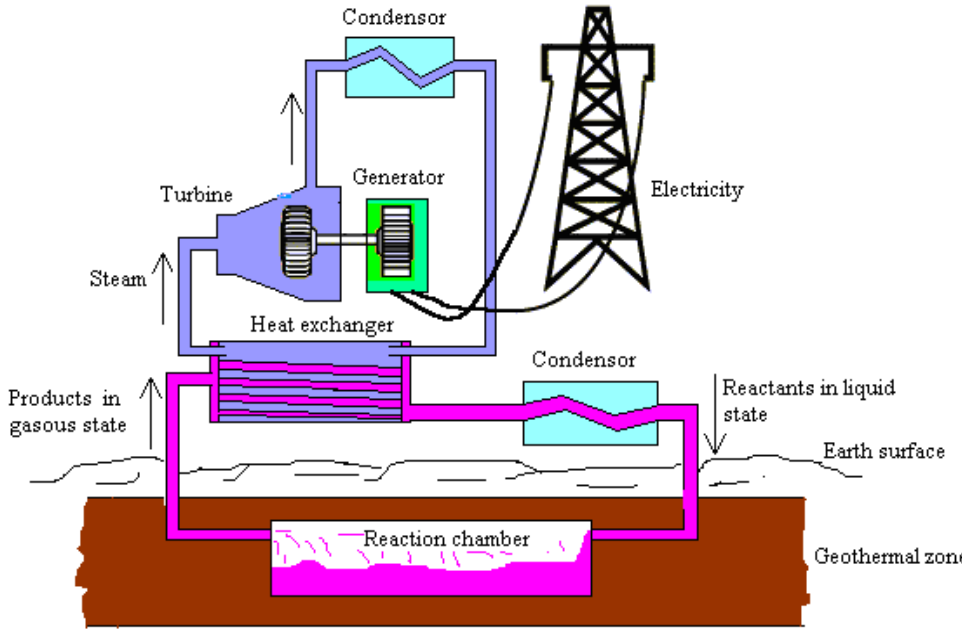

Figure-1: Working plant of chemical reaction method

After selection of proper reversible reaction for the geothermal zone, the reactants will be sent to geothermal zone through pipes. The reactants absorb thermal energy at high temperature and result into gaseous products. These gaseous products will come up through exit pipe and will be passed through heat exchanger. For aqueous products, a hydraulic pump can be installed in the reaction chamber.

The products of the reaction are subjected to low temperature in heat exchanger, where backward reaction takes place and heat is released. This heat generates steam which is fed to gas turbine. The turbine is then rotated by the steam which supplies power to generator to produce electricity. The steam and products of backward reaction are cooled down in condensers and the reactants will be sent back to the reaction chamber for next cycle.

6.0 Selection of chemical reaction

The selection of the suitable reversible reaction in Chemical Reaction method is the most important step. The selection depends upon the temperature, pressure of geothermal zone, but it is possible to employ other reactions by changing the conditions like pressure, concentration etc. The selected reaction must satisfy the following condition for higher efficiency of the plant-

1. The reactant of the reversible reaction should be either in liquid or solid state and products should be in gaseous or liquid state, so that it will be easier to transfer reactants to reaction chamber and products to heat exchanger through wells. The most suitable

reaction has liquid reactants and gaseous products which ensure involuntarily supply of reactants due to gravity to reaction chamber and products to heat exchanger. Hence, such reaction will ensure lower cost in transferring chemicals from surface to geothermal zone and vice versa.

2. The heat of reaction should be negative i.e. it should release the heat at low temperature by shifting equilibrium backwards and vice versa.
3. The chosen reaction should give the best results at temperature of geothermal reservoir.
4. Neither reactants nor products should be explosive in nature.
5. The chemicals should not harm the plant and machinery otherwise maintenance will be a major issue.

7.0 Discussion and future work

The proposed method has not been implemented yet and various experiments will be carried out to understand its feasibility. Few chemical reactions has been identified for this technique and further research is going on to discover reversible reactions for wide range of temperatures of geothermal zones, that'll help to develop a table showing suitable chemical reactions for difference temperature ranges. It will become easy to select the reaction for a available geothermal reservoir from the table.

The method possibly improves the efficiency of plant but that needs to be verified. If verified, this will eliminate the second disadvantage of low efficiency.

8.0 Conclusion

The paper proposed a new method, namely Chemical Reaction method to harness geothermal energy by producing electricity from it. The proposed technique uses chemical reaction to transfer thermal energy from earth's crust to surface and is based on Le Chateleir's principle. The principle and working of plant of the proposed method are discussed with selection of proper reaction for a geothermal zone.

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Title: Design and Analysis of Small Scale Straight-Bladed Vertical Axis Wind Turbine

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Topic: Energy: Renewable Energy and Environmental Solutions

Title: Design and Analysis of Small Scale Straight-Bladed Vertical Axis Wind Turbine

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This study presents a combined experimental and computational study of the aerodynamics and performance of a small scale straight bladed vertical axis wind turbine. The wind tunnel tests were carried out to study overall performance of the turbine using three different airfoil profiles. It is shown experimentally that blade profile and no. of blade has significant effect on its performance. Unsteady-flow computation fluid dynamics (CFD) models were generated to help understand the aerodynamics of these turbines' performance. The two- and three- dimensional unsteady flow field simulation around the turbines were performed using time accurate Reynolds Averaged Navier Stokes (RANS) solver. Interesting features about the dynamic stall around the blades and the interaction of the blade wakes with the following blades were observed. Comparisons of the 2D and 3D simulations highlight the strong 3D effects, including the blade tip losses and effects. Wind tunnel measurements were carried out at low TSR to study the self-starting capability. Significant tunnel wall effects were observed from simulation results and strongly influence the *Cp* results.

Nomenclature

b	Blade length (m)
c	Chord length (m)
ω	Rotating Speed (rpm or rad/s)
Cp	Power coefficient, a measure of turbine efficiency
U	Free stream wind velocity (m/s)
θ	Azimuth angle (deg)
α	Angle of attack (deg)
λ	Tip speed ratio
TSR	Tip speed ratio

Introduction

As the demand for renewable energy grows, the use of small wind turbines is increasingly attractive. The simple straight-bladed Darrieus type vertical axis wind turbine (SB-VAWT) is gaining attention due to its simple blade design. In general there are two main categories of wind turbines: Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbines (VAWT). This latter group is divided again in two groups: lift driven VAWT (Darrieus) and drag driven VAWT (Savonius). As the maximum possible efficiency of lift driven turbines is larger than for drag driven turbines, the main attention nowadays is focussed on lift driven turbines.

The HAWT designs are highly developed and widely used in all current large scale wind farms due to its self-starting at low wind speeds. However, while the HAWT have the disadvantages that they have to be positioned perpendicular to the wind direction. VAWT have the advantage that they are independent of wind direction for their operations. Thus, the majority of research on VAWT design was carried out as long ago as the late 1970s and early 1980s, notably at the USA department of Energy Sandia National Laboratories (Sandia National laboratory Staff, "Vertical axis wind turbines:

the history of the DoE program", http://www.sandia.gov/wind/other/ VAWThist.pdf) and in UK by Reading University, and VAWT Ltd., who erected several prototypes including a 500 kW at Carmarthen Bay. Extensive research projects were carried out in the UK to investigate the potential of fixed pitch H-rotor VAWT for large scale power generation.

VAWTs have poor self-starting torque due to the blade stall condition at high angle of attack. The H-rotor has better self-starting ability than the Darrieus curved bladed turbine [1]. The blades are straight and therefore the radius is equal over the whole length of the blade. The power is now generated over the complete length of the blade. The blade can be swept in a helical manner to disperse the moment forces on the axis over a larger angle. The blades of a VAWT have to develop lift and must have enough thickness to withstand the loads. For a grid connected turbine, the grid can be used to start the turbine by using the generator as a motor [2] and therefore the self-starting is not a major issue. The performance of a wind turbine is expressed by the power coefficient, *Cp*, which states how much of the power in the wind is absorbed by the wind turbine. For a HAWT, the *Cp* value is usually between 0.40 and 0.50 [3] and the theoretical maximum power coefficient called the Betz limit is 0.59 for an idealised turbine. However, it is difficult to state the exact value of *Cp* for VAWTs because there are many different designs. Musgrove has shown that VAWTs have efficiencies comparable with the best modern HAWT through his extensive experimental and theoretical studies in 1987[4]. Comparisons of power performance between H-rotor Darrieus and HAWT have been carried out based on the existing data from Sandia National Laboratories and National Renewable Energy laboratory. Investigation shows that the turbines operate at different optimum tip speed ratios and the Darrieus turbine is known to have a lower *Cp* than HAWT. However, Paraschivoiu claim that the gap of Cp between Darrieus and HAWT is not large and that the performance can be improved by changing the airfoil design that induces drag.

The application of Computational Fluid Dynamics (CFD) techniques for VAWT is an emerging subject. Considerable improvements in the understanding of VAWT can be achieved through the use of CFD and experimental measurements. It is known that VAWT exhibit complex unsteady aerodynamics. A rapid change in angle of attack and the resultant wind velocity result in the phenomenon that different Reynolds number are experienced as the blade rotates, which leads to the dynamic stall phenomenon. Previous researches performed by Fujisawa et al. [5] and McCroskey et al. [6] revealed complex mechanisms of dynamic stall, in which two counter-rotating vortices being generated and transported in the wake. Several studies relating to the detailed flow field and aerodynamic prediction of VAWT have been performed previously. In a research carried out by Brahimi et al [7] in 1995, a computational code called "Tkelow" was developed to perform 2D incompressible unsteady flow simulation on Darrieus-type VAWT, including prediction of the dynamic stall. More recently Hwang et al. [8] employed a commercial CFD package, STAR-CD with moving mesh and k-ϵ high Reynolds turbulence model. Investigation on actively controlling blade pitch angles was performed. However no detailed flow field studies were made.
The motivation for the current research is to get better understanding of self-starting capability on the characteristic of VAWT. The focus of present paper is to illustrate some of the improved understanding of the aerodynamics of vertical axis wind turbine performance through wind tunnel testing and computational simulation of the flow field around the turbine.

VAWT Lab Model

Three different types of blade profiles were used for the study of the turbine performance. Much previous research on Darrieus – type VAWTs has employed NACA0012 [7], which shifted later to thicker airfoil NACA 0015 [9], NACA 0018 [10], and NACA 0022 [11]. Our investigation started with the study of airfoil NACA 0022 first for validation purpose. It was followed by the comparison of high lift curved blade S1223 and symmetric airfoil SD8020 with thicker airfoil NACA0022. In order to study the self-starting capability of VAWT, the S1223 concave out configuration is tested here as well. The blade profile was created with a thickness equal to its relative camber and a chord of 100mm. The blade span of 400mm (limited by the CNC foam cutter machine), gave the blades an aspect ratio of 4 and the turbine solidity (defined as sum of chord ÷ turbine diameter) value of 1.0. The blades were attached on 200 mm long rotor arms resulting in a blockage ratio of 25% (based on turbine frontal swept area). A small prototype of three and four-bladed configurations was studied and the performance efficiency and power output were compared. Figure 1 show the prototype of small scaled vertical axis wind turbine and the model installed inside our wind tunnel. Wind tunnel measured results were obtained for cases of different wind velocity, tip speed ratio and different blade profile.

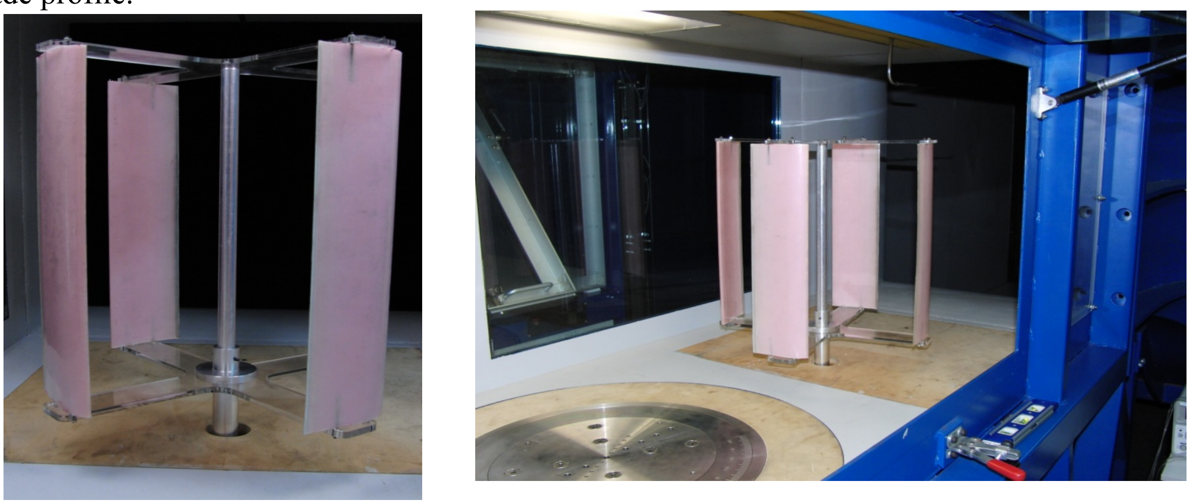

Figure 1. Prototype of VAWT turbine model and model turbine in the wind tunnel

Wind Tunnel Experiment Set-up

The wind tunnel tests were conducted at the Aerospace Engineering Laboratory at Nanyang Technological University (NTU). The low speed wind tunnel used for this study has test section dimensions of 720mm (H) x 780mm (W) x 2000mm (L). Figure 2 shows the braking and torque measurement setup. The turbine shaft (1) is connected through a Huco Uni-Lat coupling (2) to an electromagnetic brake (3). The Uni-Lat coupling allows both angular and radial misalignment. The brake is a Placid Industries B6-24V.

The brake is mounted on a brake frame (4). The other end of the frame is rigidly held in the chuck of a torque sensor (5). The torque sensor is the Chatillon STS-0050, with a measurement range of 0 to 5 Nm. The torque readings are manually read from the digital gauge DFS-R-ND (6). The procedure for reading was to manually store 20 readings over a period of about 10 seconds and then record the average.

The shaft of the brake has a light interrupter wheel (7) to trigger a slotted through-beam optical sensor. The signal from the sensor is processed by a micro-controller (8) which displays the rotating speed reading on an alpha numeric LCD screen. The micro-controller is the Microchip PIC16F690. The calculation of the rotating speed uses the built-in oscillator of the micro-controller as a reference signal. However, the oscillator frequency has a tolerance of 5%. A comparison of the LCD readings was made with a hand-held optical tachometer and the two readings generally agree. However, the fluctuation of the readings from the hand-held instrument means that this should not be considered a rigorous calibration procedure.

The micro-controller also controls the brake in two selectable modes. The first mode is constant duty cycle. The duty cycle of the applied current is user selectable in steps of 1%. The second mode of operation is constant RPM mode. The desired RPM is selected by the user and the micro-controller automatically varies the duty cycle of the applied current in order to maintain the turbine at the desired RPM. When braking is applied, there is opposition to motion between the shaft and the body of the brake, i.e., the shaft does not turn easily, but slips with difficulty. This means that torque applied to the shaft is transmitted to the body of the brake, via the brake frame and finally to the torque sensor. Hence the non-rotating torque sensor is able to measure the torque produced by the rotating turbine shaft. Wind speed at the most upstream end of the wind tunnel test section is measured by an Airflow thermal anemometer.

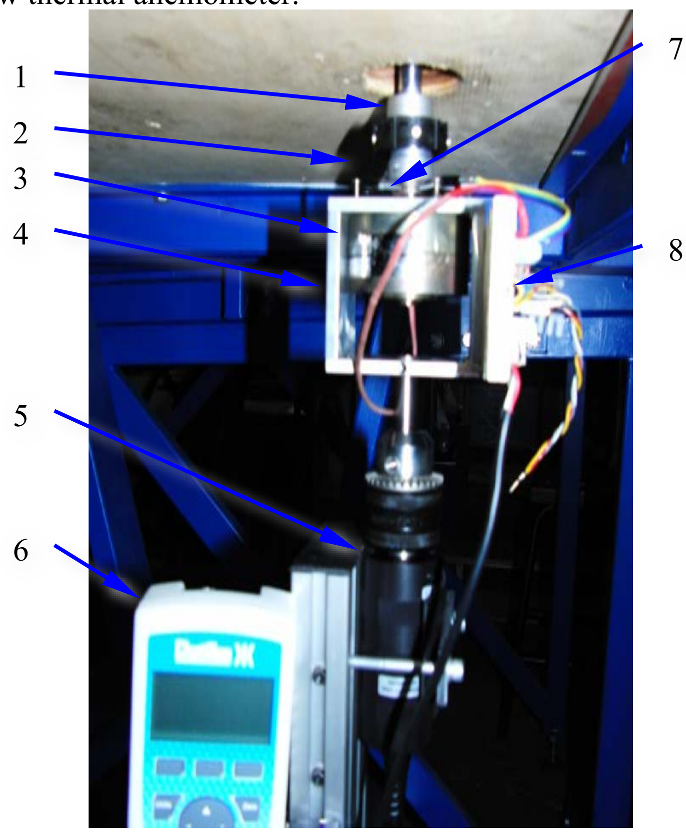

Figure 2. Braking and torque measurement system setup

Experimental results

This section presents the results obtained from the wind tunnel measurements. Most of the operation range of the current turbine model was with very low range of TSR < 1, as the VAWT did not attain high TSR in self-starting mode. Figure 3, Figure 4 and Figure 5 shows the performance coefficient of the turbine model with four straight blades at different wind speed with different blade profiles. The experiments were carried out at range of wind speeds between 6 – 15 m/s. Both three- and four blade profiles NACA 0022, S1223 concave out and SD 8020 were tested. The comparisons of turbine performance coefficient show that NACA 0022 gives maximum power extraction and highest performance coefficient among three of them. The next better performer is the S1223 concave out blade profile. The reason is that this configuration experiences positive incidence on the upstream pass and negative incidence on the downstream pass. The concave out arrangement optimises angle of attack of the blade during the upstream pass, even though it results in an un-optimised, negative angle of attack on the downstream pass. However, because there is more energy in the wind on the upstream side, the loss of optimality during downstream pass is a small sacrifice in exchange for the larger gain in energy extraction resulting from an optimised upstream pass. This configuration ensures maximum power extraction from the undisturbed flow on the upstream side according to Kirke [1].

Figure 3 show the self-starting capability of different blade profile. It shows that both NACA 0022 turbine configurations can self-star at low wind speed. The overall comparisons of turbine performance with different airfoil profile are shown in Figure 4, Figure 5 and Figure 6. It was observed that the Cp is quite high at lower TSR. This is unusual as typical VAWTs do not self-start, i.e., the Cp is not positive at low TSR. Note that the turbine diameter of 0.4 m is more than 50% of the wind tunnel test section width of 0.78 m. Therefore the high Cp is probably because of the blockage effect and constraint wall effect that adds to the turbine performance.

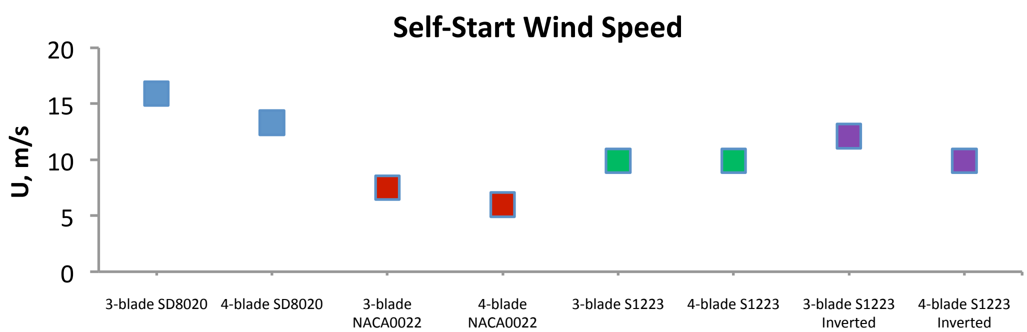

Figure 3. Self-starting capability of different blade profile

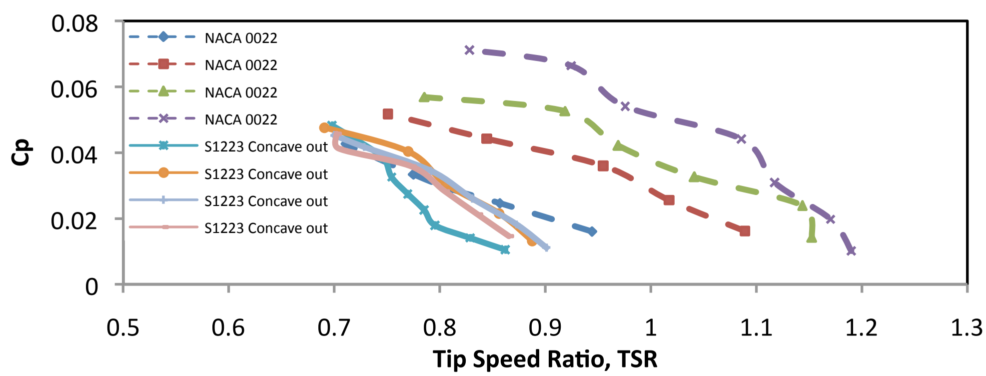

Figure 4. Comparison of TSR vs Cp of four blade turbine rotor with range of wind speed 8 – 10 m/s

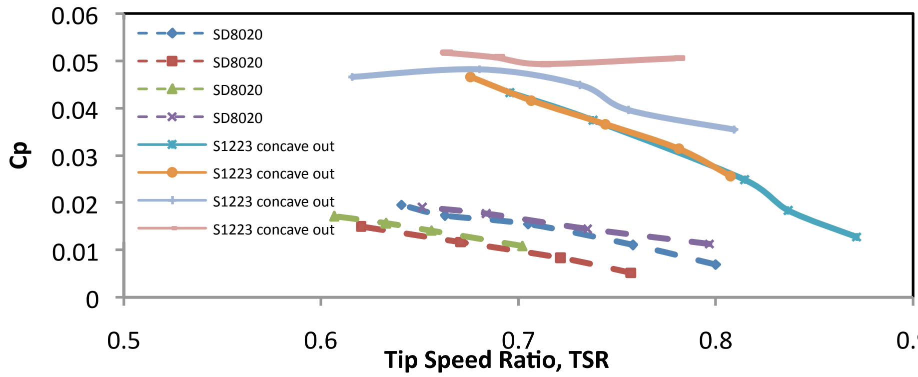

Figure 5. Comparison of TSR vs Cp of four blade turbine rotor with range of wind speed 11–15m/s

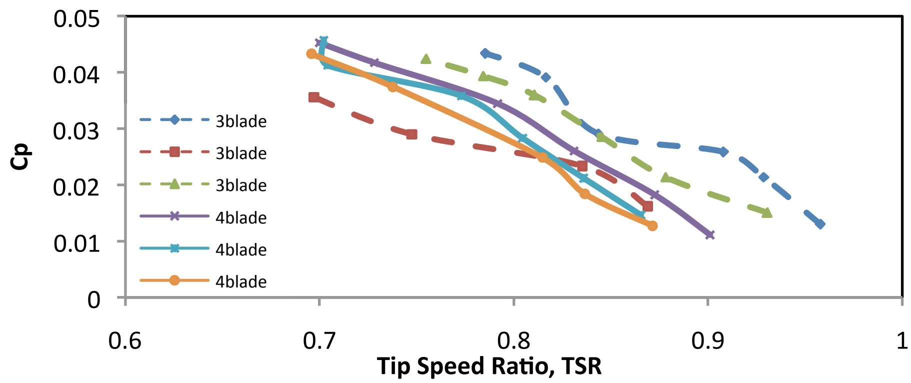

Figure 6. Comparison of TSR vs Cp for both three- and four- blade configuration of S1223 concave out

Computational analysis

The complexity of the unsteady aerodynamics of the VAWT makes it attractive for analysis with Computation Fluid Dynamics (CFD) models. The difficulty of the problem and the need for new design approaches for the VAWT have driven the focus of this research on the CFD modelling of the VAWTs to study the flow interaction with its blades during its rotation.

Computational domain: The geometry of the model is a representation of the wind tunnel experiment setup. The model is bounded by two walls spaced 780mm apart, where the 200mm rotor radius with four-blades VAWT is placed. The rotor is represented by a c = 100 mm chord airfoil and 400 mm span. The rotor axis is placed at centre of the tunnel test section, which is 140mm from the lower and top walls, as in the experiment setting for both 2D and 3D CFD simulation set up. The inlet and outlet boundary conditions are placed 10c upwind and 20c downwind of the rotor, respectively shown in Figure 7. The choice of the location of these boundary conditions is determined by verifying the influence of the rotor in the upwind boundary, and allowing a fully development of the wake in the downstream.

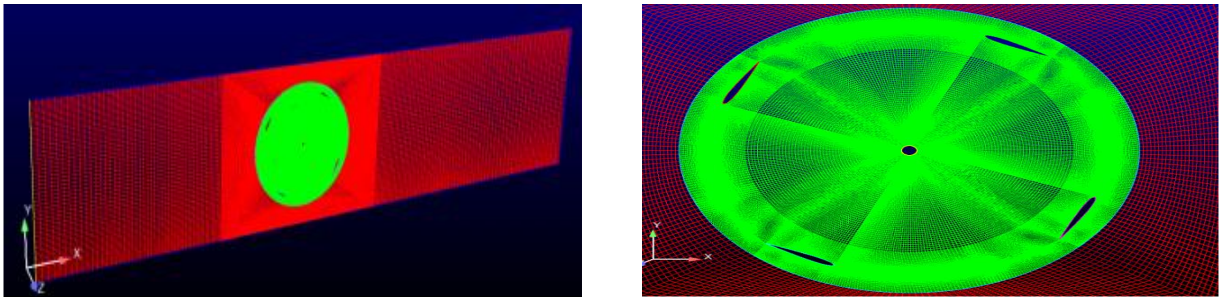

Figure 7 : Two-dimension grid generation of (a) with stationary zone (b) rotating zone only

Computational method: The grid generation was carried out using Gambit and the sliding mesh technique was utilized to model turbine motion into the commercial CFD code, *Fluent* for numerical analysis. All simulation results presented in the current work refer to the revolutions of the rotor after periodic solutions were attained. The Unsteady Reynolds-Averaged Navier-Stokes (URANS) equations govern the transport of the averaged flow quantities, with the whole range of the scales of turbulence being modelled. The RANS equations were solved using the Green-Gauss cell based gradient option and the sliding mesh method was used to rotate the turbine rotor blades. SIMPLEC algorithm was used for pressure-velocity coupling. The RNG k-ε model was adapted for the turbulence closure. Time integration was done implicitly and the minimum convergence criteria were set to 1×10^{-6}.

The whole computational domain divided into two region, the rotating region and stationary region. The rotating region contains four symmetric aerofoils placed on the circular rotation path with zero pitch, equally spaced 90 degrees apart from each other and rotate with a given angular velocity (rotating speed) ω. The stationary region which represents wind tunnel test section area has a rectangular outer boundary with a hole to fit in the rotating zone. The support arms are not considered because the aspect of interest of the 2D simulation was only on the aerodynamic performance and flow field investigation.

Boundary conditions: The boundary conditions are shown in table 1. The inlet was defined as velocity inlet, which has a constant velocity while the outlet was set as outflow. The velocity properties at the outlet were determined by the extrapolation from interior. The no-slip wall boundary condition was applied on the turbine blades, shaft surface and tunnel walls.

Table 1. Boundary condition set up for both 2D and 3D simulation

Location	Boundary condition type	Turbulence intensity	Turbulence length scale
Upstream face of domain	Known inlet velocity	1%	0.01 m
Downstream face of domain	Outlet		
Domain walls, blade surfaces, central shaft surface	No-slip walls		
Contact surfaces between rotating region and rest of domain	Interface boundary		

The flow condition used in the comparisons section were carried with incoming flow velocity U = 6 m/s. Time step was set corresponding to different degree for each rotational speed of the rotor (ω). The performance coefficient was tested and compared with different tip speed ratio at 0.6, 0.7 and

0.8.

Code validation: To verify the reliability of the computational method, the lift characteristic of conventional symmetrical airfoil, SD 8020 was computed from different angle of attack with inlet velocity. The chord length was set to 1m and the corresponding chord-based Reynolds number Re, were 60, 600 and 204,200. The simulation results has compared with experimental data performed in the University of Illinois at Urbana-Champaign (UIUC). Comparisons show good agreement with the experimental data for angle of attack between -6° to 18°. The lift coefficient comparison are shown in Figure 8 .

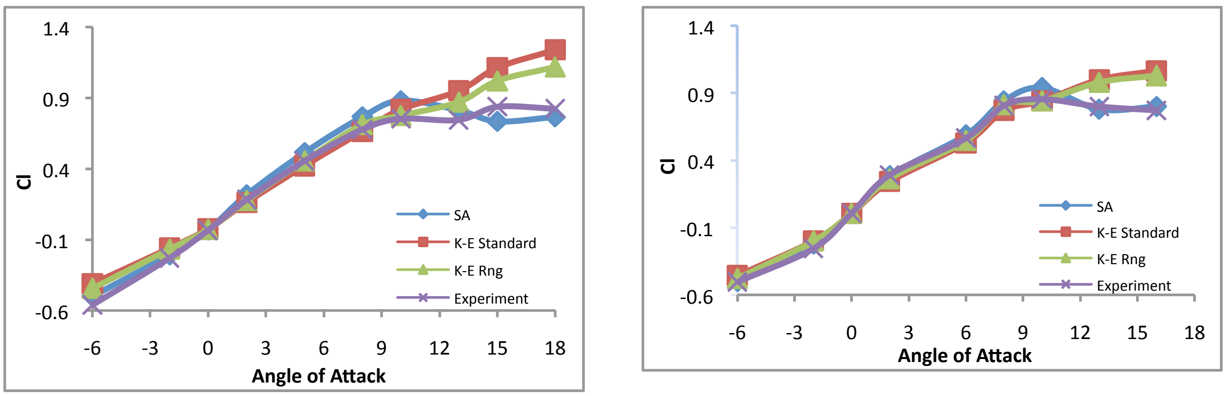

Figure 8. Lift coefficient comparison, for Re = 60,600 and Re = 204,200

Computational Results

In this section, we present the results of two- and three- dimensional simulation that we performed to study the characteristic of the flow field with rotating turbine blade. With appropriate boundaries condition applied, simulation was allowed to run until a converged solution was achieved. Figure 9 shows the perdition of moment coefficient for the four blade rotor turbine model. The moment coefficient curves are obtained from 2D simulation using the following conditions: free stream velocity: 6 m/s; rotating speed: 39 rad/s; TSR=1.3.

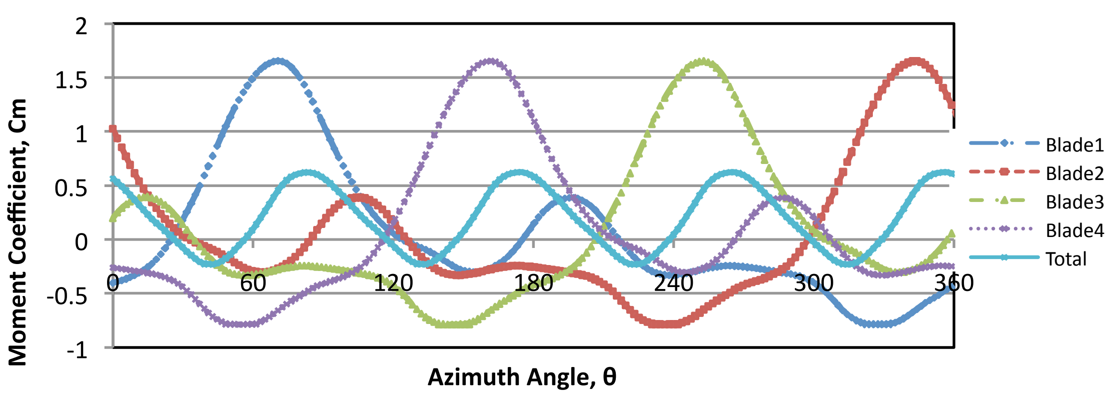

Figure 9. Prediction moment coefficient for individual blades and the total moment developed by turbine model

Referring to the curve for blade 1 in Figure 9, we see that when the blade is at an azimuth angle of 0 degrees, it experiences a negative torque. This is within expectations because at this position, the angle of attack is zero degrees. Thus the blade is produces negligible lift and experiences mainly drag. Figure 10 (left) illustrates our explanation.

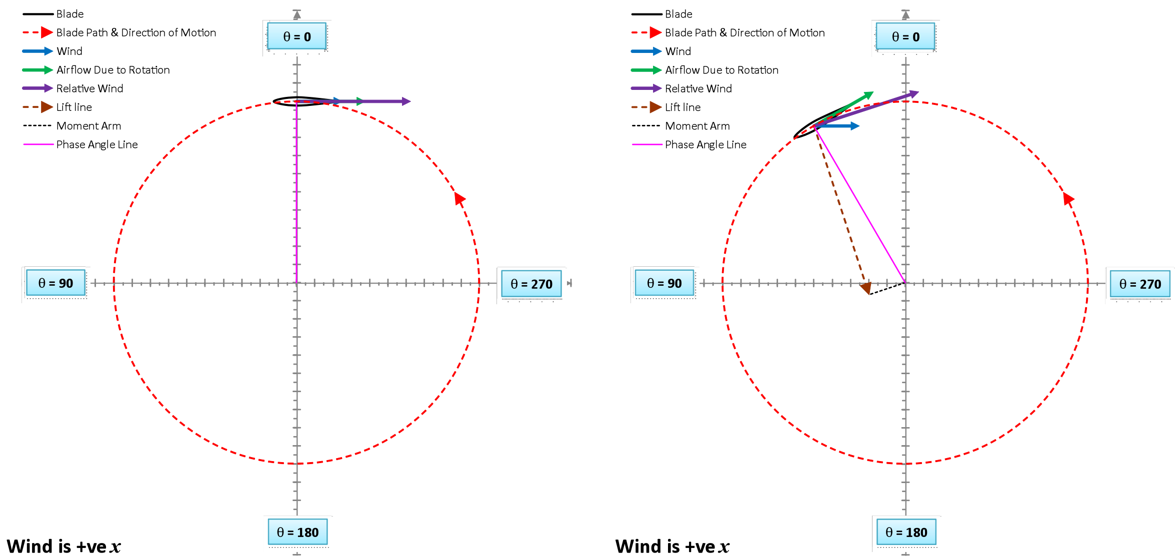

Figure 10 : Definition of azimuth and explanation of torque

As the blade rotates, it reaches a position of zero torque at an azimuth of about 30 degrees. Using Figure 10 (right), it can be seen that at this position, an angle of attack of about 10 degrees is experienced. Furthermore, the line of action of lift (brown dashed arrow in Figure 10) has deviated slightly from the turbine axis and thus lift is able to provide torque due to the emergent lift moment arm (black dashed line in Figure 10). The drag on the blade is still present, and because of the much larger drag moment arm (represented by the length of the brown dashed arrow) the overall result is that the positive torque due to lift is approximately overcome by the negative torque due to drag.

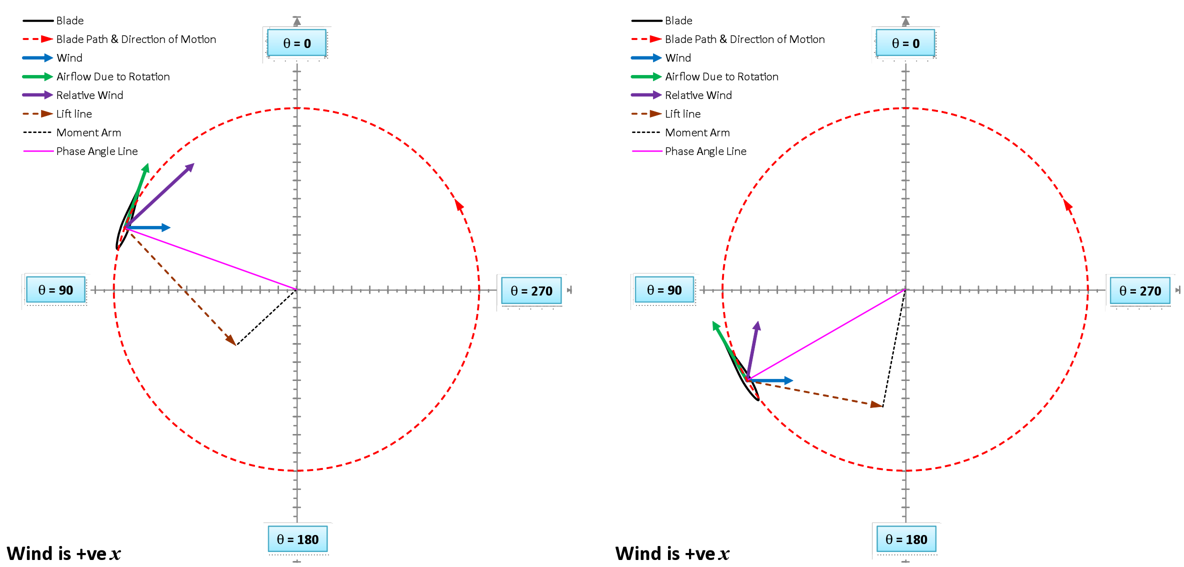

Figure 11: Explanation of torque

The torque rises to a maximum value at azimuth angle of about 70 degrees. Referring to Figure 11 (left), this position corresponds an angle of attack of about 20 degrees, which is approximately the most optimum angle of attack. This position also results in a long lift moment arm length. At the same time, the drag moment arm length is reduced. Beyond azimuth angle of 70, the torque decreases until an azimuth angle of 120 degrees. At this position, the angle of attack is excessive, about 40 degrees, and the blade is badly stalled. So even while the lift moment arm is nearing its maximum length and the drag moment arm nearing its minimum, the poor lift to drag ratio of a stalled blade means that once again the positive lift torque is approximately overcome by the negative drag torque.

From azimuth angle of 120 onwards, the torque is mostly negative, with the exception of a small region from 180 to 200 degrees. In this region, the angle of attack is again approximately at the most optimum value of about 20 degrees, as shown in Figure 12. However, the blade is now moving with the wind and thus the magnitude of the relative wind over the blade is low, resulting in low Reynolds number and hence poorer lift performance compared to the case when azimuth angle is 70 degrees.

In the remaining region of azimuth angle, the wind interacting with the blade would have been affected by its earlier pass over an upstream blade and would not be perfectly horizontal nor close to the free stream wind speed. Thus the torque can only be more accurately predicted by simulation. A wind vector diagram similar to Figures 10 to 12 will not give an accurate prediction. For example, the simulation result show that the most negative torque occurs at azimuth angle of about 330 degrees. Upon examining Figure 12 (right), we note that the angle of attack at this condition is about 10 degrees, which should logically give a reasonable lift and without excessive drag. This exemplifies the usefulness of CFD simulation in predicting complex flow phenomena.

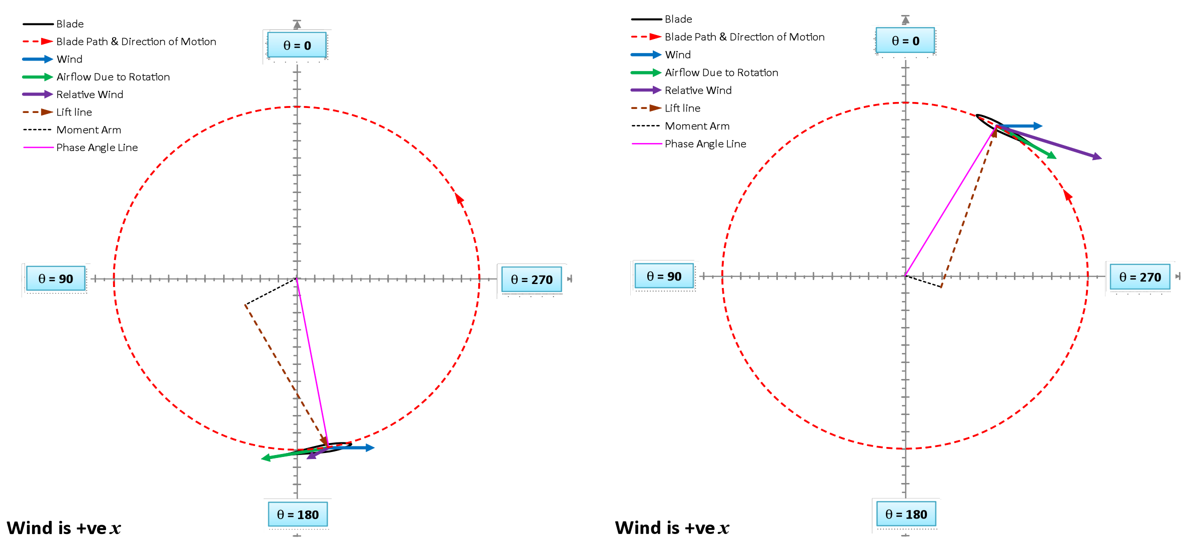

Figure 12: Explanation of torque

Figure 13 shows the contour plot of velocity distributions at different time with four rotating blades at first revolution. At t = 0 s, boundary layer was attached at reference blade. With increasing time, trailing edge separation starts to occur with small vortices and it becomes bigger and bigger. It is eventually shed off in the later time around Time = 0.11. However, the leading edge vortex is starts to grow at time = 0.11, it becomes larger during the rotation.

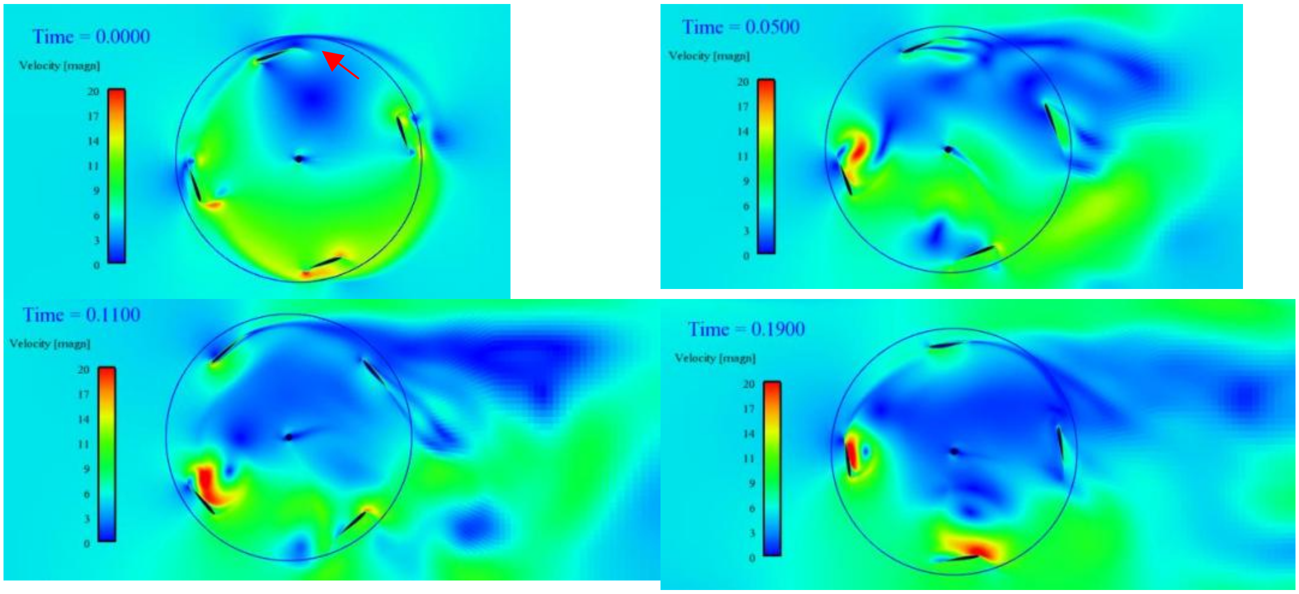

Figure 13: Simulation results of velocity contour plot at first revolution of 2D VAWT

The steady flow phenomena has captured here after several rotation when the turbine produces periodic torque. This two-dimension visualization has been used here to further understand the rotor blade interaction. It is very clear from Figure 14. The wake caused by the blade tip vortex extends to a considerable proportion of the area swept out by the rotor blade. As the blade continues to rotate, the wake segment continues to flow downstream steadily and it will interact with the blade rotor that created it. After three revolutions, at t = 0.77s to t = 1.8s, it observed that the wake development is stabilized from turbine rotor, and the flow field is not much changed until 6 revolutions.

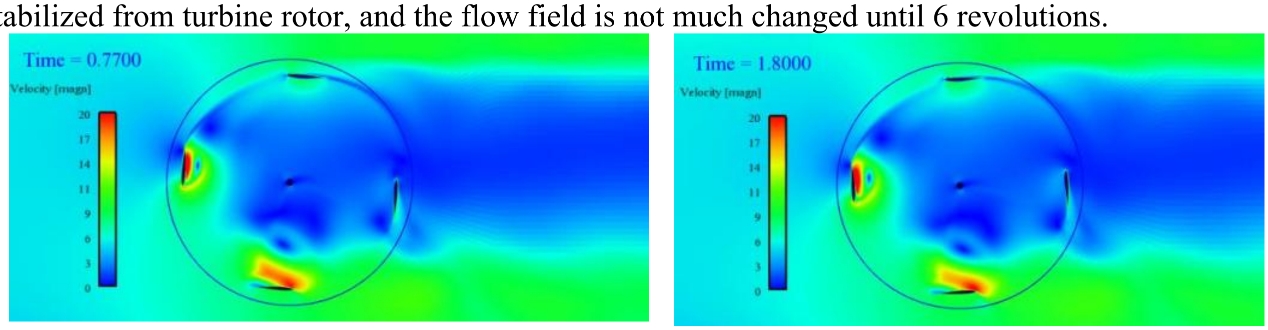

Figure 14: Simulation results of velocity contour plot with steady solution of 2D VAWT

Three- dimension simulation analysis shown in Figure 15. The flow can be characterized by the shedding of strong vortices which is located at the leading edge, resulting from leading edge separation where the counter clock-wise vortices detach from the surface. At the trailing edge, where a wake is formed from the pressure-side boundary layer and the boundary layer developed on the suction side, after of the reattachment point of the separated leading edge flow. This wake is formed at the trailing edge of the aerofoil by the merging of the two boundary layers, it experience rotation due to the strong vortices that is present. The changing in vortex is due to the changing lift developed by the turbine rotor blade as it rotates through different angles.

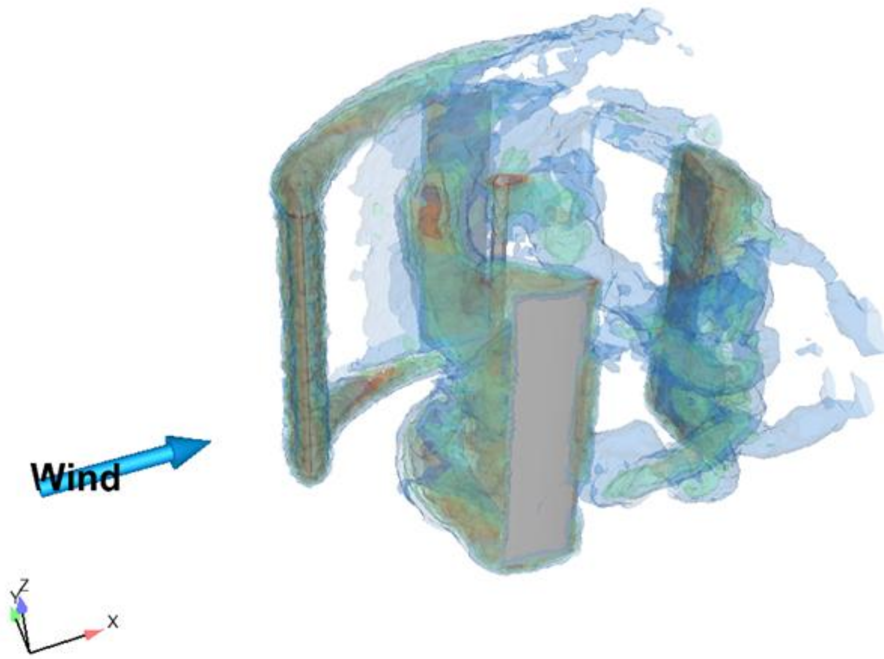

Figure 15. Contour of vorticity for the four blades illustrating the strength of changing tip vortex at 39 rad/s, U = 6 m/s

Conclusion and Future Work

A small scale model of straight-bladed vertical axis wind turbine with different airfoil profiles have been manufactured and tested over a range of operating conditions. The straight bladed turbine rotor, with a aspect ratio of 4:1, operated at relatively very low tip speeds. The tunnel test results show that the performance of the three tested airfoil profiles rank in the following order, highest performance first: 1) traditional NACA 0022 with thicker airfoil; 2) asymmetric airfoil S1223 with concave out configuration; 3) Symmetric airfoil SD8020.

Numerical analysis of two dimensional unsteady flow field of straight bladed vertical axis wind turbine revealed significant influences of flow field on the upstream blade performance. This explains a relatively low wind power extraction potential when the blade is moving through the downstream azimuth angle. The three-dimensional CFD model captured interesting phenomena, such as blade tip vortices and support arm profile drags, in the VAWT operation. Significant difference are observed in the flow fields regarding the tip vortices, the wake from the supporting arms and shaft, which result in a significant reduction in the wind power extraction.

Almost all the wind tunnel results presented in this paper are different from others' in that the peak power occurs at very low TSR. This is satisfactory for our present need because it allowed us to study the self-starting capability of the turbine itself. In the future, a motor will be installed on the present prototype to accelerate the turbine until its operating speed. Tests covering the full range of TSR will be carried out to study the overall performance with various blade profiles and configurations.

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Cover Page

Income, Energy Consumption and Carbon Dioxide (CO2) Emissions in India: Modeling of Causal Relationships

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Contributed paper prepared for presentation at the Asian Conference on Sustainability, Energy and the Environment (ACSEE, 2011), 2-5 June, 2011, Osaka, Japan

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Income, Energy Consumption and Carbon Dioxide (CO2) Emissions in India: Modeling of Causal Relationships

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Abstract

The paper investigates the causal relationships among income, energy consumption and CO2 emissions in India using a time series econometric model. In addition, the paper also utilizes the generalized impulse response function to investigate the persistent profiles of the macroeconomic variables from an unanticipated shock. Our results provide evidence of the existence of bi-directional Granger causality between CO2 emissions and energy consumption in the long-run but neither energy consumption nor CO2 emissions causes movements in income. There is no causal relationship between income and energy consumption in any direction in the long-run. The result has strong policy implication for India, for instances, the country could follow energy conservation policies without limiting income growth. This will allow India to reduce CO2 emissions and contribute significantly towards combating global warming and climatic instability problem.

Keywords: pollution, economic development, energy consumption, causality, India

1. Introduction

The carbon dioxide (CO2), a major green house gas (GHG) emission resulting from combustion of fossil fuels is being considered as one of the most important causes for increasing global warming and climatic instability (IPCC, 1996). The GHG emissions seem to aggravate these problems in the current decade (Kaygusuz, 2009). The recently held United Nations Climate Change Conference at Copenhagen in 2009 has attracted unprecedented participation by the world leaders to reach a consensus on legal binding GHG emission reduction to protect the environment and make the world a 'sustainable' place for present as well as future generations. According to UN, the main contributors of GHG emissions are China (17%), United States (16%), European Union (11%), Indonesia (6%), India (5%), Russia (5%), Brazil (4%), Japan (3%), Canada (2%), and Mexico (2%). The crux of the debate among the academics, researchers and practitioners is how to alleviate or reduce GHG emissions by high polluting economies without limiting the economic development. This is because of the contradiction between a commonly held view that higher income growth is highly associated with higher GHG emissions on one hand and that the economic growth itself will reduce the environmental pollution (known as the Environmental Kuznets curve (EKC hypothesis) of Kuznets (1995)) on the other (see Hill and Magnani, 2002; Stern, 2004; Dinda, 2004 for detail review of EKC hypothesis). Also, Dinda and Coondoo (2006) argue that in order to maintain environmental quality, the developed countries have to forgo their income growth and the developing countries have to restraint their growth ambitions to combat CO2 emissions. Moreover, the Kyoto Protocol (1997) is highly criticized for the lack of inclusion of obligatory reduction of GHG emissions' by developing countries (Pittel and Rubbelke, 2008) because participation of the economies such as Indonesia, India, China, and Brazil are crucial in solving the global problem.

Hence, investigation of causality relationships among income, energy consumption and CO2 emissions are of utmost important in order to formulate strategies by specific countries to reduce global warming and climatic instability. The relationships are widely discussed in the literatures but the results are inconclusive. Three viewpoints are dominant in the literature. First, the income of a country could be highly linked with energy consumption and, therefore, like any other factors of production, the energy consumption can be a limiting factor to income growth. For example, Stern (1993, 2000) found that energy is a driving factor for economic development in the US; which was echoed by Masih and Masih (1996) for India, Wolde-Rufeal (2005) for Algeria, Cameron, Congo DR, Egypt, Nigeria; Wolde-Rufael (2004) for Shanghai; Soytas and Sari (2003) for France, Germany and Japan; Chontanawat, *et al.,* (2008) for Kenya, Nepal and the Philippines. In this view, reduction in energy consumption tends to reduce income and, therefore, energy conservation policy may be harmful to the economy. *Second,* a *neo-classical* view which states that income of a country can be 'neutral' to energy consumption and, therefore, the country can undertake energy conservation policy to reduce CO2 emissions to combat environmental degradation, defined as the 'neutrality hypothesis'. *Third,* the causality relationship between environmental pollution and income is widely debated over the past decades under the EKC hypothesis. The EKC postulates that there is an inverse U-shaped relationship between income and environmental pollutions. It explains that environmental degradation initially increases with the increase in income, reaches a threshold point and then it declines with corresponding increased in income (Grossman and Krueger, 1991; Selden and Song, 1994; Stern *et al.,* 1996). All of these views were developed based on a bivariate analytical framework of either energy consumption-income or environmental pollutions-income nexus. Recently some studies expanded the scope to a multivariate dimension: i.e., energy consumption, income and environmental pollutions. For example, Soytas and Sari (2009) found that CO2 emission Granger cause energy consumption in Turkey without any feedback. Similarly, income does not Granger cause CO2 emissions in US but energy does (Soytas *et al.,* 2007) also echoed by Xing-Ping and Xiao-Mei (2009) for China. An interesting result was found by Ilhan and Ali (2010) for Turkey who used an auto-regressive distributed lag (ARDL) approach and concluded that that neither CO2 emissions nor energy consumption Granger causes real income. However, the empirical evidence still remains controversial and ambiguous.

Given this backdrop, the main objective of this paper is to investigate a country specific causal relationship that combines income, energy consumption and CO2 emissions under a single framework. This is because the empirical analysis at the aggregate level using multiple countries are so far unable to capture the complexities of the economic environment of each individual countries. Therefore, we postulate that a country specific case study will provide precise inferences on the issues we are investigating. Our choice of India as a case study is motivated by the fact that the country is a fastest growing economy next to the China, currently the largest economy in the world (World Development Indicators (WDI), 2010). The growth rate of commercial energy consumption in India is 4.9% per annum during the period of 1965-2007. And both the income and CO2 emissions have grown at a rate of 4.7% per annum during the same period (Balachandra *et al.,* 2010). The main sources of energy are crude oil, natural gas and coal which accounts for 90% of total energy consumption. The country is the fifth largest total GHG emitter in the world although it is one of the lowest per capita emitter country. The share of coal consumption to total energy consumption is about 70% (WDI, 2010) and is increasing over time, which implies that the intensities of GHG emissions may increase as burning of coal is the main source of higher CO2 emissions. Apart from that, India has the second largest installed wind mill in the world which implies potentiality in switching energy consumption from combustion of coal dominated fossil fuels to renewable energies. Since the energy consumption is increasing faster, the dependence on energy from non-renewable sources can exert a fierce constraint if energy consumption and income co-move in the long-run. Therefore the country is in need of fixing target to reduce consumption of fossil fuels and combat CO2 emissions which may have strong long-term implications for India and global level.

Other motivating factor is that the held view that reduction in GHG emissions may limit income growth and, that may be a reason why India is strongly against the international pressure to make a commitment for legally binding agreement of its GHG emissions. Therefore, it is important to determine whether CO2 emissions reduction could really undermine income growth in India, which may very well explain India's position on legally binding emission reduction commitments. To our knowledge, our paper is the first attempt to investigate the dynamic causality relationships in a multivariate framework which overcome the widely discussed problems of omitted variables bias and stationarity of selected variables in the estimation of bivariate modeling framework. The contributions of our study to the existing literature are two folds: (i) use of a multivariate framework of the Toda and Yamamoto (1995) hereafter TY model, i.e., energy- CO2 emissions-income; and (ii) use of additional variables, such as the labour force and fixed capital stock in the analysis. Hence, depending upon the causality relationships, India may resort to different strategies to fight against global warming and climatic instability. Additional contribution is that TY model has some advantages over others when dealing with finite sample as well, implying that it is unlikely to provide misleading inferences. The finding of this paper has strong policy implications for India as well as for the global level. Specifically, the policy makers in India are under pressure from the environmental delegates to cut emissions although the country still faces huge challenge to reduce its poverty level (currently about 29% of its population live below the poverty line- WDI, 2010) requiring economic growth. Therefore, if income is associated with energy consumption (and energy consumption drives the economy) and energy consumption is associated with GHG emissions (and energy consumption drives GHG emissions) then policy makers in India faces a major *dilemma* because the environmental degradation through GHG emissions would aggravate the economy in the long-run, perhaps in the short-run as well. If the result is otherwise, then policy makers may place higher attention to find alternative less polluting and renewable energy sources to meet increasing energy demands. In this way, India could become energy secured and GHG emissions itself will not be a constraint for long-term economic growth. The energy consumption and emissions reduction policy in India could also be a very good example for the similar economies across the world.

The dynamic causality relationship between energy consumption-income, environmental pollution-income (under the EKC hypothesis) has been well documented in the literature. The aims of these studies were mainly to find out temporal relationships but largely with the application of bivariate model particularly for India. Yet, there seems to be no consensus regarding the dynamic causality relationship between energy consumption-income and environmental pollution-income. The plausible reasons of not having the consensus and conclusive results may be due to misspecification of the estimated models, omitted variables bias, or failure to select true lag lengths (which are very sensitive to Granger non-causality). The existing literatures in India show mixed evidences and sometimes conflicting results even when using similar databases. Most of the studies dealt with the causality relationship between energy consumption and income. However, results from the literatures can be broadly categorized into three different strands i.e., a unidirectional causality, a bi-directional causality and no causality at all. Ghosh (2010) investigated the causality relationship between CO2 emission and economic growth and included additional variables, investment and employment but used ARDL and Johansen model which has a low power in the test results in case of small sample. Recently, some studies (for example, Soytas *et al.,* 2007; Soytas and Sari, 2009; Xing-Ping and Xiao-Mei, 2009) investigated dynamic causality relationships among energy consumption-income-environmental pollution within a single framework applying multivariate model of TY (1995), multivariate Johansen and Jesulius (1990) error correction model (ECM) (Ang, 2008), panel cointegration (Apergis and Payne, 2009, 2010a; Apergis *et al.,* 2010b). But such an advanced application of modeling approach is non-existent for India which happens to be one of the top GHG emitters and also one of the top income growth and energy consumption growth country in the world. Although it has been recognized that the interrelationships among the capital accumulation, environmental pollutions and other growth parameters are of central importance in the growth theory (Xepapadeas, 2005), but there is a void in literature examining relationship between income, energy consumption, and CO_2 emissions which also included labour and fixed capital stock as additional variables under the same framework, specifically for India.

The remainders of the paper are structured as follows. The next section presents the data and methodologies. Section 3 presents the results and discussions. The final section concludes and presents policy implications.

2. Data and econometric framework

2.1 Data

The study uses annual time series data for India which are taken from the world development indicator database (CD-ROM, 2010) of the World Bank. The study uses real gross domestic product (GDP) (in 2000 constant prices), total commercial energy consumption (kt of oil equivalent), total carbon dioxide emissions (kt) and additional two variables, the total labour forces (derived from total employees, self employees and unpaid family workers) and the gross fixed capital formation (as a proxy for stock of physical capital) (in 2000 constant prices). The data are defined as follows: Y is for GDP (income), EN is for commercial energy consumption, C is for carbon dioxide emissions, L is for labour forces and K is for gross fixed capital formation. All data are converted into natural logarithm and covers the period from 1971 to 2006 based on the times series data availability. There are some debates in the literatures as to whether to use the total or per capita basis data but in a single country study, dividing the variables by number of population only scales the variable down (Soytas *et al.,* 2007) with apparently no other advantage. Also, Friedl and Getzner (2003) argued that the Kyoto Protocol calls for a reduction in the percentage of emissions from its base of total emissions rather than per capita emissions. Therefore, our study uses aggregate data rather than per capita data to estimate the dynamic causality relationships among C emissions, energy consumption and income in a multivariate TY model.

2.2 Econometric modelling framework

2.2.1 Unit root tests

Before proceeding to estimate the TY model, unit root test is required to obtain the maximum integration order of the variables. Therefore, we perform different unit root tests – the augmented Dickey-Fuller (ADF) (1979), and the Phillips-Perron (PP) (1988) to obtain robust results. The

ADF test with an optimal lag length determined by Schwarz Bayesian information criteria (SBC) is used in the following specification:

$$\Delta m_{i,t} = c + \rho m_{i,t-1} + \sum_{j=1}^{k-1} \Gamma_i \Delta m_{i,t-j} + \beta T + \varepsilon_{i,t} \qquad (1)$$

Where $m_{i,t}$ is the respective variables (Y, EN, C, K and L), Δ is a first difference operator, T is the time trend and $\varepsilon_{i,t}$ denotes white noise error term. Equation (1) tests the null of a unit root $(\rho = 0)$ against a mean-stationary alternative $(\rho \neq 0)$. The term $\Delta m_{i,t-j}$ is a lagged first difference to accommodate serial correlation.

When the time series data are subject to both a deterministic trend (T) and an exogenous shock that causes a structural break, the ADF test tends to under-reject (Perron, 1988). Therefore, we perform the presence of a unit root using PP in the following specification.

$$m_{i,t} = c + \beta \left\{ t - \frac{T}{2} \right\} + \rho m_{i,t-1} + \varepsilon_{i,t} \qquad (2)$$

Where $m_{i,t}$ is respective time series, $\left\{ t - \frac{T}{2} \right\}$ is the time trend and where T is the sample size, $\varepsilon_{i,t}$ is the error term. This procedure, in fact, uses a non-parametric adjustment to the Dickey–Fuller test statistics and allows for dependence and heterogeneity in the error term.

2.2.2 Model

The often used methodologies in the literature for testing causality are standard Granger non-causality, causality in Johansen and Jesulius (1990) ECM, causality in ARDL model proposed by Pesaron and Shin (2001), causality in TY multivariate model. The empirical evidence presented in our paper is carried out by using TY because of its advantages over others. The TY procedure is used even when the variables have different order of integration. In the Johansen model, a pre-requisite is that the variables must be in the same order of integration. Toda and Yamamoto (1995) showed that that the pre-tests for cointegration ranks in Johansen type ECM are very sensitive to the values of nuisance parameters in finite sample. Hence, causality inference based on Johansen may suffer from severe pre-test biases. If the system contains unit root, standard Wald statistics based on OLS of level vector auto-regressive (VAR) model for testing coefficient restrictions have non-standard asymptotic distribution that may involve nuisance parameters (Sims *et al.,* 1990; Toda and Phillips, 1993). The augmented VAR model of TY on the other hand, much appealing because it can be applied for any arbitrary level of integration, I(0), I(1) or I(2) and do not need to be in the same order of integration either. The TY procedure uses a modified Wald test (MWALD) for putting restrictions on the parameters of the VAR (k) from a augmenting VAR ($k+d^{max}$) model, where k is the lag length and d^{max} is the maximum order of integration of variables. The novelty of the TY procedure is- since it estimates a VAR in level therefore there is no loss of information due to differencing. The model is valid until $k \geq d$ (Kuzozumi and Yamamoto, 2000). Following Soytas *et al.,* (2007); Soytas and Sari (2009), Xing-Ping and Xiao-Mei (2009); Mohammad *et al.,* (2010) we apply TY to examine the dynamic causality relationships among energy consumption, C emission and income in India.

The TY model can be written in a simpler form as following specification

$$m_t = \alpha_m + \varphi_1 m_{t-1} + \dots\dots\dots + \varphi_n m_{t-n} + \omega_{m,t} \qquad (3)$$

The model in equation (4) can be written in a full system as follows:

$$\begin{bmatrix} \ln E_t \\ \ln Y_t \\ \ln C_t \\ \ln L_t \\ \ln K_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} + \begin{bmatrix} \varphi_{11,1} & \varphi_{12,1} & \varphi_{13,1} & \varphi_{14,1} & \varphi_{15,1} \\ \varphi_{21,1} & \varphi_{22,1} & \varphi_{23,1} & \varphi_{24,1} & \varphi_{25,1} \\ \varphi_{31,1} & \varphi_{32,1} & \varphi_{33,1} & \varphi_{34,1} & \varphi_{35,1} \\ \varphi_{41,1} & \varphi_{42,1} & \varphi_{43,1} & \varphi_{44,1} & \varphi_{45,1} \\ \varphi_{51,1} & \varphi_{52,1} & \varphi_{53,1} & \varphi_{54,1} & \varphi_{55,1} \end{bmatrix} \begin{bmatrix} E_{t-1} \\ Y_{t-1} \\ C_{t-1} \\ L_{t-1} \\ K_{t-1} \end{bmatrix} + \ldots\ldots + \begin{bmatrix} \varphi_{11,3} & \varphi_{12,3} & \varphi_{13,3} & \varphi_{14,3} & \varphi_{15,3} \\ \varphi_{21,3} & \varphi_{22,3} & \varphi_{23,3} & \varphi_{24,3} & \varphi_{25,3} \\ \varphi_{31,3} & \varphi_{32,3} & \varphi_{33,3} & \varphi_{34,3} & \varphi_{35,3} \\ \varphi_{41,3} & \varphi_{42,3} & \varphi_{43,3} & \varphi_{44,3} & \varphi_{45,3} \\ \varphi_{51,3} & \varphi_{52,3} & \varphi_{53,3} & \varphi_{54,3} & \varphi_{55,3} \end{bmatrix} \begin{bmatrix} E_{t-3} \\ Y_{t-3} \\ C_{t-3} \\ L_{t-3} \\ K_{t-3} \end{bmatrix} + \begin{bmatrix} \omega_{1,t} \\ \omega_{2,t} \\ \omega_{3,t} \\ \omega_{4,t} \\ \omega_{5,t} \end{bmatrix} \quad (4)$$

From equation 4, we can test the hypothesis that C does not Granger cause EN consumption; similarly Y does not Granger cause EN consumption; L does not Granger cause EN consumption; and K does not Granger cause EN. In the similar way the Granger causality test can be performed for all variables.

In summary- the steps of TY procedure are as follows: (i) investigating the maximum order of integration, I (d) of the selected variables by performing different unit root tests; we define it as d^{max} (ii) determining the optimum lag length, p, of a level VAR using different lag length criteria, (iii) estimating the augmented VAR ($p+d^{max}$) in level as defined in equation (4) (iv) since the TY procedures is sensitive to the number of lag, therefore, checking the robustness of augmented VAR ($p+d^{max}$) model by different diagnostic tests (v) performing a MWALD test on first p parameters instead of all parameters in the augmented VAR model and ignore the coefficients of lagged vectors from d^{max} (Caporale and Pittis, 1999); the statistics follow an asymptotic Chi-square distribution (Toda and Yamamoto, 1995; Zapata and Rambaldi, 1997).

2.2.3 Generalized impulse response function (GIRF)

The TY results give the long-run Granger causality within the sample period but it does not allow to gauge relative strength of causality in out-of-sample. The innovation accounting method, the impulse response function (IRF) in contrary, shows how a variable respond from a shock in other variables and whether shock persists or dies out over time. However, the paper uses a generalized IRF proposed by Koop *et al.,* (1996) and Pesaran and Shin (1998) as this approach has the advantages over the standard impulse response function (Ewing and Payne, 2005).

3. Results and discussion

3.1 Unit root test

The unit root test results are reported in Table 1. The unit root results confirm the maximum order of the integration for the selected variables is 1 which is necessary for TY procedures of Granger non-causality analysis. The ADF, PP and ZA tests confirm the same conclusion. Our results are robust however. Therefore having determined d_{max} =1, we proceed to determine the true lag length k.

Table 1: Unit root test results

Tests→ Variables↓		**ADF**	**PP**	**Decision**	**ADF**	**PP**	**Decision**
		Drift (τ_u)			Drift and slope (τ_t)		
Level	EN	0.269 (0)	0.280 (2)	Non-stationary	-2.092 (0)	-2.192 (2)	Non-stationary
	Y	2.719 (0)	4.218 (4)	Non-stationary	-1.624 (0)	-1.624 (0)	Non-stationary
	C	-1.339 (0)	-1.771 (7)	Non-stationary	-0.939 (0)	-0.766 (2)	Non-stationary

	L	0.402 (1)	0.663 (4)	Non-stationary	-2.301 (0)	-2.387 (4)	Non-stationary
	K	2.839 (0)	4.394 (10)	Non-stationary	0.123 (0)	1.263 (8)	Non-stationary
First differe -nces	EN	-6.043*** (0)	-6.043*** (2)	Stationary	-5.947*** (0)	-5.948*** (2)	Stationary
	Y	-6.008*** (0)	-6.018*** (2)	Stationary	-7.195*** (0)	-8.506*** (5)	Stationary
	C	-6.826*** (0)	-6.825*** (0)	Stationary	-7.178*** (0)	-7.528*** (5)	Stationary
	L	-2.337*** (1)	-3.878*** (3)	Stationary	-3.823*** (0)	-3.901** (3)	Stationary
	K	-4.102*** (0)	-4.025*** (4)	Stationary	-5.024*** (0)	-5.063*** (8)	Stationary

Notes: Lag length for augmented Dickey-Fuller (ADF) test is decided based on Schwarz info criteria (SBC) and are in the parentheses; maximum bandwidth for Philip Perron (PP) test is decided based on Newey-West (1994) and are the parentheses; *** and ** indicates that unit root tests are rejected at 1%t and 5% level; τ_u and τ_t indicates *tau*-statistics of random walk with drift, random walk with trend respectively; critical values are -3.633, -2.948, -2.613 at 1% and 5% respectively in the case of only drift; -4.244 and -3.544 are at 1% and 5% level respectively in the case of drift and slope; probability levels are based on MacKinnon (1996)

Next, for determining the optimum lag length we follow Lutkepohl's (1993). We have checked all criteria including likelihood ratio (LR), final prediction error (FPE), Akaike information criteria (AIC), Schwarz information criteria (SBC) and Hannan-Quinn (HQ). Irrespective of the number of maximum lag, we find that SIC shows consistent results of optimum lag to be 1 but in all other criteria the optimum lag length vary with varying maximum lag length. Therefore keeping the small sample in mind, we have decided to accept the optimum lag length to be 1. To complement our decisions we checked all diagnosis tests and we did not find any violation. Given both the maximum order of integration (d_{max}) and the optimum lag length (k) to be 1, we estimated the augmented VAR ($k+d_{max}$) in level, that is- VAR (2) for Granger non-causality test including trend and quadratic trend as exogenous in level VAR (2). We checked the VAR stability condition and have found that no roots are outside of the unit circle. Table 2 shows the results of diagnosis check for the estimated VAR (2) and find no problems of non-normality, autocorrelation and heteroskedasticity. Recall that before proceeding to test the Granger non-causality we are subject to check the diagnosis results for all equations of endogenous variables in VAR (2) what we do next.

Table 2: Diagnosis test results

Diagnosis tests	Test statistics	p-values
J-B test (Doornik-Hansen)	13.291	0.2078
Autocorrelation LM	34.212	0.1034
White heteroskedasticity	490.330	0.201
VAR stability	No root lies outside the unit circle	-

Notes: J-B test null is residual normality, autocorrelation LM test null is no serial correlation up to selected lag, ARCH (auto-regressive conditional heteroscedasticity) test null is no ARCH effect up to selected lag, white heteroskedasticity test includes cross terms and the null is no heteroscedasticity, VAR stability reveals that all roots have modulus less than one and lie inside the unit circle

The diagnostic results are presented in Table 3. The B-G test results suggest that there is a serial correlation problem only in the C equation but neither the Correlogram nor the squared Correlogram shows there is no problem of serial correlation for this. Apart from that, VAR (2) as a system failed to accept the null hypothesis of serial correlation (see Table 3). The Ramsey RESET tests show that there is a problem only in equations L and K, but on the other hand, CUSUM tests do not show any evidence of instability (test results are not presented here because of brevity). Apart from that VAR system shows stability as all roots lie within the unit circle. Given all of these diagnostic test results from level VAR (2), we safely proceed to test Granger non-causality with MWALD test.

Table 3: Diagnosis test results of estimated endogenous equations

Equations	J-B test	B-G test	ARCH-LM test	White test	Ramsey RESET
Y	1.817 (0.403)	0.949 (0.622)	1.456 (0.227)	6.459 (0.891)	1.976 (0.159)
EN	4.589 (0.102)	5.596* (0.061)	0.676 (0.411)	9.501 (0.659)	2.609 (0.106)
C	0.919 (0.632)	6.334** (0.042)	0.238 (0.625)	16.348 (0.176)	0.919 (0.338)
L	0.186 (0.911)	3.854 (0.146)	3.199* (0.074)	16.904 (0.153)	20.376*** (0.000)
K	0.587 (0.746)	1.812 (0.404)	0.777 (0.378)	12.197 (0.430)	3.963** (0.047)

Notes: ***, ** & * indicates the significant level at 1%, 5% and 10% level respectively; the probability level are in the parentheses; J-B test is for null of normality, B-G test null is no serial correlation up to the selected lag, ARCH (auto-regressive conditional heteroscedasticity) test null is no ARCH effect up to selected lag, White test null is no heteroscedasticity), Ramsey RESET test (with one fitted term) null is no specification problem using LR, CUSUM test is based on the cumulative sum of the recursive residuals that explains parameter instability if the cumulative sum is not within the band of two critical lines at 5% significance level

3.2 Causality test results

Results of the estimated Granger causality test are presented in Table 4. As we are more interested on the variables income, energy consumption and CO2 emissions we concentrated on explanations for these variables. We find very interesting result in case of energy consumption and income. There is no causality relationship between the two in either direction which means that energy consumption does not drive the income in India at all and income level does not proceed to energy consumption. The neo-classical view supports our results that energy consumption is neutral to the economic development. Therefore, the government of India may follow energy conservation and energy efficiency policies without limiting income growth potential. Our result is different from the existing results in the literature for India, and also from those who followed bivariate models except Chontanawat *et al.,* (2008) and Huang *et al.,* (2008). However, Soytas and Sari (2009) found similar result for Turkey. Furthermore, Xing-Ping and Xiao-Mei (2009) found that there is a uni-directional causality running from income to energy consumption in China but without any feedback implying that energy consumption is neutral to income, found in Turkey and India. Dynamic panel data model estimation by Bwo-Nung *et al.,* (2008) also reports similar findings, i.e., in the group of low income country, no existence of causal relationship between energy consumption and income. However, for the middle income country, income drives energy consumption but the opposite does not hold true. We argue that our inferences are correctly drawn as our approach overcomes the inherent problems associated with bivariate modeling explained earlier.

Another important result is the existence of bi-directional causality between energy consumption and CO2 emissions. It is straightforward and intuitive that energy consumption drives CO2 emissions because the main source of emission is the combustion of coal dominated fossil fuels in India. But probably the most interesting result is that the opposite also holds true. The unidirectional causality from energy consumption to CO2 emissions has clear policy implication for India. That is, the higher the combustion of fossil fuels, higher is the environmental pollution and vice-versa. So energy conservation could be an appropriate way for reducing emissions and for contribution to global warming control. Since, energy consumption is neutral to income, energy conservation will not undermine income but would rather combat CO2 emissions in India.

We do not find any evidence of causality relationship between income and CO2 emissions in either direction which, however, differs from Dinda and Coondoo (2006) but similar to Soytas *et al.,* (2007) for US, Soytas and Sari (2009) for Turkey, Xing-Ping and Xiao-Mei (2009) for China. The similar result is also found by Ghosh (2010) for India who used ARDL model. This result indicates that income growth does not improve the forecast of environmental quality and will not solve the problem of environmental degradation in India which is at conflict with EKC hypothesis. The result has strong policy message. The reluctance of the Indian policy makers to sign up for legally binding environmental abatement policy for the fear of declining economic development seems to be either a fallacy or may be due to a lack of clear evidence. Our findings are complimentary to the findings of China, Turkey and USA. Since it is not the income that proceed CO2 emissions in the long-run, as observed in China, USA and Turkey, India could very well reduce CO2 emissions without affecting its income growth potential and may contribute significantly to combat increasing global warming problem.

Table 4: Granger causality results based on Toda-Yamamoto's modified WALD test

Dependent variables	Modified Wald test results					Causality inference
	EN	Y	C	L	K	
Y	1.955 (0.162)	-	0.013 (0.909)	1.1782 (0.278)	4.438** (0.035)	Y ← K
EN	-	2.242 (0.134)	4.919** (0.027)	1.735 (0.188)	1.372 (0.241)	EN ← C
C	3.481* (0.062)	0.671 (0.413)	-	0.7220 (0.396)	10.969*** (0.001)	C ← EN C ← K
L	0.279 (0.597)	0.519 (0.471)	2.400 (0.121)	-	4.909** (0.027)	L←K
K	1.694 (0.193)	0.474 (0.491)	0.299 (0.584)	2.049 (0.152)	-	-

Notes: ***, ** and * indicates the significant level at 1%, 5% and 10% respectively; the probability level are in the parentheses; ← denotes a uni-directional causality

3.3 Generalized impulse response function results

Next, we have estimated a GIRF to determine the profile of macroeconomic variables and its response to shocks. Recall that the GIRF show two different results, the initial impact from a shock and the persistent of the impact. The significance is determined by using robust confidence interval presented with dotted lines. The standard errors are obtained by using a Monte Carlo simulation with 5000 replications. Since our main goal is to see the response of CO2, energy consumption and income from a standard deviation shock in the innovations of all endogenous variables therefore we present the results of responses only for these variables.

Title: The significance of competent photoexciton diffusion process in order to accelerate the power conversion efficiency of organic solar cell

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Topic of Submission: Energy: Renewable Energy and Environmental Solutions

The significance of competent photoexciton diffusion process in order to accelerate the power conversion efficiency of organic solar cell

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Abstract— **The performance of Organic Photovoltaic (OPV) solar cell, the technology that has ample potential for low cost production of solar cells, can be ameliorated by upgrading the value of individual efficiency parameters, i.e., absorption efficiency, exciton diffusion efficiency and charge collection efficiency. Based on the study of basic operating principle and diverse structural designs of device architecture of OPV solar cell, it can be adverted to that exciton diffusion efficiency plays the most significant role among all efficiency parameters stated above. Here, we demonstrate a modified design of bulk heterojunction organic solar cell architecture that tenders to deflect the major loss mechanisms during its internal operating steps especially in case of exciton diffusion process. We would like to introduce textured active layer of OPV cell replacing the conventional flat layer style that brings the exciton generation site and the dissociation site close contact to each other, meaning that their internal distance is reduced, which creates an opportunity to generate the photoexcitons at the close proximity with respect to the dissociation site such that the photoexcitons can be generated with limited exciton diffusion length. Such moderate exciton diffusion length makes best use of the short lifetime of the photoexcitons before they are being recombined. Application of a strong and dedicated electric field is one of the major recommendations to achieve a higher exciton diffusion rate. Deployment of different organic materials is the responsible issue in this respect. P3HT:PCBM, perhaps, is deliberated as the most successful combination to achieve the goal of enhanced efficiency rate. An analytical analysis depicts that the proposed model can enrich the exciton diffusion efficiency by about 10-20% that effects the overall power conversion efficiency.**

Keywords- device structure, material selection, exciton diffusion efficiency.

I. INTRODUCTION

The development of polymer (organic) based optoelectronics has been proved themselves as one of the most demanding research fields in recent times. This is because plenty of peer reviewed investigations have been conducted by the researchers on this topic since last two decades or so [1]. The flexibility of organic materials offered diverse chances through the chemical tailoring desired properties along with cheap technology. As a result, polymer based organic materials are highly welcomed for all PV applications nowadays. Diodes, light-emitting diodes, photodiodes/solar cells, field-effects transistors, and memory devices are the noteworthy gifts of optoelectronics research of the modern era [7].

Polymer solar cells based on conjugated polymer and fullerene composites offer special openings as renewable energy sources because they can be fabricated to extend over large areas by means of low-cost printing and coating technologies that can simultaneously pattern the active materials on lightweight flexible substrates [2].

Although promoting improvisation has been made with respect to power conversion efficiency of organic solar cell about 6% having been reported, the limited efficiency has hindered the path toward commercialization [2]. The matter of concerned is that some serious issues are there still alive related to OPV efficiency improvement that the researchers are struggling to overcome. Such obstacles are come to light as concurrent accessories of the OPV technology during basic working procedure taken place. It is believed that the fundamental working process to generate electricity from incident solar light by organic PV solar cells is little bit multifaceted comparing to the inorganic PV solar cell technology. That is why researchers from all around the world are now concentrating to lessen the loss mechanisms that are experienced in OPV technology. In this article, we would like to emphasis on the of importance of two elementary parameters, i.e., (i) device design,

(ii) material selection, that help enrich the efficiency of exciton diffusion process, the most important and complex segment of an organic PV solar cell operation.

II. Working Principle

The basic operating principle of OPV consists of four major steps in order to produce electricity from incident solar light. These essential steps are: (1) Absorption of sunlight (photon) and hence creation of photoexcitons, (2) Exciton diffusion at the dissociation site, (3) Charge transport, and (4) Charge collection at the corresponding electrodes.

When the sunlight (photon) of sufficient energy level is absorbed by the organic materials, an electron jumps to the LUMO (Lowest Unoccupied Molecular Orbital) level abandoning a hole in the HOMO (Highest Occupied Molecular Orbital) level of the Donor (D) component of the organic materials, and as a result, an electron-hole pair (photoexciton) is created in between LUMO-HOMO. Due to electrostatic interactions, the binding energy of such exciton is huge, considered roughly 200-500 meV, which is one order of magnitude larger than for inorganic semiconductors i.e., silicon [4-5].

After the formation of photoexciton, it has to be diffused successfully at the heterojunction to free the charge carriers. For efficient dissociation, the exciton has to travel a required distance from its generation site to dissociation site, which is called exciton diffusion length, with its limited lifetime. To make this process easier few precautions are taken, such as: (i) the donor and acceptor materials are kept in close proximity to each other, usually in the range of few tens of nanometers, (ii) the active layer thickness is managed such a way that it could be analogous to the insight length of the incident light, characteristically which is 80-200 nm in case of organic semiconductors [3], (iii) a devoted electric field can be supplied either via the potential difference of the D/A interfaces or via externally applied electric field. After crossing the exciton diffusion length, an electron-hole pair is split up into separated free charge carriers due to the abrupt changes of the potential energy at the D/A interface [6]. A major challenge lies in fabricating polymer solar cells, in which free-charge-carrier generation is a critical step [7]. However, efficient charge transfer can be boosted through the organic materials i.e., donor and acceptor molecules, with suitable energy level offsets. Photoinduced electron transfer from a donor to an acceptor-type organic semiconductor film introduces free charge carriers (positive charge carriers on the donor layer, i.e., p-type, and negative charge carriers on the acceptor layer, i.e., n-type). D/A-type bilayer devices can thus work like classical p-n junctions [6]. The strong electric field at the molecular interface of two materials with different electrochemical potentials is capable of separating the excitons into weakly bounded Coulombic pairs, and thereafter separated charge carriers. A high interfacial area is achievable within a bulk material through control of the morphology of the phase separation into an interpenetrating network.

At the third stage, the separated charges need to be transported towards the appropriate electrodes. The potential difference ($\Delta\Phi$) between HOMO of the Donor (D) and the LUMO of the Acceptor (A) accelerates the speed of movement of free charge carriers to reach the electrodes.

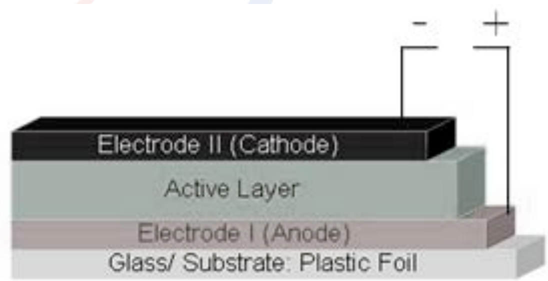

Figure 1. The proposed textured OPV solar cell architecture

Since the electrochemical potentials of the excited conjugated polymer (one electron excited to the LUMO level) and of the excited fullerene component (one hole left in the highest occupied molecular orbital, HOMO, level) are both very high, it might immediately lead to direct electrochemical interactions with the ambient air humidity, etc.

A suitable energy-level alignment between the donor and acceptor to provide the driving force for charge transfer as well as a large ratio of interfacial area to volume for efficient charge dissociation are prerequisites to ensure that charge transfer is the dominant decay channel of photogenerated excitons. That is why control of the charge transport at the heterointerfaces of multilayered OPV structures is one of the most important issues for the efficiency improvement of OPV cells [8]. High internal quantum efficiencies can be expected, provided that efficient D-A charge transfer and transport in the bulk heterojunctions occurs. Finally, the charge carriers are taken out from the device through selective contacts- ITO (work function, $W_f \approx 4.7$ eV) matches the HOMO levels of the hole contact and Al (work function, $W_f \approx 4.2$ eV) matches the LUMO of the acceptor.

III. Critical Parameters

The study on basic working principle of OPV leads to abridge the critical parameters that drive the performance of the corresponding solar cell as follows:

A. *Absiorption of sunlight*

- Absorption surface structure
- Bandgap of organic materials
- Absorption spectra of organic materials

B. *Exciton Diffusion*

- Physical structure of active layer
- Exciton generation length
- Exciton diffusion length
- Exciton diffusion lifetime
- Dedicated electric field
    - Internal: e-field created by the potential difference of D-A
    - External : externally supplied e-filed

C. *Charge Transport*

- A percolating pathway that can be used by the photoexciton to reach towards near electrodes
- Charge career mobility

D. *Charge Collection*

- Overcoming the barriers of electrodes

IV. Loss Mechanisms

The short listed loss mechanisms that we experience during the function of OPV technology are as follows:

A. *Absiorption of sunlight*

- Reflection of sunlight
- Transmission of sunlight

B. *Exciton Diffusion*

- Recombination of excitons
- Short lifetime of excitons

C. *Charge Transport*

- Recombination of free charges
- The clash of free charges

D. *Charge Collection*

- Recombination near electrodes
- The barriers of electrodes

V. Device Architectures

The research on device physics has been introduced few important types of solar cell device architectures. Based on the innovation time we can classify those architectures as follows:

Time	**Generation**	**Features**	**η_p**	**Ref**
1975	1st Gen.	Small molecules	0.001 %	[9]
1986	2nd Gen.	Bilayer Structure	1%	[10]
2003	3rd Gen.	Bilayer Structure + cosublimation	1.5%	[11]
2005	3rd Gen.	Bulk heterojunction	5%	[12-14]

Throughout this work, our reference device architecture is bulk heterojunction device, explaining rest of the device concepts go beyond the scope of this article.

Bulk heterojunction Device

Bulk heterojunction is a blend of the donor and acceptor components in a bulk volume (Figure 1). It can be achieved by co-deposition of donor and acceptor pigments or solution casting of either polymer/polymer, polymer/molecule, or molecule/molecule donor-acceptor blends [6]. Bulk heterojunction exhibits a D/A phase separation in a 10-20 nm length scale [6]. The major plus point of such a nanoscale interpenetrating network is that each interface is within a distance less than the exciton diffusion length from the absorbing site.

Unlike the bilayer heterojunction, where the donor and acceptor phases are completely separated from each other and can selectively contact the anode and cathode, in the bulk heterojunction both phases are intimately intermixed [7]. This admixture has a priori no symmetry breaking in the volume. There is no preferred direction for the internal fields of separated charges; that is, the electrons and holes created within the volume have no net resulting direction they should move. Therefore, a symmetry breaking condition (like using different work-function electrodes) is essential in bulk heterojunctions. Otherwise, only concentration gradient (diffusion) can act as driving force. It has been reported that the insertion of buffer layers between the organic layer and the electrodes improves the device performance [8]. For example, the insertion of a LiF layer that is several angstroms thick between the organic layer and the Al electrode is one of the most effective ways to improve performance. Therefore, the bulk heterojunction devices are much more sensitive to the nanoscale morphology in the blend.

However, the detailed effects and mechanism of the improvement of parameters are still not entirely clear. In addition, heterointerfaces can be easily affected by external factors over time, which makes evaluation even more difficult [8]. In order to clarify the heterointerface phenomena, it is necessary to evaluate OPV cells soon after the formation of the interface vacuum deposition of a metal electrode.

VI. Material Selection

The research history of organic solar cell is not very older, ironically, it has been experienced a wide variety of usage of organic materials as donor (D) and acceptor (A). The reason why such experiments have been taken place is, perhaps, to find out the optimal combination of the organic materials that can best advocate aggrandizing the performance of the OPV solar cell device. The primary chemical structures of polymer and fullerene determine the solubility in organic solvents and the miscibility between these two compounds [15]. The solvent itself furthermore influences the drying time during film formation, whereas thermal annealing enables the recrystallization. Diffusion of one or both components in the blend leads to a modification of the phase separation. It is already demonstrated that the power conversion efficiency of bulk heterojunction solar cells can be improved dramatically by manipulating the morphology of the components as well as of the blend [16-17]. The resulting several-fold enhancement in the short circuit current of PV devices originates from improved mobility of the charge carriers [15]. The study of bulk heterojunction OPV cell design has grown up based on poly(3-hexylthiophene) and 6,6-phenyl C61-butyric acid methyl ester (P3HT:PCBM) as the baseline. Because P3HT:PCBM systems have shown some of the largest reported single layer cell efficiencies for OPVs and are therefore of interest when analyzing bulk heterojunction OPV efficiency losses [18]. A number of reports have been published on chemical doping of a semiconductor matrix by introducing small concentrations of reagents (dopants) [17]. The buckminsterfullerene C_{60} is an electron acceptor, which can be electrochemically reduced up to 6 electrons [16]. For photoinduced electron-transfer reactions (i.e., photodoping), it has been blended into electron-donating matrices with hole conducting properties [6]. The solubility of simple C_{60} is limited. Wudl et al. synthesized a soluble derivative of C_{60}, PCBM (1-(3-methoxycarbonyl) propyl-1-phenyl[6,6]C_{61}), which has been widely used in polymer/fullerene solar cells due to its remaekable advantage: solubility [6]. Some of the important representatives of hole conducting donor-type semiconducting polymers on the other side are (i) derivatives of phenylene vinylene backbones such as poly[2-methoxy-5-(3,7-dimethyloctyloxy)]-1,4-phenylenevinylene) (MDMOPPV), (ii) derivatives of thiophene chains such as poly(3- hexylthiophene) (P3HT), and (iii) derivatives of fluorine backbones such as (poly(9,9'-dioctylfluorene-*co*-bis-*N*,*N*'-(4-butylphenyl-1,4-phenylenediamine) (PFB) [6]. Phthalocyanine and perylene have commonly found applications in thin film organic solar cells. Phthalocyanine is a p-type, hole conducting material that works as electron donor, whereas perylene and its derivatives show an n-type, electron conducting behavior and serve as electron-acceptor material.

VII. Exciton Diffusion Efficiency

The separation of photoexcitons into free charge carriers, which is considered as the most significant part of the entire working procedure of OPV, takes place in the exciton diffusion step. Basic operating principle of OPV technology depicts that once the photoexciton is generated inside the active layer upon absorption of sunlight it needs to be diffused at the donor-acceptor (D/A) interface to free the charge carriers. Based on the above discussion, the short listed key challenges that involve the exciton diffusion process are: (a) protecting the photoexcitons from being recombined before splitting up, (b) generating photoexcitons with moderate exciton diffusion length, and (c) ensuring the best use of limited lifetime of the photoexcitons.

In order to resolving such confronts, here we propose to moderate the structural design of the conventional OPV cell according to Figure 2. In this case, the active layer is folded such a way that the excitons can be formed as near as possible to the dissociation site. As a result, the short exciton diffusion length as well as the limited span of lifetime of the photoexcitons can be employed more efficiently. This is because the suggested triangular textured model offers the potential to cut the travelling distance for an exciton from its generation site to dissociation site.

Exciton diffusion efficiency is the fraction of photogenerated excitons that reaches a D/A interface before recombining. It is alleged that the chief parameters that run exciton diffusion process are basically (i) exciton generation length-the distance between exciton generation site and dissociation site and (ii) exciton diffusion length-the minimum required distance that has to be travelled by the exciton to split up. The exciton generation site adverts to the place where the exciton forms after sunlight absorption which is basically depends on the optical absorption length of organic materials.

Here, we propose a formula for calculating the exciton diffusion efficiency:

$$\eta_{ED} = 1\text{-exp}\left(-\frac{L_{EG}}{L_{ED}}\right) \text{ .... (1)}$$

Where, exciton generation length, $L_{EG} = L_{DS} - L_A$, $L_{DS=}$ Dissociation site length (with respect to anode), L_A = optical absorption length. Here, $L_{DS} > L_A$ (since optical absorption length cannot exceed dissociation site length). The proposed equation affirms the key concepts of the exciton dissociation occurrence, such as, (i) the exciton diffusion efficiency decreases if the exciton diffusion length increases and vice versa (ii) the exciton diffusion rate increases with the increment of exciton generation length.

On the other hand, exciton diffusion efficiency can be described as the ratio between the number of electrons leaving the device under short circuit condition per time per area and the number of photons incident per time and area [3]. This is termed as incident photon to converted electron efficiency (IPCE). ICPC is a ratio described as a function of wavelength, indicating that the charge carrier collection is a sensitive function of the morphology. The increase in efficiency relies on an increase of charge carrier mobility as observed by field-effect mobility measurements of the single components as well as of the mixtures processed forms the different solvents. Mathematically, IPCE can be expressed as follows [3,6]:

$$\text{IPCE} = \frac{\text{no. of extracted electrons}}{\text{no. of extracted electrons}} \text{ .... (2)}$$

$$= \frac{1240 * Isc}{\lambda * Pin} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where, λ[nm]= incident photon wavelength, I_{sc}[μA/cm^2]= photocurrent of the PV device. IPCE is regarded as one of the core parameters of external quantum efficiency, which includes few lose mechanisms like losses due to reflection at the surface, transmission through the PV device [3].

VIII. Efficiency Calculation in Organic Solar Cell

The power conversion efficiency of a solar device can be calculated using the following formula [13]:

$$\eta_P = K_P * \eta_A * \eta_{ED} * \eta_{CT} * \eta_{CC} \ldots\ldots\ldots \text{(4)}$$

Here, K_P = power conversion constant, η_A = absorption efficiency, η_{ED} = exciton diffusion efficiency, η_{CT} = charge transfer efficiency, η_{CC} = charge collection efficiency.

IX. Underlying Challenges

It is widely believed that the low mobility of the organic materials put significant constraints on the thickness of the layers used in organic solar cells. Meanwhile, it is reported that layers that are thicker than 200-300 nm do not absorb more sunlight comparing to a thinner film but exhibit a larger series resistance [21]. As a result, optical interference is produced as the optimal film thickness is less than the wavelength of the incident light. Then the complex indices of refraction and thickness of layers within the device architecture drive the standing wave pattern which is created
by effect of reflection and transmission at each material

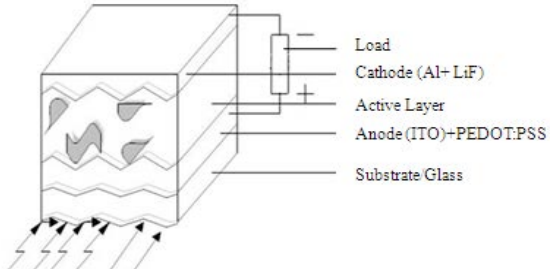

Figure 2. The proposed textured OPV solar cell architecture

interface. Such optical interference pattern, which can be calculated by transfer matrix method (TMM), corresponds directly to the exciton generation rate throughout the layer structure [16-18]. The percentage of excitons that reach a dissociation site is then calculated from exciton generation profile by solving diffusion equation (Equation 1).

The second factor limiting the efficiency of P3HT:PCBM cells is the absorption range of P3HT. P3HT absorbs visible light until about 650 nm, meaning that most of the red portion of the visible spectrum and all infrared photons cannot be harvested [13, 19]. Efforts have been undertaken to increase the absorption range by synthesizing novel low-bandgap polymers. One major problem with these low band-gap polymers was their low mobilities, which limited the efficiency. The mobility plays an important role especially for low-bandgap polymers, since at longer wavelength much thicker layers are needed for absorption of sunlight and the buildup of a space charge has to be prevented to achieve high fill factors and short circuit voltages.

All forms of recombination process are treated as the sources of loss mechanisms for the photoexcited charge carriers in an organic solar cell. Non-radiative recombination, however, affects photoexcited charge carriers statistically much faster than the inevitable radiative decay that does not require any semiconductor defects. Consequently, if there is only radiative recombination event is experienced the charge carriers have much better chances to reach the electrodes and circumvent the rediative decay by entering an external circuit. One of the foremost challenges for the photoexcitons to avoid recombination is the short diffusion lifetime. If an exciton cannot reach to the dissociation site within its short lifetime it recombines.

In order to avoid such important loss mechanism achieving longer diffusion length for the singlet excitons could be a paragon solution. For long exciton diffusion length the material in solid film should posses a long exciton diffusion lifetime along with a strong optical transition (emission and absorption) and the spectral overlap between emission and absorption should be large, implying a small stokes shift. In some materials, generated singlet excitons rapidly transfer to triplets. Although population of triplet states by direct absorption from the ground state is insignificant, a more efficient process exists for population of triplet states from the lowest excited singlet state in many molecules. The process is adverted to as intersystem crossing and a spin-dependant internal conversion process. As singlet-triplet processes are generally less probable than singlet-singlet process, one may be startled that a singlet-triplet process such as intersystem crossing can occur within lifetime of an excited singlet state (10^{-8} sec). It should be noted that the mechanism for intersystem crossing involve vibrational coupling between the excited singlet state and a triplet state.

The intersystem crossing of the polymer (or the fullerene) produces triplet excited states and these may in return react by energy transfer creating singlet oxygen. This highly reactive form of oxygen is expected to react with the polymer backbone creating carbonyl type defects eliminating the conjugation. By the ultrafast photo-induced electron transfer the intersystem crossing to the triplet state. The intersystem crossing of the polymer (or the fullerene) produces triplet excited states and these may in return react by energy transfer creating singlet oxygen. This highly reactive form of oxygen is expected to react with the polymer backbone creating carbonyl type defects eliminating the conjugation. By the ultrafast photo-induced electron transfer the intersystem crossing to the triplet state is also completely quenched as stated above.

X. Results, Simulations and Discussions

Fig. 3 shows an analytical analysis of the increment of exciton diffusion efficiency that is observed through the proposed textured device model. In this case we obtain about 8% increment in η_{ED} which can be further accelerated over 10% tuning the optimal width of the triangular textured active layer.

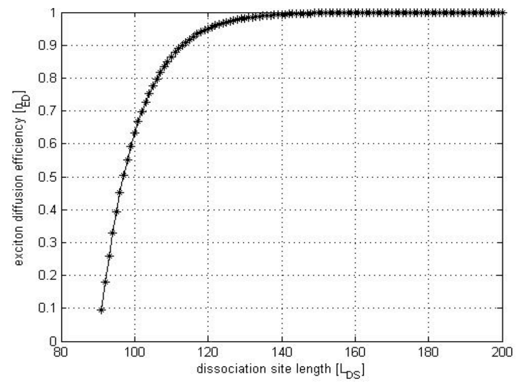

Figure 3. Increment in exciton diffusion efficiency after texturing

XI. Conclusion

Organic photovoltaic cells are expected to be the next-generation solar energy conversion devices that promise to be light, flexible, and printable. That is why it has drawn a great attention to the corresponding researchers due to its ample opportunities that lie ahead in the near future. Despite the high attainable EQE, overall power conversion efficiencies (PCE) reported are still low, due to abortive diffusion of photoexcitons, the inferior charge-transport properties and limited spectral absorption range of the polymer active layer. Finding some acceptable ways to decrease the major system losses in OPV is the foremost duty of the PV researchers nowadays. Being the most dominating parameter among all, the exciton diffusion process drives the OPV solar cell efficiency at a large scale. With a view to assisting this vital function our proposed textured Bulk heterojunction solar cell provides an amicable environment that help diffuse more photoexcitons than the conventional device format offers. What would be the most beneficent material as donor and acceptor in order to add extra momentum to the diffusion process is a matter of thinking till today. In this millennium, PV energy conversion will gain in momentum. This clean and regenerative energy source should be utilized by exploiting all possible mechanisms, materials, and device.

Acknowledgment

The authors gratefully acknowledge the partial support of Ali Iftekher Arif, Nowshad Amin,

Jasim Uddin, Nahid Rahman, Rashedur Rahman, Ahmedul Haque, Tausif Alam and Fariha Sultana.

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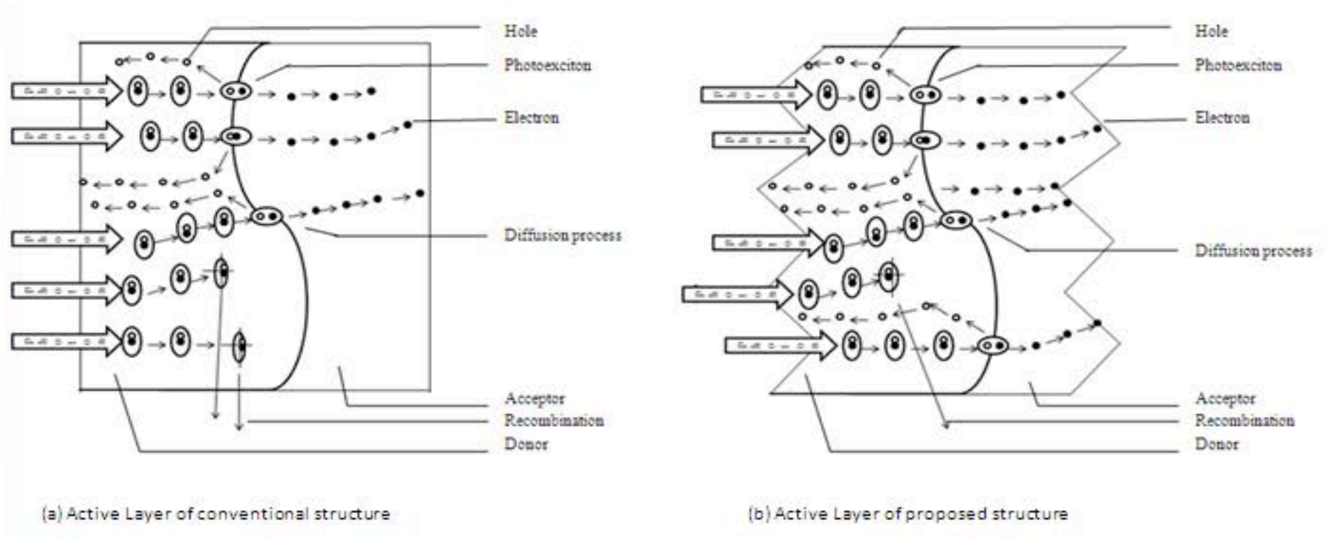

Figure 4. Comparison of active layer structure: (a) Conventional bulk heterojunction OPV cell and (b) Proposed triangular textured bulk heterojunction OPV cell. Here, we can experience that our proposed triangular textured bulk heterojunction OPV cell offers less loss mechanisms (recombination loss) than the older one.

The Implementation of an Open Space Policy by the States in Peninsular Malaysia: The Need for a Uniform Policy?

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Abstract
The provision of open spaces within a residential development is often seen as unimportant. The Malaysian Government targeted to provide 2 hectares of open space per 1000 population to be achieved as a developed nation status by the year 2020. This vision can be seen as the Government attempt to ensure the sustainability of open spaces in Malaysia. The Federal Department of Town and Country Planning, Peninsular Malaysia (FDTCP) has produced a planning standard guideline to supervise the implementation of the open space policy in Malaysia. According to FDTCP; until December 2009, Malaysia has achieved a percentage of 1.19 hectares of open space per 1000 population. Achieving the standard requires commitment of local authorities to implement the open space policy. However, the adoption of open spaces policy differs among local authorities, from a simplistic general approach of land ratio techniques to an ergonomics method. The paper examines the local allocation practices using 5 different approaches and it argues that implementation of open space by local planning practices requires the knowledge of and understanding by planning profession towards a long term sustainable green objectives.

1.0 Introduction

The importance of open areas or open spaces has been widely covered by writers and researchers. This is because open spaces provide huge benefit to human lives in terms of quality of life. However, a review by Luqman, Yusoff Mohd, et al. (1999) highlights the fact that developments in cities are being designed solely to emphasize commercial values and profits. Green spaces are sacrificed to make way for the development in cities. This has resulted in the neglected interest and welfare of city dwellers as the developers' main focus is to reap maximum return on investment. By and large, developers have not been adequately providing open spaces for city dwellers for outdoor activities. Sometimes the provision of open spaces is merely to meet the approval requirements set by state governments and local authorities (LA's). Therefore, it is important that the state governments in Malaysia ensure that the implementation policy for its open spaces is in accordance the provision with the Planning Standard Guidelines for Open Spaces and Recreation (JBPD 7/2000) issued by the Federal Department of Town and Country Planning, Peninsular Malaysia (FDTCP). The commitment by each LA to implement the open space policy within their respective jurisdiction is a key step in ensuring that the provision for open spaces is not ignored by the developers in their proposed developments. Thus, the research will be focusing into the aspect of policy implementation by the decision maker and planning administrative at the local level. Emphasis on the implementation and application of open space policy is the first step taken before a development can be approved. Therefore, strong enforcement by the LAs will is highly needed to ensure the sustainability of open spaces will be more secure.

2.0 Definition of Open Spaces

It is believed that the term ‘open space’ was first used in 1833 by a committee in a *“public trail”* in London. This committee is also believed to be the agency responsible for creating the term ‘open spaces’ (Maruani and Amit-Cohen, 2007, p.4). The usability and design of open spaces evolved in line with the developments and trends of the times. Today, the term ‘open spaces’ is adopted worldwide as areas for various activities such as recreation and as places to meet and socialize. In the Malaysian local context, the definition of open spaces under Section 2 (1) Town and Country Planning Act 1976 (Act 172) is "any land that is enclosed or not enclosed, for use or reserved for the use in whole or in parts as public gardens, public parks, public sports and recreational fields, tourism areas, pathways or public places" (p.l5). In general, open spaces can be considered as an open area designated for the public to carry out their recreational activities. Grose (2009) has similar views with regards to the definition of open spaces as that in Act 172, and defines open spaces as ‘public spaces’. It can be deduced from the definitions in Act 172 and writings of Grose that open spaces are areas built for public recreational purposes. Thus, it should be noted that the term ‘open spaces’ used in this paper refers to the open spaces in residential areas provided for the public use of recreational activities.

3.0 Conservation of open space as a tool for sustainable development

It is widely known when a new development occurs it involves the opening of an area. The total area of development is based on the capital and the greatness of the project to be developed. If the development occurred on the outskirts of town; the problem of land is not a big issue. However, if the location of the project is in the city centre, developer will face a problem to find a suitable location. Review of Girling and Helphand (1994) indicates that green space is gradually decreasing in addition to the development of more houses especially in urban area. This situation is in line with the current situation in Malaysia in which the urban population will increase up to 70 percent by the year 2020 (Department of Statistics Malaysia, 2000). Review of Bengston, Fletcher et al. (2004), states open space protection is the main issue of sustainable development. This is because to achieve the objective of sustainable development, it should have some allocation of open spaces for public use. Developers are required to provide open spaces and greenery in each development undertaken. This is important for the fact that people need open spaces to perform outdoor activities while green areas are necessary to act as a buffer zone and green belt area. Open spaces provision indirectly provides 'balance' between development and environmental protection. Thus it appears clearly that conservation of open space is one of the right ways to accomplish sustainable development. Therefore, preservation of such spaces is highly important to ensure a better quality of life can be achieved.

4.0 Existing Policy for Open Spaces in Malaysia

As a result of rapid development urban areas are experiencing a critical shortage of green areas. Thus, for every development within and near urban areas, the location and allocation of open spaces must be seriously considered by the authorities to prevent the reduction in the urban green areas due to development. To realise the concept of “a city in a park” mooted by the former Prime Minister of Malaysia, His Excellency Tun Dr Mahathir Mohamad, FDTCP issued a general guideline which is the JBPD 7/2000. The main objective of the guideline is to assist state governments through their respective LAs to achieve the vision in making Malaysia a “Garden

Nation". The intention of the guideline is to assist town planners, developers, and the general public to better understand the key issues of open spaces with respect to financial provisions, sizes, definitions, usage, and design requirements that must be met. With respect to open spaces, the Town and Country Planning Act 1976 (Act 172) is important and relevant as open spaces are clearly defined in this Act. As stated in Section 2.0, a clear description of what constitutes 'open spaces' in Act 172 is vital as it serves as the basis of reference in defining the true meaning of open spaces in the Malaysian context. The provisions in the Act seem to be genuine and workable. The approaches and measures by the government in the agenda are to ensure the preservation and sustainability of open spaces and green areas in the country.

5.0 Implementation of Open Spaces Policy at States Level

Malaysia comprises of 14 states[i], 12 states are located in Peninsular Malaysia, while Sabah and Sarawak located in Borneo Island. In relation to open space policy, the 11[1] states in Peninsular Malaysia are bounded by the Act 172 (Town and Country Planning Act) with exception of Federal Territory of Kuala Lumpur, Sabah and Sarawak. The Town and Country Planning Act 1976 (Act 172) was passed by the Malaysian Parliament with the intention to coordinate matters relating to the laws and town and country planning in all the states of Peninsular Malaysia (Lee, Abdul Mutalip et al., 1990; Goh, 1991). The states under Federal Territories (Kuala Lumpur, Labuan and Putrajaya), Sabah and Sarawak, as mentioned uses its own act because the states under the Federal Territories have adopted the Federal Territory Act 1982 (Act 267). Likewise, Sabah and Sarawak are not bound by Act 172 because the two states have adopted different acts which is referred to as the Town and Country Planning Ordinance (Sabah Cap.141) and the Town and Country Planning Ordinance (Sarawak Cap.87) (Phang, 2006; Zakaria, 2006; Ainul Jaria and Bashiran Begum, 2009).

In general, FDTCP has set a policy of 10 percent for open spaces for each development application. However, the 10 percent policy is merely a base reference. According to FDTC (2009), the states bound by Act 172 have the option of implementing the open spaces policy in various ways for development in their respective states. **Table 1** shows the guidelines for open spaces adopted by the states that are enacted under Act 172. It is believed that the adoption of open spaces policy differs among LAs within states because many LAs are responsible for all administrative matters at the local level. Each authority has its own guidelines with respect to matters in open spaces. **Table 1** present five basic types of approaches that the 11 state governments in Peninsular Malaysia adopt to determine the appropriate guidelines for use in their respective areas. The approaches can be divided into *general*, *ergonomics space*, *land ownership*, *number of housing units*, and *the size of the development area*. The common denominator is the provisions of open spaces, but the approaches differ because of the differences in economic development status, population, demand, and physical locations of the approved areas. Below is a brief discussion of the guidelines:

5.1 General Approach

The 'general approach' implemented by Negeri Sembilan and Kelantan is based on the basic 10 percent provision of open spaces for all types of residential development. The general approach is applied in total (stand-alone) or as a continuous policy as set by FDTCP.

[1] All the 11 states are Johor, Kedah, Kelantan, Melaka, Negeri Sembilan, Pahang, Pulau Pinang, Perak, Perlis, Selangor, and Terengganu.

Table l: **Existing Open Spaces Guidelines in the States of Peninsular Malaysia**

State	Guidelines	Approaches
Negeri Sembilan	● Adopts the 10% base for open spaces	General
Kelantan		
Pulau Pinang	● Adopts the 4 m^2 for open space per resident (on the ground and building)	Ergonomic space
Terengganu	● For state owned land, 10% of open spaces must be provided ● For private owned land, 5% of open spaces must be provided	Land ownership
Perlis	● Adopts the 10% base for open spaces for housing development exceeding 4 units ● The 10% is part of the 30% reserved for public facilities	Number of housing units
Pahang	● For housing development of 30 units or more (3 acres), 10% or a minimum of 7% of open spaces must be provided	
Kedah	● For housing development of 0.25 acres or more, 326.7 Sq Ft for each house must be provided. ● For commercial and industrial areas, 10% of open spaces must be provided	
Melaka	● For housing development of 2 acres or more, 10% of open spaces must be provided. ● For development less than 2 acres there is an option of providing 10% of open spaces or the discretion and goodwill of the respective PBTs	Size of the development area
Selangor	● Selangor Land and Mines Office Circular - for development of ≥ 10 acres, 10% of open spaces must be provided - for development of 5 – 10 acres, option to provide open spaces or pay contribution fees - for development of ≤ 5 acres, payment of contribution fee based on the following rates: RM 50,000/acre for areas within the Klang Valley RM 35,000/acre for areas outside the Klang Valley ● Guideline Manual for Selangor - for development ≥ 10 acres, provision of 10% of open spaces ● For development of ≤ 5 acres, provision of 5% of open spaces	
Perak	● Adopts the 10% base for open spaces ● For development > 5 acres - Semi-detached housing and bungalow development, approximately 7% of open spaces must be provided - Low cost, medium high/low cost housing, flats development, 10% of open spaces must be provided ● For development < 5 acres - Semi-detached housing and bungalow development NOT required to provide any open spaces. ● Low cost, medium high/low cost housing, flats development, 5% of open spaces must be provided	
Johor	● At least 10% of the size of the development site ● From the total, 7% must be the absolute open spaces and 3% can be considered from the public facility reserves handed over to the government.	

	● Exemption to the application for housing development of less than 2 acres, also for application for homestead development. For the purpose of calculating open spaces, 30% from the public facilities can be considered as open spaces.	

Federal Department of Town and Country Planning, Peninsular Malaysia (2009).

5.2 Ergonomic Space Approach

The ergonomic[2] space approach implemented in Pulau Pinang for the provision of open spaces refers to the measured requirements for an individual to feel comfortable. The measurement for an ideal ergonomic space can be visualised by stretching out both human arms. The ergonomic space with an area of 2m x 2m for each individual is believed to be ample for the individual to move freely and feel comfortable in carrying out activities in open spaces.

5.3 Land Ownership Approach

Determining the percentage for the provision of open spaces for each development in Terengganu is based on the 'land title'or 'land use' areas to be developed. The 10 percent provision approach is not easy to apply for developments on government land because the LAs are occasionally forced to be lenient towards certain parties who request exemptions.

5.4 Number of Housing Unit Approach

Perlis, Pahang and Kedah adopt the number of housing unit approach to determine the percentage for the provision of open spaces required of the developer. However, it was discovered that the conditions under which this approach is implemented differ between the three states because the number of developments and population differ greatly.

5.5 Size of Development Area Approach

There are four states that have adopted the size of development area approach as a method to determine the percentage for the provision of open spaces required of the developers. In Melaka, for developments that achieve the minimum qualification, the provision of open spaces by the developer is at the discretion and goodwill of the LA. While in Selangor, developers are required to pay a contribution to the LA if they cannot meet the provision of open spaces due to limited land or minimum development qualification. In Perak; the emphasis is on the provision of open spaces for high-rise housing development. Developers are not given any leniency in the provision of open spaces for high-rise housing development. Last but not least, the state of Johor breaks down the percentages for the provision of open spaces into 'absolute open spaces' and public facilities. 'Absolute open space' here means a completely open area.

Undoubtedly, the five approaches discussed have their own issues and problems. Whichever the approach adopted, it should promote the provision of sustainable open spaces for public use.

[2] Ergonomics as in The Concise Oxford Dictionary of Current English (8th' Edition, 1991) means the study of a person's comfort in their work environment.

However, each approach adopted must be implemented with a single goal, which is to ensure that the provision of open spaces in housing developments cannot be easily neglected.

6.0 Research Approach

As the research focus on policy implementation by the decision maker and planning administrative at the local level, respondents involved in the survey were the town planning officers and their technical assistants. The survey manages to obtain a sample size of 240 units with response rates of 52.6% from 98 local authorities in Peninsular Malaysia[3]. The first section of the research looks into personal information of the respondents such as gender, age, job position and council status. Section 1 of the survey will include questions with regards to dissimilarity in application of open space policy among LAs, Section 2 will be discussing on independent policy implemented by the states in Peninsular Malaysia. Finally, Section 3 will talk about the effectiveness of the JBPD 7/2000 guideline.

7.0 Research Findings

The research findings indicate male respondents formed the majority (59.6%) of the responds; the remaining 40.4% are female respondents. The average age of respondents was 35 years old. The planning officers formed the major group of the respondents with 57.5% while the remaining 42.5% was the response of the technical assistants. The respondents involve in the survey work in three categories of council status which are *city council*, *municipal council* and *district council*. Majority of the respondents work in a municipal council that comprises of 43.9%; followed by a district council that is 43.1% and 13% out of the respondents work in a city council.

a) Different application of open space policy by LAs.

The first section of the survey was to investigate the differences in the application of open space policy guideline by the LAs from 11 states in Peninsular Malaysia. Two questions were asked to draw out respondent's opinion with regards to the differentiation; (1) do the respondent's aware of dissimilarity in the application of JBPD 7/2000 guideline among LAs; and (2) the differences in application of JBPD 7/2000 is due to the development situation in the jurisdiction.

Table 2: Dissimilarity in application of JBPD 7/2000 guideline

	Frequency	Percent
Disagree	5	2.1
Not sure	13	5.4
Agree	220	91.7
Total	238	99.2

As expected, majority of respondents stated that they are aware of the differences in application of JBPD 7/2000 guideline among LAs. **Table 2** shows high percentage of 91.7% (n = 220) agree with the statement. Out of 240 respondents only 5 was not aware of the differences and 13 was not sure. The result provides initial observation; majority of

[3] The questionnaire survey was conducted for a period of three months from 1st January 2011 and ended on 31st March 2011 using a mail method. Since the study will be focusing on the execution of the *Planning Standards and Guidelines for Open Space and Recreational Areas (JBPD 7/2000)* among local authorities in Peninsular Malaysia; for the purpose of writing, this guideline will subsequently be referred as the JBPD 7/2000 guideline.

the respondents are highly experience planning professionals. A small percentage of 2.1% that was not aware of the differences was probably young and inexperienced respondents.

Table 3: Difference in application is due to development situation

	Frequency	Percent
Disagree	6	2.5
Not sure	68	28.3
Agree	162	67.5
Total	236	98.3

Table 3 also indicates high percentage in term of agreement - more than half of the respondents agree (67.5%) the differences in application of the JBPD 7/2000 guidelines is because of development situation. The remaining 32.5% was not sure and disagree with explanation of diverse application of the JBPD 7/2000 guideline by LAs in Malaysia is because of distinction in development pace. The initial result from the two questions can be concluded; the JBPD 7/2000 is standard open space guideline used by the states government for the purpose of open spaces provision. However, through the respective LAs the guideline has been *'adopted* and *adepted'* to suit with the development situation in jurisdiction.

b) Different guideline approaches implemented by the state governments.

Section 2 of the survey focus on independent policy implemented by the states in Peninsular Malaysia. As been indicated in Table 1, there are five basic types of approaches that the state governments adept from the JBPD 7/2000 guideline pertaining to open space provision. The approaches was different and independent therefore what is seem to be appropriate to be implemented in one state might not be suitable to other. Consequently, the state government needs to determine the most appropriate procedure for the use in their respective areas. In Section 2, respondents were asked to select the open space guideline application that is put into practice by the LAs they work with. The purpose of the question is to calculate the percentage for each methods of open space policy application used. Before proceeding with the question, the research needs to explore the distribution number of LAs for the 11 states in Peninsular Malaysia.

Table 4: Statistics Of Local Authorities According To Status

	State	City Council	Municipal Council	District Council	TOTAL
1.	KELANTAN	0	1	11	12
2.	NEGERI SEMBILAN	0	3	5	8
3.	PULAU PINANG	0	2	0	2
4.	TERENGGANU	1	2	4	7
5.	KEDAH	1	3	7	11
6.	PERLIS	0	1	0	1
7.	PAHANG	0	3	8	11
8.	MELAKA	1	3	0	4
9.	PERAK	1	4	10	15
10.	JOHOR	1	6	8	15
11.	SELANGOR	2	6	4	12
	TOTAL	7	34	57	98

Local Government Department, Ministry of Housing and Local Government (2011)

Table 4 presents the statistics of LAs based on their status that are bounded under Act 172. It was observed the state of Kelantan, Kedah, Pahang, Perak, Johor and Selangor have more than 10 LAs for each state regardless of council status. Three states has the least number of LAs which are Perlis (1); Pulau Pinang (2); followed by the state of Melaka (4). Last but not least, the state of Terengganu has 7 LAs and the state of Negeri Sembilan has 8 LAs. The number of LAs in each state is indeed important in the survey because it will affect the estimated potential respondents.

Table 5 shows the percentage of guideline application that was put into practice by respondents involves in the survey. Out of five types guideline approaches used by the 11 states in Peninsular Malaysia; *total of land development* method scores the highest percentage of 50.9% (n = 112). In this method, the size of open spaces in an area will be based on calculation; 10 percent out of total development size.

Table 5: Guideline Application

	N	Percent of Cases
General	43	19.5%
Ergonomic Space	4	1.8%
Land Ownership	14	6.4%
Total of Housing Unit	47	21.4%
Total of Land Development	112	50.9%
Total	220	100.0%

As expected this method will have the highest fraction because four states adopted this approach[4]. The second highest percentage score is the *total of housing unit* method and three states opted for this approach[5] with 21.4% (n = 47) of respondents indicated this technique is put into practice by the LAs they work with. In this method the amount of open spaces need to be provided in a development will depend on the numbers of houses built. The *general* approach which is implemented by the state of Kelantan and Negeri Sembilan, scores the third highest percentage with 19.5% (n = 20) followed by the *land ownership approach* with 6.4%. (n = 7) applied in Terengganu. The lowest percentage of 1.8% (n = 4) is the *ergonomic space* approach which was implemented by a single state in Peninsular Malaysia; Pulau Pinang. Considering the distribution of LAs in **Table 3** confirm the percentage and number of responses obtained in the survey. It was difficult to accomplish higher number of respondents in the states that have a few LAs. Other than that the types of guideline application opted by the state government also play important roles in anticipating the result.

c) Effectiveness of the JBPD 7/2000 guideline.

[4] Melaka, Perak, Johor and Selangor.
[5] Kedah, Perlis and Pahang.

Although the 11 states have options of implementing the open space policy in different ways the JBPD 7/2000 guideline plays an important role to prevail the general parameters with regards to open space provisions. As an attempt to investigate views on the effectiveness of the JBPD 7/2000 guideline among LAs town planners and technical assistants; series of questions were asked to elicit their opinion with regards to the stated guideline. The identified attributes listed to measure effectiveness in the study are (1) do the respondents feel the guideline is important for open space planning; (2) to what extend the respondent think the guideline is a useful planning tool; (3) usage of the guideline as a reference material in daily work.

Table 6: Important Policy and Useful Planning Tool

	Important Policy		Useful Planning Tool	
	Frequency	Percent	Frequency	Percent
Disagree	66	27.5	49	20.4
Not sure	45	18.8	68	28.3
Agree	128	53.3	118	49.2
Total	239	99.6	235	97.9

As expected; majority of respondents feel that JBPD 7/2000 guideline is indeed a very important guideline. **Table 6** shows a total of 53.3% (n = 128) agree the guideline is indeed significant for open space planning. The remaining 27.5% disagree with the statement and 18.9% was unsure. Even though there was a big difference in agreement for this, **Table 6** also indicates almost half of the respondents (49.2%, n = 118) agree the guideline is a useful planning tool. This is because the guideline indicates detail parameter pertaining to open space planning. The results provide an idea that the guideline is considered fundamental with respondent's nature of work. The JBPD 7/2000 guideline can be said as an essential reference material in the preparation of conducive open spaces.
The effectiveness of the guideline further examined with regards to its usage as a reference material. The result indicated 44.6% (n = 107) of respondents stated they always use the JBPD 7/2000 guideline in their daily work and 29.6% indicated they seldom use the guideline. Of those who responded, only 59 (24.6%) said they never use the JBPD 7/2000 guideline. The research predicted this is probably because of the nature of their work. The Planning Department in LAs have various units such as planning control, GIS and research and development unit. Therefore, it was envisaged respondents who never use the guideline does not involve in process of planning permission.

The research further interested to know usage rate among three council groups namely; city council, municipal council and district council. Based on the descriptive analysis obtained, there were differences observed between the means. District council had achieve the highest means score (M = 4.76, SD = 1.660) followed by municipal council (M = 4.83, SD = 1.700) and city council (M = 3.77, SD = 1.765). However it should be noted; higher mean scores for the district council group does not signify respondents from other councils is less using the JBPD 7/2000 guideline. It was observed higher number of respondents a single council group will contribute to higher mean scores. Other than that, the output of Levene' for equality of variances test confirmed the data does not violate the homogeneity of variance assumption with p value of 0.053.

Table 7: Usage of the JBPD 7/2000 Guideline

	Sum of Squares	df	Mean Square	F	Sig.
Between	35.969	2	17.985	6.855	.001

Groups				
Within Groups	611.264	233	2.623	
Total	647.233	235		

At first a one way analysis of variance was conducted to examine the usage rate among the three council groups. An interesting finding was discovered in term frequency of usage by respondents working in city council, municipal council and district council. The result in **Table 7** indicates; there was a significant difference in the usage of the guideline among the groups [F(2,233) = 6.855, p = 0.001]. Despite reaching statistically significance the effect size, calculated using eta squared was 0.0555. This mean only 5.55% of the variances in JBPD 7/2000 guideline usage is explained by the difference among the levels within the council status. According to the guidelines proposed by Cohen (1988, p.284-7) for interpreting the value of eta squared; 0.0555 is considered small. In addition, a Post Hoc comparison using Scheffe test was carried out to identify the differences occur between the three council groups. The output of the Post Hoc test indicated that the difference in the mean scores between city council (M = 3.77, SD = 1.765) and municipal council (M = 4.83, SD = 1.700) and between city council (M = 3.77, SD = 1.765) and district council (M = 4.76, SD = 1.660) are statistically significant with p = 0.001. However, the difference between municipal council (M = 4.83, SD = 1.700) and district council (M = 4.76, SD = 1.660) was observed to be not statistically significant.

8.0 Discussion

Clearly, policies with respect to open spaces adopted by the states in Peninsular Malaysia differ from one another. This is because the JBPD 7/2000 guideline issued by FDTCP is a general guideline. The guideline describes the need for open spaces in every development. It outlines several approaches that must be adopted by all parties involved in ensuring the provision of open spaces for public use. For that reason, all state governments have taken the initiative to produce guidelines specifically to assist their respective LAs to carry out their tasks in realizing the government's vision for Malaysia to become a garden nation. High awareness level among town planners and technical assistants regarding different application of the JBPD 7/2000 guideline was expected since as a decision maker and planning administrator in the LAs; both town planners and technical assistants are the main implementer of the open space policy at their jurisdiction. Therefore, respondents are aware open space policy adopted by the states governments is different and independent. Apparently several approaches that have been discussed will raise issues and problems.

Even though the FDTCP has set a policy of 10 percent for open spaces for each development application, the 10 percent policy of open spaces for each development maybe difficult to implement in states with developed status. A good example is Pulau Pinang, with its excellent geographical location and very rapid development. However, the size of the main areas on the island is rather small making it difficult for Pulau Pinang to cope with the rapid development in the state. This has resulted in most housing developments being high-rises. The state government has provided an alternative, which is the provision of 'roof top gardens' to replace the open spaces. Roof top gardens seem to be a good solution to overcome the land shortage in Pulau Pinang. However, roof top gardens in the context of the definition of open spaces in the Town and Country Planning Act 1976 (Act 172), do not conform to open spaces for public use as highlighted in the said Act. Roof top gardens are clearly not for public use because it is the exclusive rights of the owner of the high-rise.

The research also interested to investigate the effectiveness of the JBPD 7/2000 guideline in the opinion of LAs town planners and technical assistants. However, review of Koomen, Dekkers et al. (2008) states, the effectiveness of a policy is difficult to be analysed. This is because according to Ingram and Mann (1980) the success or failure of an established policy is very subjective depending on the person who evaluates it. Based on the result obtained, it can be assumed the JBPD 7/2000 guideline has been productively helping LAs planning professionals in the matter of open spaces planning. In term of usability of JBPD 7/2000 guideline between councils, the researcher expects the differences occur between respondent's working in city council and district council is because of development situation. It is well known that development rate in rural areas are less compare to urban areas therefore respondent's working in city council might receive more application for planning permission. Thus it will lead to more usage of the JBPD 7/2000 guideline for reference purposes. Therefore higher usage of the guideline as a reference material is expected from respondents working in urban areas because the planning administration and decision maker need to be more stringent in term of open space matter since urban areas are experiencing land shortage and high demand from the public.

On the other hand, there are several factors that contribute to the ineffectiveness of policies initiated by the government. The demand or the need for open spaces is a factor in determining the effectiveness of an implemented policy. Population density, especially in large towns, causes residents to demand provision of more open spaces for them to release stress from the daily hustle and bustle as well as congestion of urban environments. It is believed that LAs in states experiencing rapid development like Johor are more stringent in ensuring that the open space policy is implemented properly. The Johor state government stresses the need for a 7 percent absolute open space out of the 10 percent required of developers. The "no compromise" approach by the Perak state government requiring developers to provide open spaces irrespective of the development size should be an exemplary. There are other scenarios in states experiencing slow economic development as in Perlis and Kelantan. The need for open spaces by residents in the two states is not as critical as that faced by the residents of Selangor and Pulau Pinang. This may be due to an abundance of unused areas, and subsequently, the states possess plenty of green areas. The LAs are believed to be concentrating on the main affairs such as formulating strategies and ensuring the provision of good infrastructure in their respective areas. Thus, it is not surprising that the implementation of policies with respect to open spaces in these states is not as stringent compared to that for states that are experiencing more rapid development.

9.0 Conclusion

It can be summarized that the above discussion clearly shows that the different applications and implementation of the provision of open spaces policies by the states implied in the Town and Country Act 1976 (Act 172) may have several implications within the context of the government's target to provide 2 hectares of open spaces for every 1,000 residents as achieved by developed countries (as; New York, Melbourne and Toronto). In line with Vision 2020 for Malaysia to become a developed country, several important steps must be taken to ensure that this target can be achieved. The issuance of the JBPD 7/2000 guideline by FDTCP is a prudent move to ensure that the provision of open spaces for public use is not neglected. However, a uniform guideline should be issued by FDTCP to standardize the application and implementation of open spaces policies in all states. The uniform guideline should focus on the various types of development rate undergone by the states. This is difficult task but important in order to avoid the implementation of open spaces policy in states that are not facing a critical need for open spaces. FDTCP should not focus solely on the total average of open spaces for each state, but should recognize the differences of size and growth rates. In other words, the policy formulated should be responsive to growth pressures and at the states level the willingness to change the state policy environments. As discussed, the introduction of the alternative roof top gardens to replace the provision of open spaces for high-rise housing in Pulau Pinang is an effort at conforming to the criteria in terms of definition, and thus the definition of open spaces as in Act 172 and its related policy application should be expanded

10.0 Acknowledgement

The authors would like to thank the Research and Development Unit, Federal Department of Town and Country Planning, Peninsular Malaysia (FDTCP) for the information and support given.

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[i] Map of 14 States in Malaysia

Biohydrogen Production from Alcohol Distillery Wastewater in an Anaerobic Sequencing Batch Reactor under Thermophilic Temperature

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Abstract

The production of hydrogen from wastewater by anaerobic fermentation is considered to be the most efficient and economical process. In this research, hydrogen production via dark fermentation from alcohol distillery wastewater using an anaerobic sequencing batch reactor (ASBR) with a working volume of 4 L was investigated. The ASBR system was operated at different COD loading rates (30, 45, 60, and 75 kg/m^3 d) at a fixed feed COD of 40 kg/m^3 under a thermophilic temperature of 55°C, with a controlled pH at 5.5 and a recycle time of 6 cycles/day. The produced gas composition and the concentration of volatile fatty acids (VFA) in the effluents were analyzed by a gas chromatograph (GC) with a thermal conductivity detector (TCD) and a flame ionization detector (FID). The results showed that under the optimum conditions for maximum hydrogen production of a COD loading rate of 45 kg/m^3 d and a hydraulic retention time of 21 h, the produced gas contained 19.72% H_2, 73.87% CO_2 and 6.41% CH_4. The specific hydrogen production rate (SHPR) of 77.39 ml H_2/g MLVSS d and hydrogen yield of 71.78 ml H_2/g COD removed were obtained. However, when the feed COD exceeded 40 kg/m^3, the process performance in terms of hydrogen production decreased.

Keywords: Hydrogen Production; Alcohol Distillery Wastewater; Dark Fermentation; Anaerobic Sequencing Batch Reactor; Thermophilic Condition

1. Introduction

Today, global energy requirements are essentially dependent on fossil fuels, such as oil, natural gas, and coal, but they are limited. Moreover, the combustion of fossil fuels, releasing many pollutants like CO_x, NO_x, SO_x, C_xH_x, soot, ash, droplets of tars, and other organic compounds into the atmosphere, has caused a global warming effect (Das and Veziroglu, 2001 and Yokoi *et al*., 2002). With the unavoidable depletion of fossil fuels, alternative energy resources are a possible way to reduce these problems. Hydrogen is one of interesting renewable energy resources for substituting fossil fuels. It is an odorless, colorless, tasteless, and non-poisonous gas. When the hydrogen is burnt, there are no pollutants due to no CO_2 emission and generating only water. Besides, it has high energy yield of 122 kJ/g, which is 2.75 times greater than hydrocarbon fuels. However, owing to the high hydrogen production and storage cost, it is a challenge to realize hydrogen as a potential alternative fuel in the future (Kapdan and Kargi, 2006 and Chong *et al*., 2009)

At present, there are many ways to produce hydrogen, mainly from fossil fuels, biomass, and water. Nearly 90 % of hydrogen production processes are steam reforming of natural gas, the reactions of natural gas or light oil fractions with steam at high temperature. Other methods for hydrogen production are coal gasification and electrolysis of water. Nevertheless, these hydrogen generation processes give low amounts of hydrogen and are operated at high temperatures (> 850°C), thus energy intensive and not always environmentally friendly. Accordingly, biological hydrogen production processes are of interest because they can be operated at ambient temperatures and pressures (Das and Veziroglu, 2001).

Biological hydrogen production processes can be divided into two types: photosynthetic (photo-fermentation) and anaerobic (dark fermentation) processes. Since the photo-fermentation mainly uses sunlight to produce hydrogen and carbon dioxide, while the dark fermentation does not, a high constant hydrogen production rate throughout the day and night can be achieved from the dark fermentation. For the anaerobic fermentation, the first step is hydrolysis of high-molecular-weight organics in wastewater to smaller organics. Then, they are further fermented in the second step to produce volatile fatty acid (VFA), hydrogen, and carbon dioxide (Sreethawong *et al*., 2010a). Because hydrogen production via the dark fermentation process uses wastewater as a substrate, a type of wastewater is an important parameter that affects yield of hydrogen production. Previous studies show that carbohydrate is suitable for producing hydrogen because they can be decomposed to glucose, which can produce 4 moles of hydrogen for 1 mole of glucose. However, the use of raw carbohydrates, like cassava or corn, for hydrogen production is not economically feasible due to their high cost. Thus, industrial organic wastewater carrying high concentration of carbohydrate is a possible alternative as a substrate for the hydrogen production.

Alcohol distillery wastewater is one of attractive raw materials for the hydrogen production process because it consists of carbohydrate-rich materials. The use of alcohol distillery wastewater not only provides hydrogen as a renewable source but also improves the wastewater treatment process. In addition, biohydrogen production from alcohol distillery wastewater in an anaerobic sequencing batch reactor (ASBR) has been scarcely reported. In this research, wastewater from an alcohol distillery production process was used as a substrate for biohydrogen production in an ASBR Effects of organic loading were investigated for its roles on the hydrogen production rate by using a mixed culture of hydrogen-producing bacteria under thermophilic condition.

2. Experiment

2.1 Substrate Preparation

Alcohol distillery wastewater obtained from Red Bull Distillery (1988) Co., Ltd. Part., Samuthsakorn, Thailand, was diluted with water to obtain a chemical oxygen demand (COD) of 40,000 mg/l to reduce the effect of toxicity on hydrogen-producing bacteria.

2.2 Bioreactor Design and Operation

Two identical ASBR reactors were used in order to perform the biohydrogen production experiments. To inhibit the activity of photosynthetic bacteria, the system was operated without light illumination in 5-liter opaque PVC reactors. The reactors were operated with working volume of 4 liters under a thermophilic temperature of 55 °C. The ASBR operation was composed of four steps: feed, react, settle, and decant. During the operation, time for each step was controlled by timers, which allowed the feed pump to pump wastewater during the feeding period. Mixing was achieved by using a magnetic stirrer at 400 rpm during the reacting phase. The pH-controller and heater were used to maintain a constant pH and temperature of the system, respectively. At the beginning, alcohol distillery wastewater was feed to the reactor with an initial fed COD of 40,000 mg/l and a COD loading rate of 30 kg/m^3 d, which corresponded to the hydraulic retention time (HRT) of 32 h. The COD loading rate was then increased stepwise by reducing HRT. Under any studied conditions, the reactor was operated until the system reached the steady state, around 2 months. Then, the COD loading rate was changed in order to study the effect of COD loading rate on the hydrogen production (Table 1). The effects of COD loading rate on the biohydrogen production at a fixed cycle time of 4 h or 6 cycles per day were investigated. The feed and decant flow rates were varied at feed COD values of 40,000 mg/l and the COD loading rate was varied according to Equation (1):

$$\text{COD loading rate (kg/m}^3\text{d)} = \frac{\text{(Feed COD)} \times \text{(Feed Flow Rate)}}{\text{(Working Volume)}} \qquad (1)$$

The experiments were conducted at initial feed COD of 40,000 mg/l and different COD loading rates, as shown in Table 1. According to the literature, Bhaskar *et al.* (2008) found that the pH range of 5.5–6 was considered as the optimum pH range, which is effective for hydrogen production. In addition, Lee *et al.*, (2008) reported that an excellent hydrogen production was obtained when a bioreactor was operated under thermophilic temperature of 55 °C and pH 5.5. Volume and compositions of produced gas, COD of the effluent liquid, and compositions and amount of VFA were then analyzed. Only those obtained under steady state conditions were reported. For any fixed experimental conditions, the steady state data was averaged to assess the process performance.

2.3 Analytical Methods

The amount of VFA and VFA concentration were determined by distillation-titration method and a gas chromatograph (PR2100, Perichrom) equipped with a flame ionization detector (FID). The gas composition was determined by a gas chromatograph (AutoSystem GC, Perkin-Elmer) equipped with a thermal conductivity detector (TCD). Total suspended solids (TSS), volatile suspended solids (VSS), and COD analyses were measured according to the procedures described in Standard Methods (Greenberg *et al*., 1992).

3. Results and discussion

In an ASBR system, where acidogenic bacteria were dominant, COD was removed and converted to liquid intermediate products, such as acetic acid, butyric acid, propionic acid, and ethanol. In general, COD removal during fermentative hydrogen production from molasses is about 20 %, which is closely related to the H_2 and VFA productions (Ren *et al*., 2006). Figure 1 shows the effect of COD loading rate on the COD removal at the initial feed COD of 40,000 mg/l. It was found that the maximum COD removal was 26 % at the COD loading rate of 75 kg/m^{3}d. The results show that the anaerobic sludge more effectively converted organic materials in the wastewater at a higher COD loading rate, resulting in high gas production rate, high hydrogen production rate, as shown next. However, a lower COD removal in this present work as compared to that in the case of a sucrose-containing wastewater (Lin and Chen 2006) was observed, possibly because this alcohol distillery wastewater contained higher-molecular-weight organic components than simple sugar (Ginkel *et al.,* 2005).

The gas production rate at the initial feed COD value of 40,000 mg/l also increased with the increase in the COD loading rate. Figure 2 shows that the initial gas production rates at the first two COD loading rates of 30 and 45 kg/m^{3}d were not much different (0.42 and 0.48 l/h, respectively). After that, the gas production rate reached the maximum of 0.96 l/h at the COD loading rate of 60 kg/m^{3}d. Then, it decreased to 0.95 l/h with further increase in the COD loading rate to 75 kg/m^{3}d. This is possibly because a higher COD loading rate results in a larger amount of organic substrate available in the system. Hence, the microbes could consume this available organic substrate for producing more gas products (Yusoff *et al.,* 2010).

The compositions of the produced gas at different COD loading rates are shown in Figure 3. The hydrogen percentage increased with the increase in the COD loading rate to reach the maximum of 19.72 % at the COD loading rate of 45 kg/m^{3}d, and then decreased to 7.96 % at the higher COD loading rate of 60 kg/m^{3}d. This might be due to the toxicity of higher VFA accumulation in the bioreactor (Argun *et al.,* 2008), which will be discussed in the part of total VFA concentration. However, the carbon dioxide percentage showed the opposite trend to the hydrogen percentage, with the minimum value of 73.82 % at the COD loading rate of 45 kg/m^{3}d, and after that it increased to 87.72% at the COD loading rate of 60 kg/m^{3}d, which was not different to the next investigated COD loading rate of 75 kg/m^{3}d. The methane percentage in the produced gas seemed to be almost unchanged, about 4-6 % is might be possibly from the effect of the methanogenic bacteria gradually adjusting themselves over a long time period at high substrate concentration. It can be clearly observed that the system operated at the initial feed COD value of 40,000 mg/l—with the COD loading rate of 45 kg/m^{3}d and a HRT of 21 h—provided the maximum hydrogen content in the produced gas.

Figure 4 shows the bacterial concentration in the bioreactor in terms of MLVSS. The MLVSS increased rapidly when the COD loading rate was increased from 30 to 60 kg/m^{3}d. Again, this is possibly because the methanogenic bacteria could adjust themselves over a long time period, as mentioned before. After that, the MLVSS tended to decrease with further increase in the COD loading rate to 75 kg/m^{3}d. The further decrease may be because the methanogenic bacteria could not survive at a too high COD loading rate under a short hydraulic retention time (HRT) and a high VFA concentration (low-pH operation), resulting in the increase in the microbial washout from the bioreactor (Hawkes *et al.,* 2002). This is indicated by the increase in the bacterial concentration in the effluent in terms of TSS, as shown next in Figure 4.5.

Figure 5 shows the microbial washout from the bioreactor in terms of effluent TSS. At the COD loading rate of 45 kg/m^{3}d, the effluent TSS decreased to the lowest value of 917 mg/l. It indicates that this condition was the most appropriate for the growth of hydrogen-producing bacteria in this work, resulting in the highest hydrogen percentage in the produced gas, as previously described.

An anaerobic system not only deals with the degradation of the organic materials in the wastewater to hydrogen, carbon dioxide, and methane, but also contributes to the production of volatile fatty acids (VFA). The total VFA concentrations at various COD loading rates are shown in Figure 6. The results show that the total VFA concentration decreased from 4,360 mg/l to the lowest value of 3,680 mg/l when increasing COD loading rate from 30 to 45 kg/m^{3}d, which resulted in the maximum hydrogen percentage in the produced gas (Figure 3). The total VFA concentration then increased with further increasing COD loading rate to reach the maximum value of 4,530 mg/l at the COD loading rate of 75 kg/m^{3}d. This reveals that a further increase in the COD loading rate negatively affected the hydrogen content in the produced gas, possibly due to the production of too high total VFA concentration. This also indicates that higher total VFA concentrations were produced at a higher COD loading rate, since the bacteria would shift its metabolism towards the VFA production rather than the hydrogen production. Accordingly, it could be concluded that too much total VFA produced at a very high COD loading rate may inhibit the growth of hydrogen-producing bacteria and also reduce the hydrogen production efficiency (Fan *et al.,* 2006).

The concentrations of VFA and ethanol in the effluent at different COD loading rates were also analyzed. It can be noticed that the main VFA components were acetic acid, propionic acid, butyric acid, and valeric acid with a low concentration of ethanol. Although the butyric and acetic acid fermentations in an anaerobic system have been found to be favorable metabolic pathways of acidogenic bacteria for the hydrogen production, the acetic acid production may be also found to inhibit the hydrogen production, as shown in Equation (4.1) (Luo *et al*., 2010). The results further show that at the COD loading rate of 45 kg/m^{3}d, the amount of acetic acid was the lowest, which resulted in the highest hydrogen percentage.

Acetic acid production: $4H_2 + 2CO_2 \rightarrow CH_3COOH + 2H_2O$ (4.1)

The propionic acid and ethanol fermentations have been found to be the metabolic pathway for the consumption of produced hydrogen (Hawkes *et al.,* 2002). According to the Equations (4.2) and (4.3), the low propionic acid and ethanol concentrations were obtained with the high hydrogen composition, as shown in the Figure 7, which presents the VFA and ethanol concentrations at different COD loading rates. The results show that at the COD loading rate of 45 kg/m^{3}d, the lowest

VFA and ethanol concentrations were obtained. In the meantime, this COD loading rate also provided the highest hydrogen percentage in the produced gas (Figure 4.3), as well as the lowest bacterial washout (Figure 5). Therefore, this COD loading rate was the most suitable for operating the ASBR system.

Propionic acid production: $C_6H_{12}O_6 + 2H2 \rightarrow 2CH_3CH_2COOH + 2H_2O$ (4.2)

Ethanol production: $CH_3COOH + H_2 \rightarrow CH_3CH_2OH + H_2O$ (4.3)

The hydrogen production rate depends on both the gas production rate and the gas composition, and the results of hydrogen production rate are shown in Figure 8. It was found that the hydrogen production rate was in the range of 0.08-0.12 l/h with the COD loading rate between 30 and 75 kg/m^{3}d.

The specific hydrogen production rate (SHPR) can also be used to identify the ability of bacteria to produce hydrogen in the bioreactor, and the results are shown in Figure 9. Because the degradation of the organic materials in the wastewater to produce gaseous products and VFA affected the hydrogen production in the ASBR system, the optimum condition for the SHPR could be realized. Although the COD loading rate of 75 kg/m^{3}d provide the maximum SHPR of 68.6 ml H_2/g MLVSS d (or 699 ml H_2/l d), the VFA and alcohol concentrations were on the high side with low hydrogen percentage in the produced gas. For the COD loading rate of 45 kg/m^{3}d, the maximum hydrogen percentage in the produced gas and the minimum VFA and alcohol concentrations was obtained. Moreover, the SHPR at this COD loading rate was also acceptably of high, 65.3 ml H_2/g MLVSS d (or 562 ml H_2/l d), being only lower than the maximum value. Therefore, the optimum condition of the SHPR for the hydrogen production in the ASBR system was at the COD loading rate of 45 kg/m^{3}d.

The hydrogen yield was calculated from the hydrogen production rate and COD removal results, as shown in Figure 10. Similar to the SHPR, the degradation of the organic materials in the wastewater to produce various gaseous and liquid products also affected the hydrogen yield. Although the highest hydrogen yield was obtained at the COD loading rate of 30 kg/m^{3}d (82.1 ml H_2/g COD removed), the low hydrogen percentage in the produced gas, as well as high VFA and alcohol concentrations, were observed at this COD loading rate. At the COD loading rate of 45 kg/m^{3}d, the hydrogen yield was the second highest of approximately 56.1 ml H_2/g COD removed, with the highest hydrogen percentage in the produced gas and the lowest VFA and alcohol concentrations. Accordingly, the optimum condition of the hydrogen yield from the hydrogen production in ASBR system was also considered to be at the COD loading rate value of 45 kg/m^{3}d.

Other two factors that may inhibit the hydrogen production is the toxicity of potassium and sulphate. For the toxicity of potassium, the alcohol distillery wastewater used in this work contained a high concentration of potassium (about 9,000 mg/l in the as-received wastewater with a COD value of 120,000 mg/l) of 3,000 mg/l in the initial feed COD value of 40,000 mg/l. Parkin and Owen (1986) work reported that the potassium concentration in the range of 2,500–4,500 mg/l could moderately inhibit hydrogen production (Table 2), which can be toxic to acedogenic bacteria in an anaerobic digestion. Similarly, the toxicity of sulphate, about 5,200 mg/l in the as-received wastewater with a COD value of 120,000 mg/l and 1,700 mg/l in alcohol distillery wastewater at initial feed COD value of 40,000 mg/l, also inhibited the hydrogen production. This might be a reason why the hydrogen production rate at the initial feed COD value to 40,000 mg/l resulted in the low hydrogen production. However, this work only focused on the feasibility study of hydrogen production from the alcohol distillery wastewater without any pretreatment step. Therefore, an interesting perspective for the future work is to reduce the toxicity of potassium and sulphate to enhance the hydrogen production efficiency.

Searmsirimongkol (2010) studied the hydrogen production from alcohol distillery wastewater using an ASBR under mesophilic temperature or 37 °C with the COD loading rates of 30, 45, 60, and 75 kg/m^{3}d at the initial feed COD value of 40,000 mg/l. Comparison to the present work shows that at the COD loading rate of 30 kg/m^{3}d, the hydrogen production was more efficient when the temperature was increased from 37 to 55°C. However, at the COD loading rate between 45 and 75 kg/m^{3}d, the efficiency of the hydrogen production was not much different. Unlike Searmsirimongkol's work, some methane was obtained along with hydrogen. This might be because the methanogen cells may gradually adjust themselves over a long time period, and the organic acid composition, used as substrate for the methane production, in this research was less than the previous work. Moreover, the different operating temperatures may affect the methane production. Even though there was no work to confirm this hypothesis, Dugba and Zhang (1998), who studied the effect of temperature for methane production in two-stage anaerobic sequencing batch reactor systems, reported that the thermophilc-mesophilic system produced more methane than the mesophilic-mesophilic system, which can be deduced that methane production was favorable in the thermophilic condition.

4. Conclusions

The study of hydrogen production from the alcohol distillery wastewater in an ASBR system under the thermophilic temperature of 55 °C and a controlled pH of 5.5 was found to greatly depend on the COD loading rate, as well as the amounts of VFA and alcohol produced. The optimum conditions for the maximum hydrogen percentage in the produced gas (19.72 %) and minimum VFA and alcohol concentrations were a COD loading rate of 45 kg/m^{3}d and a HRT of 21 h. These conditions resulted in the hydrogen yield of 56.1 ml H_2/g COD removed and the specific hydrogen production rate of 65.3 ml H_2/g MLVSS d (or 562 ml H_2/l d). Methane was another produced gas from the ASBR system due to the presence of the methanogenic bacteria survived at high substrate concentration.

Acknowledgements

The authors would like to thank the Sustainable Petroleum and Petrochemicals Research Unit, Center for Petroleum, Petrochemicals, and Advanced Materials, Chulalongkorn University, Thailand. In addition, the authors would like to thank Red Bull Distillery (1988) Co., Ltd. Part., Samuthsakorn, Thailand, for kindly providing the seed sludge and alcohol distillery wastewater.

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List of Table

Table 1 Operation conditions for the ASBR system at 6 cycles per day

Table 2 Potassium toxicity level for hydrogen production (Parkin and Owen, 1986)

Table 1 Operation conditions for the ASBR system at 6 cycles per day

Feed and decant volume (l/cycle)	Feed and decant flow rate (l/d)	HRT	COD loading rate (kg/m^3 d)
0.5	3	32	30
0.75	4.5	21	45
1	6	16	60
1.25	7.5	13	75

Table 2 Potassium toxicity level for hydrogen production (Parkin and Owen, 1986)

Toxicity level	Potassium concentration (mg/l)
Stimulatory	200–400
Moderately inhibitory	2,500–4,500
Strongly inhibitory	12,000

List of Figure Captions

Figure 1 COD removal during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 2 Gas production rate during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 3 Gas composition during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 4 MLVSS during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 5 Effluent TSS during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

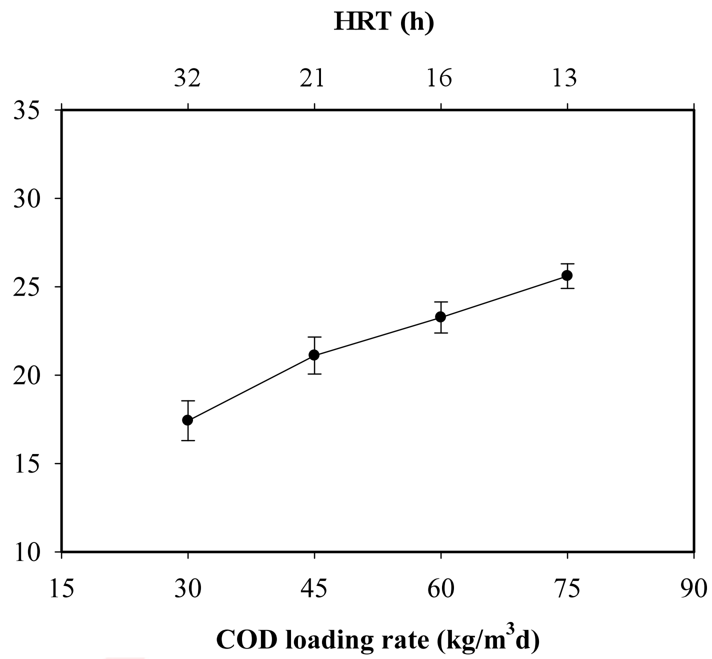
Figure 6 Total VFA concentration during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 7 VFA and ethanol concentrations during the hydrogen production in the ASBR system the thermophilic condition (55 °C) and pH 5.5.

Figure 8 Hydrogen production rate during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 9 Specific hydrogen production rate (SHPR) during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

Figure 10 Hydrogen yield during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.



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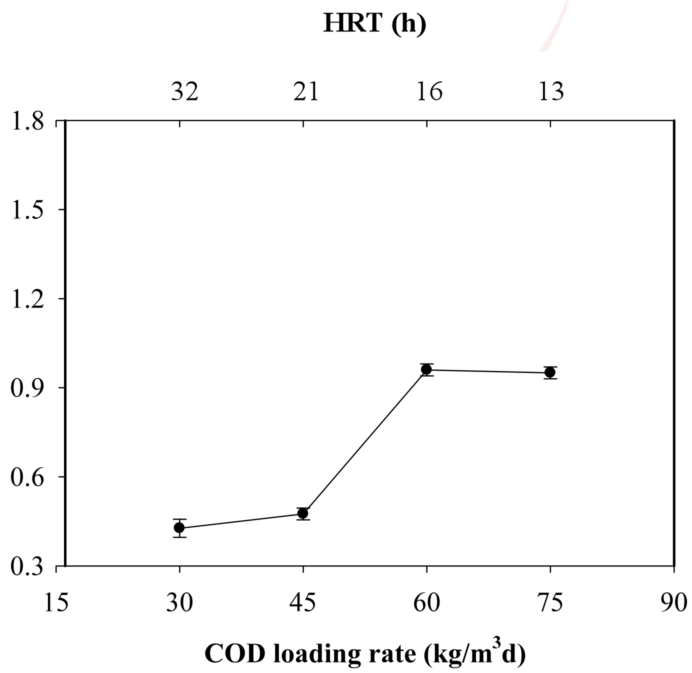


Figure 2 Gas production rate during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

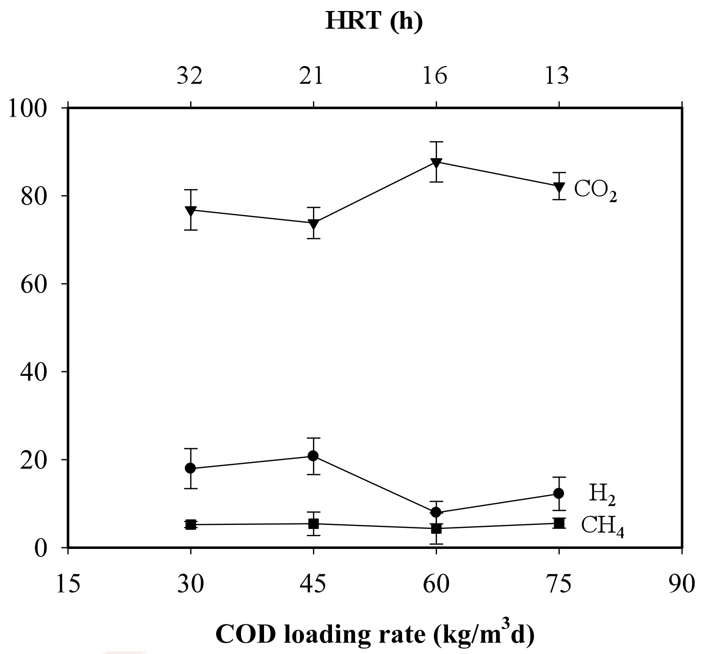


Figure 3 Gas composition during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

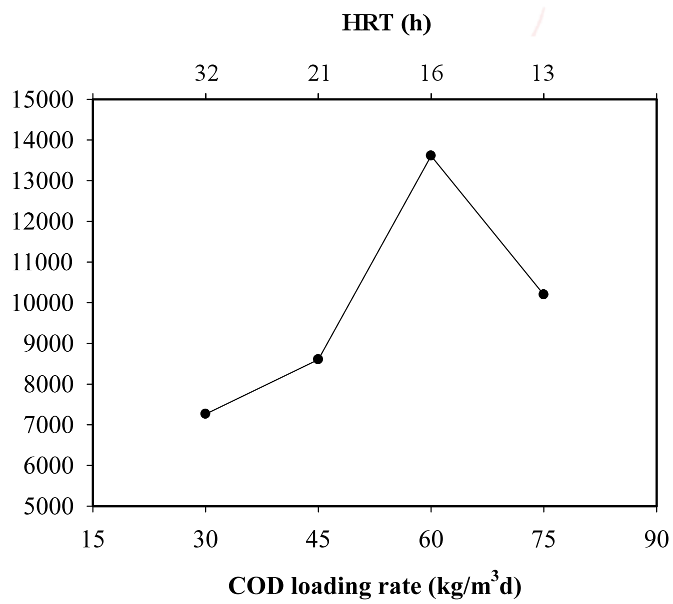


Figure 4 MLVSS during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

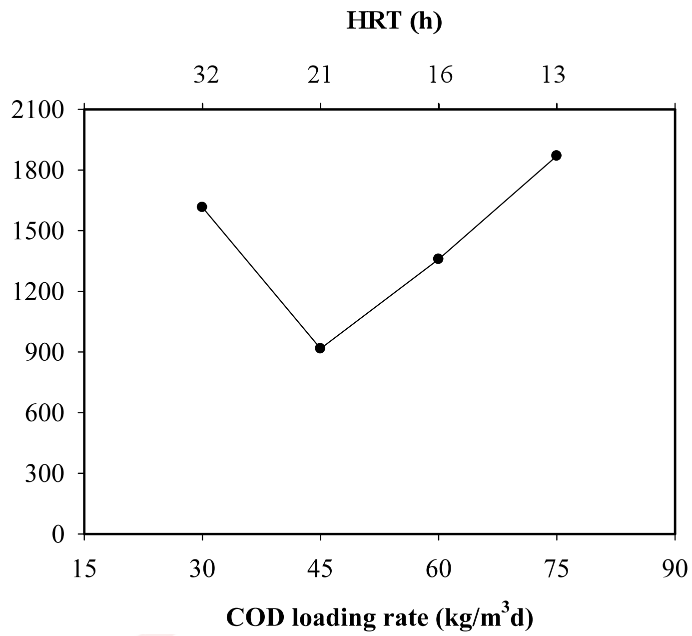


Figure 5 Effluent TSS during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

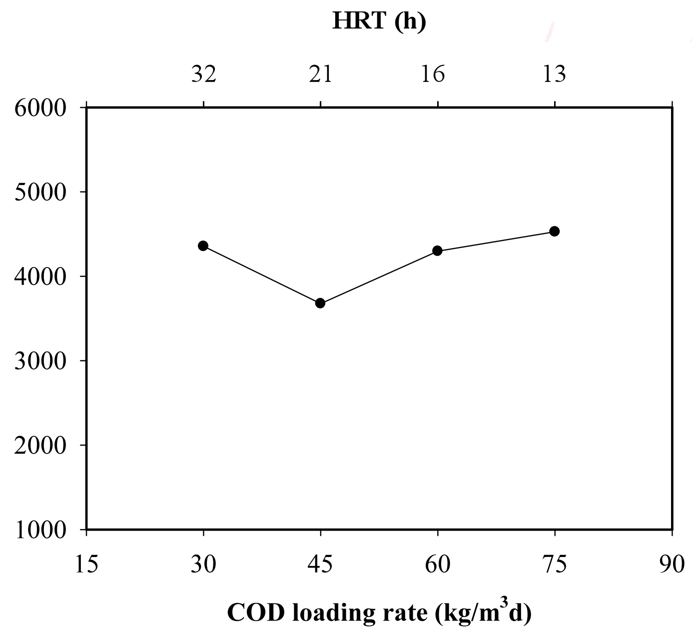


Figure 6 Total VFA concentration during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

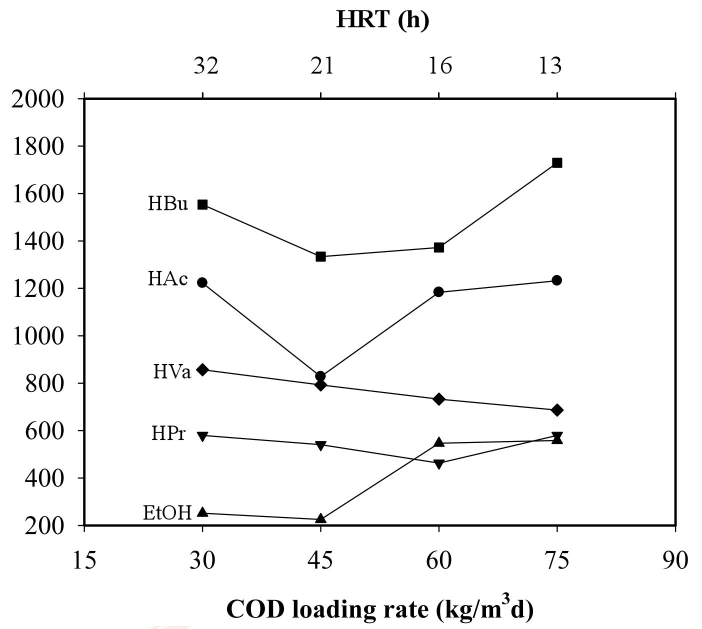


Figure 7 VFA and ethanol concentrations during the hydrogen production in the ASBR system the thermophilic condition (55 °C) and pH 5.5.

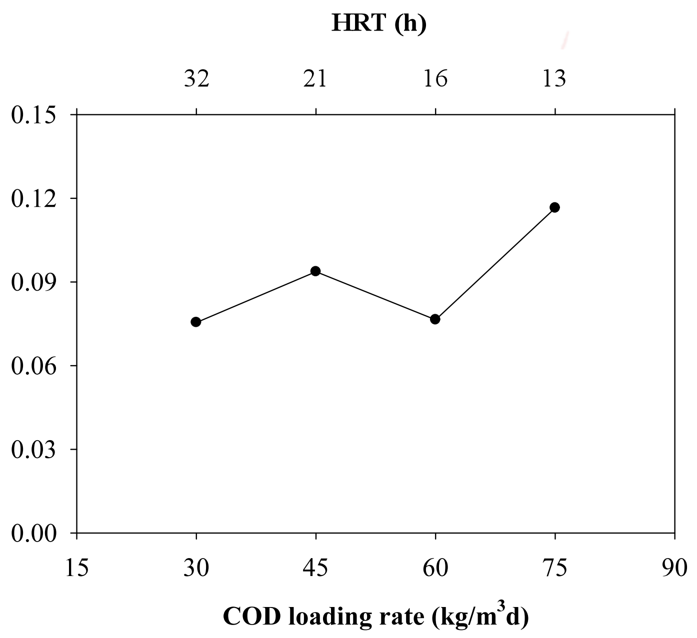
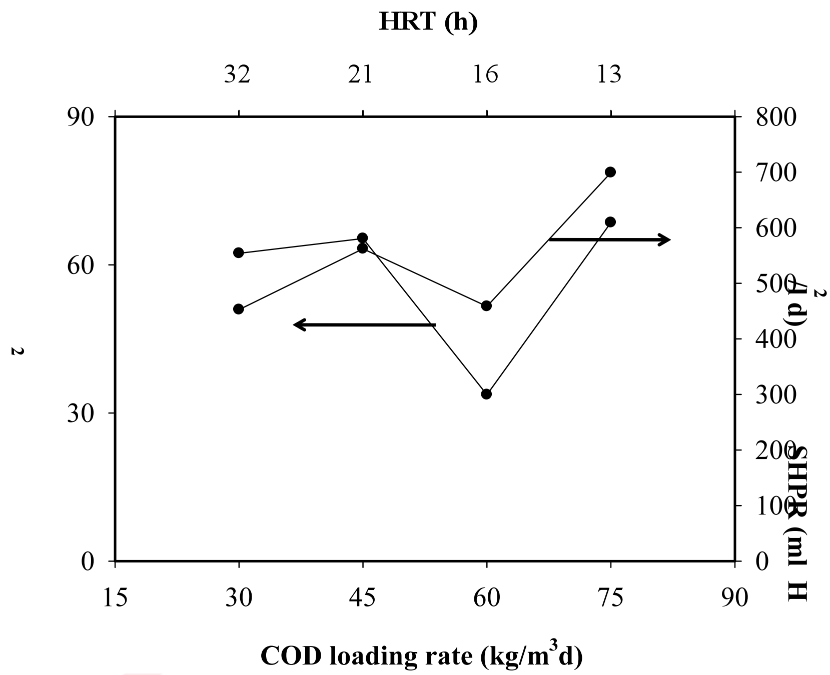


Figure 8 Hydrogen production rate during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.



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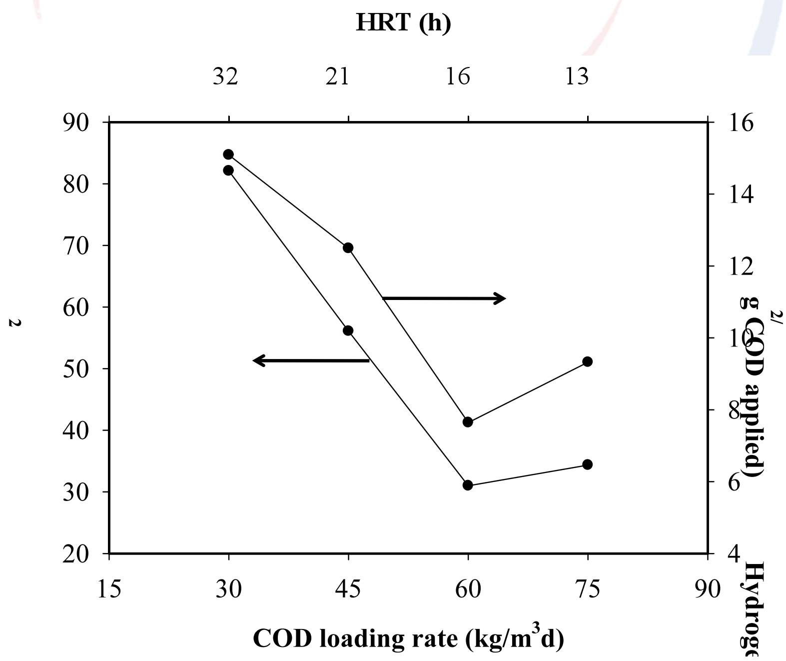

Figure 10 Hydrogen yield during the hydrogen production in the ASBR system at the thermophilic condition (55 °C) and pH 5.5.

ENERGY CONSUMPTION - INCOME NEXUS IN CHINA: HETEROGENEOUS PANEL CAUSALITY ANALYSIS

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ENERGY CONSUMPTION - INCOME NEXUS IN CHINA: HETEROGENEOUS PANEL CAUSALITY ANALYSIS

Abstract

Recently, energy production in China fell behind energy consumption. This poses important challenges for the rapidly growing Chinese economy. As a consequence, the causal relationship between energy consumption and GDP is an important empirical issue. This paper examines the Granger causality between energy consumption and GDP in China using province-level data. The current paper extends the Granger causality analysis employed in the previous studies by taking into account panel heterogeneity. Specifically, four different causal relationships are examined: homogeneous non-causality (HNC), homogeneous causality (HC), heterogeneous non-causality (HENC), and heterogeneous causality (HEC). The results of the analysis demonstrate that the panel made up of 30 Chinese provinces is not a homogeneous panel. Causality tests for the heterogeneous panels (HEC ad HENC) are then conducted for each province. HC and HNC hypotheses are rejected for causality in either direction, from GDP to energy or from energy to GDP. For the causality running from GDP to energy, 19 provinces exhibit HEC and 11 provinces exhibit HENC. For the causality running from energy to GDP, 14 provinces exhibit HEC and 16 provinces exhibit HENC.

Keywords: Energy, China, Granger causality, heterogeneous panel

1. Introduction

The causal relationship between energy consumption and economic growth has important policy implications for China. The issue as political as it is economic. From the long-term policy perspective, if there exists Granger causality running from energy to income, reducing energy consumption may lead to lower economic growth. Given the sustaining pressure on employment, industrial upgrading, and the growing pace of urbanization, it would be difficult for the central government in China shift to a policy regime which gives the priority to energy conservation. This consequently poses challenges to environment because the current Chinese energy-consumption structure heavily relies on coal. On the other hand, if there is a causal relationship from income to energy, it may be implied that energy conservation policies can be implemented without or with limited adverse impacts on economic growth.

China's total energy consumption surpassed total energy production in the late 1990s and this situation persisted since then (see Figure 1). Extensive energy shortage, particularly, electricity shortage, has been witnessed repeatedly in the last decade. In 2004, 24 provinces experienced power brownouts, the power deficit amounting to 10 percent of the installed capacity. In 2008, 19 provinces experienced power brownouts (Wang et al. 2009).[1] The energy shortage problems led the researchers to investigate the causal relationship between energy consumption and GDP in China, but the large number of studies in the literature did not reach a general conclusion. A review of these studies is available in Ma et al. (2010), and a review of more recent studies is presented in Table 1.

A brief overview of the studies that employ the Granger causality approach is noteworthy. These previous studies yielded conflicting results presumably due to different analytical methods, different study periods, and different indicators of energy consumption (total energy consumption, electricity, coal, oil, natural gas). Chan and Lee (1996), Shiu and Lam (2004), Huang and He (2006), Wang and Liu (2007), Yuan et al. (2007), Zhao and Fan (2007), Wang and Shen (2008), Zhang et al. (2009), and Ding and Zhou (2010) found that energy consumption Granger causes GDP.[2] On the other hand, Zhang and Li (2004), Fan and Zhang (2005), Wu et al. (2005), Liu (2006), Liu et al. (2007), Wang and Yao (2007), Wang and Yang (2007), Wang and Zhao (2008), Ning (2010), and Zhang and Cheng (2009) found the opposite, that GDP Granger causes energy consumption. A few other studies found bidirectional causality relationship (e.g., Han et al. 2004, Ma et al. 2004, Qian and Yang 2009, Yang and Chi 2009, Zhou and He 2009, Li et al. 2010) or no causality relationship at all (e.g., Yang et al. 2004, Shao and Jia 2006, Chen et al. 2007). Yuan et al. (2008) found a more complex picture for different energy consumption indicators. They found that Granger causal relationship from energy consumption to GDP in the case of electricity and oil but not for coal and total energy. Most recently, three studies shed light on the regional difference of energy-income relationship in China (Xu et al 2008, Yu and Meng 2008, Yang and Yang 2010). They used provincial panel dataset to investigate the causal relationship between energy consumption and economic growth respectively for east region and west region. All three studies found a bidirectional causal relationship for the east region of China. However, with regard to the west region, Xu et al (2008) and Yu and Meng (2008) found a unidirectional causal relationship from energy to income, while Yang and Yang (2010) found the opposite. These studies suggest the existence of heterogeneity at the sub-national level.

In this paper, we take a look at the causality relationship between energy consumption and GDP in China from a disaggregated perspective at the provincial level. For this purpose, we construct a panel made up province-level data. Granger causality between energy consumption and GDP for panel data is generally examined by dynamic panel Granger causality techniques. In the literature about energy-income nexus in China, most studies used time series techniques. Recently, there is a surge on the studies using panel

[1] Due to energy shortages, energy imports increased after 1998 and averaged 3.1 percent of total energy consumption during 1998-2007. China has been a net importer of oil since 1993.

[2] Shiu and Lam (2004), Yuan et al. (2007), and Wang and Shen (2008) examined the relationship between economic growth and electricity consumption. Zhang et al. (2009) examined the relationship between economic growth respectively with coal, crude oil, and natural gas. The remaining five studies used total energy consumption.

data in which province-level data are collected over limited time periods. An important shortcoming of the panel-data studies is the implicit assumption of panel homogeneity. If the panel is heterogeneous when Granger causality assumes a homogeneous panel, then there is a heterogeneity bias (Pesaran and Smith, 1995). Hurlin and Venet (2001) offers a new approach to test homogeneous causality against heterogeneous causality. This method was used by He and Zhang (2010) to examine the causal relationships between exports and economic growth in China.

The purpose of this paper is to examine Granger causality between energy consumption and GDP for 30 provinces in China for the period 1986-2008. The current paper contributes to the literature about the causal relationship between energy consumption and income in China by extending the panel Granger causality techniques beyond those currently available. We take into account panel heterogeneity and, to this end, we use the method for panel data Granger causality with fixed coefficients proposed by Hurlin and Venet (2001). We first test homogeneous (non)causality hypothesis and if this test fails, we test heterogeneous (non)causality hypothesis for the panel.

The rest of the paper is organized as follows. Energy policies in China are briefly discussed in Section 2. Data are explained in section 3. Section 4 presents the method of analysis. The results are presented in Section 5. Finally, the sixth section concludes with a summary of the results and policy implications.

2. An Overview of Energy Policies in China after 1978

Until the opening up of the economy in 1978, the energy sector in China was a state monopoly. With the start of the economic reforms which opened up the Chinese economy in 1978, the energy sector in China went through a regulation and structural reform process. The institutional reforms in the energy industries are briefly outlined in Wang (2007). After a series of restructuring of coal, oil, water, and nuclear power ministries from 1988 to 1998, the state monopoly was restructured and the government and business functions of the energy facilities were unified with gradual opening of the power generation sector (Xu and Chen, 2006). A regulatory authority, State Economic and Trading Commission, was established in 1998. The functions of the government and business enterprises were separated after 1998 (Xu and Chen, 2006). In 2002, State Electricity Regulation Commission (SERC) was established to oversee the regulation process and market entry in the electricity sector. In addition, the National Development and Reform Commission (NDRC) was established in the same year to regulate electricity prices and investments in the electricity sector.

The reform process also involves energy pricing reforms. At the start of the reform process, strict controls on energy prices by the government were abolished in 1982 and a double-track pricing system was introduced where the central plan of the government set the prices for the energy sector of the plan and gradually market prices for the market segment of the energy sector replaced the plan prices (Wu 2003, Hang and Tu 2007). In 1992, energy price reforms were introduced but the price controls were reintroduced in 1994 due to the 1993 inflation (Hang and Tu, 2007). However, full liberalization of the coal price has been achieved shortly after 1993 (Wu, 2003). Following the acceleration of the energy price reforms after 1996, plan allocation of energy was largely abolished in the late 1990s (Hang and Tu, 2007). Dual-track pricing was also abandoned for oil after 1994 and the central government started strict controls on oil prices while natural gas has always remained under government regulation (Wu, 2003).

In the electricity sector, before 1985 the central planning authority set the demand and supply and allocated the determined quotas to the generation facilities across the country based on the plan. Due to power shortages, after 1985 the government started reforms in the electricity market with an aim to attract private entrepreneurs into the generation sector. The government exercised rate-of-return regulation in the electricity generation sector. The generation facilities had to arrange coal out of the plan, from the free market in China's dual-track economy and this led to increases in electricity tariffs as the extra costs by the generators arising from the changing prices of fuel were allowed to be passed to the tariffs (Wang 2007). As a result, electricity prices rose rapidly during the 1990s. Due to various pricing schemes, electricity tariffs were highly complicated. In 1993, electricity tariffs were unified by the government (Wang, 2007). Independent power producers entered the electricity market in the 1990s and under the decentralized public electricity generation and distribution sector the rate of return they earned under the regulation was around 12-15 percent (Cherni and Kentish, 2007). Currently, electricity generation and retail tariffs are set by the government.

During the development of the energy sector under the ongoing reforms, an imbalance existed between different energy sectors as well. For instance, although the liberalization in the electricity generation sector started in 1985, electricity tariffs remained under strict control while coal prices are set free (Wang, 2007). Since coal is the most important input for electricity generation, the price of coal sold to electricity generation sector is controlled by the government, which in turn causes disputes between these two sectors.

Energy efficiency and energy saving is another important issue for the Chinese economy. China performs far worse than the developed nations in terms of energy efficiency and energy intensity. Energy intensity of GDP, i.e., GDP divided by energy consumption, was 2.4 times the world average, 2.5 times the level of the US, 4.9 times the level of the EU and 8.7 times the level of Japan in 2000 (Yuan et al, 2008). To address this issue, the government announced its aim to reduce GDP energy intensity from 26.8 tons sce per 1000 yuan (at 1990 prices) in 2002 to 22.5 tons sce per 1000 yuan in 2010 and to 15.4 tons sce per 1000 yuan in 2020 in its Medium and Long-term Energy Saving Plan in 2004 (Yuan et al, 2008). In 2006, the government declared its new energy saving goal in the Medium and Long-term Energy Saving Plan in the 11th Five-Year Plan and the 11th Five-year Plan for Energy Development (Yuan et al, 2008).

3. Data

We gathered data on real GDP and energy consumption for 30 provinces in China. Real GDP data in renminbi are measured in constant 1986 prices. Final energy use is measured in tons of oil equivalent. Provincial GDP data are obtained from *China Compendium of Statistics 1949-2008* published by the National Bureau of Statistics. Energy consumption data are obtained from various issues of *Chinese Energy Statistical Yearbook* which is also published by the National Bureau of Statistics. The data are available for all provinces from 1978 to 2008. Among 31 provinces, province-level autonomous regions, and municipalities, Tibet's data on energy consumption are not available. Among 30 provinces for which energy consumption data are available, 26 provinces have full set of data from 1986 to 2008. 1992-1994 data are missing for Shandong, Hunan and Sichuan, and 1986-1989 data are missing for Hainan. We estimated these missing data by assuming exponential growth of adjacent years. Accordingly, our dataset covers 30 provinces and the period 1986-2008.

4. Methodology

The standard Granger causality that is used to examine the existence of causality between two time series is not appropriate for panel data. Different approaches developed for dynamic panel Granger causality were reviewed and categorized into two main approaches by Erdil and Yetkiner (2005). The first method, represented by Holtz-Eakin et al. (1988) takes the autoregressive coefficients and slope coefficients in panel VAR model as variable. The second method, represented by Hurlin and Venet (2001) takes autoregressive and slope coefficients as constant. The length of the time period determines the appropriateness of either of the methods. For short periods, the second method is advised. In this study, the time period (1986-2008) is long enough to use the method proposed by Hurlin and Venet (2001).

To investigate the causality relationship between energy consumption and GDP, we employ dynamic panel Granger causality method with fixed coefficients as in Hurlin and Venet (2001). Hurlin and Venet (2001) propose four types of dynamic panel Granger causality with fixed coefficients: (i) homogeneous causality (HC), (ii) homogeneous non-causality (HNC), (iii) heterogeneous causality (HEC), and (iv) heterogeneous non-causality (HENC). The procedure for testing causality is as follows. First, we test for HNC and if it is rejected, we test for HC. If HC is also rejected, then HENC is tested. If HENC is not rejected, then we conclude that some cross-sections do not yield any causal relationship. If HENC is rejected, HEC applies, i.e., there is Granger causality for all cross-sections despite heterogeneity across cross sections.

To test for causality in heterogeneous panels, we use the following model for the causality from GDP to energy consumption:

$$E_{i,t} = \sum_{j-1}^{n} \gamma^{j} E_{i,t-1} + \sum_{j-1}^{n} \beta_i^{j} Y_{i,t-1} + u_{i,t}, \qquad u_{i,t} = \alpha_i + \varepsilon_{i,t} \qquad (1)$$

Here i refers to individual countries, t denotes time, and j is the number of lags. α, β, and γ are parameters to be estimated. In this equation, E and Y are stationary variables and the autoregressive coefficients γ^j and the slope coefficients β_i^j are assumed to be constant over the period of analysis. In addition, γ^j are identical across cross-sections and β_i^j are allowed to vary across cross-sections.

Likewise, to test for the causal relationship running from energy consumption to GDP, we use the following model:

$$Y_{i,t} = \sum_{j-1}^{n} \gamma^{j} Y_{i,t-1} + \sum_{j-1}^{n} \beta_i^{j} E_{i,t-1} + u_{i,t}, \qquad u_{i,t} = \alpha_i + \varepsilon_{i,t} \qquad (2)$$

Hurlin and Venet (2001) makes the following assumptions about the error term $\varepsilon_{i,t}$:

(i) For each cross-section unit i, individual residuals are independently and normally distributed with $E(\varepsilon_{i,t}) = 0$ and finite heterogeneous variances $E(\varepsilon^2_{i,t}) = \sigma^2_{i,t}$.

(ii) Individual residuals are independently distributed across groups, i.e., for all $i \neq j$ and for all time periods t and s, $E(\varepsilon_{i,t}, \varepsilon_{j,s}) = 0$.

(iii) E and Y are covariance stationary.

Next, we define the best linear predictor of $E_{i,t}$, i.e., $E(E_{i,t} | \widetilde{E}_{i,t}, \widetilde{Y}_{i,t})$, given the past values of $E_{i,t}$, i.e., $\widetilde{E}_{i,t} = (E_{i,-p}, \ldots, E_{i,0}, \ldots, E_{i,t-1})$, and the past values of $Y_{i,t}$, i.e., $\widetilde{Y}_{i,t} = (Y_{i,-p}, \ldots, Y_{i,0}, \ldots, Y_{i,t-1})$.

Testing for homogeneous non-causality (HNC) means testing the hypothesis that there are no individual causality relationships:

$$\forall i, E(E_{i,t} | \widetilde{E}_{i,t}, \alpha_i) = E(E_{i,t} | \widetilde{E}_{i,t}, \widetilde{Y}_{i,t}, \alpha_i) \quad (3)$$

The null hypothesis (H_0) and the alternative hypothesis (H_a) for HNC are:

$$\begin{aligned} &H_0 : \beta^{j} = 0 \ \forall i \in [1, N] \ and \ \forall j \in [1, n] \\ &H_0 : \exists (i, j) | \beta^{j} \neq 0 \end{aligned} \qquad (4)$$

The F statistic for the HNC test is calculated as follows:

$$F_{HNC} = \frac{(RSS_2 - RSS_1)/Nn}{RSS_1 / (NT - N(1+n) - n)} \qquad (5)$$

where RSS_2 is the sum of squared residuals obtained under and RSS_1 is that obtained under the unrestricted model shown by equation (1). T is the number of periods, N is the number of cross-sections (countries), and n is the number of lags. If we fail to reject the HNC hypothesis, we conclude that there is no Granger causality from Y to E (or the other way around if we consider equation (2)). Then, the causality examination procedure stops at this point. If we reject the HNC hypothesis, we then proceed to test the homogeneous causality hypothesis.

Testing for homogeneous causality (HC) means testing the hypothesis that there are individual causality relationships:

$$\forall i, E(E_{i,t} \left| \widetilde{E}_{i,t}, \alpha_i \right.) \neq E(E_{i,t} \left| \widetilde{E}_{i,t}, \widetilde{Y}_{i,t}, \alpha_i \right.) \tag{6}$$

The null hypothesis (H_0) and the alternative hypothesis (H_a) for HC are:

$$\begin{aligned} &H_0 : \beta_i^j = B^j \quad \forall i \in [1, N] \; and \; \forall j \in [1, n] \\ &H_0 : \exists j \in [1, n] \; and \; \exists (i,k) \in [1, N] \left| \beta_i^j = \beta_k^j \right. \end{aligned} \tag{7}$$

The F statistic for the HC test is calculated as follows:

$$F_{HC} = \frac{(RSS_3 - RSS_1)/(N-1)n}{RSS_1 /(NT - N(1+2n) + n)} \tag{8}$$

where RSS_3 is the sum of squared residuals obtained when the homogeneity restriction is imposed for each lag j of the coefficients associated to the variable $Y_{i,t-j}$. If we do not reject the HC hypothesis, there is Granger causality from E to Y and it is valid for all countries in the panel. Then, the causality examination procedure stops. If we reject the HC hypothesis, it means that the causality relationship does not hold for at least one province in the panel and we then proceed to test the heterogeneous non-causality hypothesis.

Testing for heterogeneous non-causality (HENC) means testing the hypothesis that there is at least one and at most $N-1$ equalities as follows:

$$\forall i, \exists i \in [1, N], E(E_{i,t} \left| \widetilde{E}_{i,t}, \alpha_i \right.) \neq E(E_{i,t} \left| \widetilde{E}_{i,t}, \widetilde{Y}_{i,t}, \alpha_i \right.) \tag{9}$$

The null hypothesis (H_0) and the alternative hypothesis (H_a) for HENC are:

$$\begin{aligned} &H_0 : \exists i \in [1, N] \; and \; \forall j \in [1, n], \beta_i^j = 0 \\ &H_0 : \forall i \in [1, N], \exists j \in [1, n] \left| \beta_i^j \neq 0 \right. \end{aligned} \tag{10}$$

The F statistic for the HENC test is calculated in two steps as follows: First, we test the hypothesis $\beta_i^j = 0$ for all $j \in [1,n]$ and compute the following set of F statistics:

$$F_{HENC}^i = \frac{(RSS_{2,i} - RSS_1)/n}{RSS_1 /(NT - N(1+2n) + n)} \tag{11}$$

where $RSS_{2,i}$ is the sum of squared residuals obtained from equation (1) when the homogeneity restriction $\beta_i^j = 0$ is imposed for all i and for all $j \in [1,n]$. In this test the n coefficients attached to the variable $Y_{i,t-j}$ are all equal to 0, i.e., they are excluded from equation (1). The n tests allow for testing individuals that exhibit no causality relationships. The second step of the F test is a test of the joint hypothesis that there is no causality relationship for a subgroup of cross-sections. Denoting the subgroup that exhibits causal relationships as I_c and that does not as I_{nc}, the following model is run for all time periods $t \in [1,T]$:

$$E_{i,t} = \sum_{j=1}^{n} \gamma_i^j E_{i,t-1} + \sum_{j=1}^{n} \beta_i^j Y_{i,t-1} + u_{i,t},$$
$$u_{i,t} = \alpha_i + \varepsilon_{i,t} \ \ with \begin{cases} \beta_i^j \neq 0, \ i \in I_c \\ \beta_i^j = 0, \ i \in I_{nc} \end{cases} \tag{12}$$

Denoting the dimensions of I_c and I_{nc} respectively as N_c and N_{nc}, the F statistic is then calculated as follows:

$$F_{HENC} = \frac{(RSS_4 - RSS_1)/N_{nc}n}{RSS_1/(NT - N(1+n) - N_c n)} \tag{13}$$

where RSS_4 is the sum of squared residuals obtained when the restriction $\beta_i^j = 0$ is imposed for all $i \in I_{nc}$.

If we fail to reject the HENC hypothesis, there is Granger causality from E to Y only for a sub-sample of countries. Testing for heterogeneous causality (HEC) means testing that there is at least one individual causality relationship and at most the number of cross-section units, N, and also that individual predictors shown below are heterogeneous:

$$\exists i \in [1,N], E(E_{i,t} \mid \widetilde{E}_{i,t}, \alpha_i) \neq E(E_{i,t} \mid \widetilde{E}_{i,t}, \widetilde{Y}_{i,t}, \alpha_i)$$
$$\exists (i,k) \in [1,N], E(E_{i,t} \mid \widetilde{E}_{i,t}, \widetilde{Y}_{i,t}, \alpha_i) \neq E(E_{k,t} \mid \widetilde{E}_{k,t}, \widetilde{Y}_{k,t}, \alpha_k) \tag{14}$$

Hurlin and Venet (2001) extend these tests to instantaneous homogeneous/heterogeneous causality/non-causality tests as well. Since we are interested in a long-run relationship based on the past values of the variables at hand, we do not run such tests. The test statistics for all these null hypotheses are available in Hurlin and Venet (2001).

5. Empirical Results

5.1. Panel Unit Root Tests

Prior to the Granger causality tests, we search for the existence of unit roots for two series, energy consumption, E, and real GDP, Y. The conventional augmented Dickey-Fuller (ADF) tests for detecting unit root are known to be weak hypothesis testing of stationarity for panel data. Therefore, we use two other more powerful unit root tests that are used widely for panel data, based on Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (2003). We abbreviate the former as LLC and the latter as IPS. While the LLC test assumes common unit root for all panel members, the IPS test allows for individual unit roots for panel members. Panel unit root test results are shown in Table 2. The results of both IPS and LLC tests lead us to accept the existence of unit root at levels. For the first differences, both series are stationary. Therefore, we conclude that both series are integrated of degree one, I(1).

5.2. Panel Cointegration Analysis

If a linear combination of two non-stationary variables are stationary, this indicates the existence of a long-run relationship. Since both series, E and Y, are I(1) and non-stationary, we check for the existence of cointegration relationships between the series using the method proposed by Pedroni (1999). In this method, the cointegration relation is represented by the following equation:

$$\begin{aligned} Y_{i,t} &= \alpha_i + \kappa_{i,t} + \lambda_i E_{i,t} + u_{i,t} \\ u_{i,t} &= \varphi_i u_{i,t-1} + v_{i,t} \end{aligned} \tag{15}$$

where α_i are fixed effects and λ_i are the slope coefficients. Both α_i and λ_i are allowed to vary across provinces. Pedroni (1999) cointegration test is a combination of two sets of cointegration tests. In all the tests, the null hypothesis in no cointegration and the alternative hypothesis is the existence of cointegration. Four tests use the common autoregressive coefficients and the resulting within-dimension test results are presented in the upper panel of Table 3. The null hypothesis for the within-dimension is H_0: $\varphi_i = 1$ for all i and the alternative hypothesis is H_a: $\varphi_i < 1$. At the lower panel of the panel are the between-dimension tests using the averages of the individual autoregressive coefficients. The null hypothesis for the between-dimension is H_0: $\varphi_i = 1$ for all i and the alternative hypothesis is H_a: $\varphi_i < 1$.

The results of the cointegration tests are presented in Table 3. Based on the test statistics, the null hypothesis of no cointegration is rejected. Therefore, we conclude that there is a cointegration relationship between *E* and *Y*.

5.3. Granger Causality

It is found so far that both *E* and *Y* series are stationary only in first differences and there is a cointegration relationship between the two. We then examine the Granger causality relationships between these two variables in this subsection. We use the first difference of both series in causality tests. We do not choose lags according to lag selection criteria such as Akaike or Schwarz but rather present the results for up to three lags. By doing so, we can also test the sensitivity and robustness of the test results. All causality equations are estimated as fixed effects equations. Critical values for F tests are based on F distribution with $(Nn,NT-N(1+n)-n)$ degrees of freedom (Hurlin and Venet, 2001).

5.3.1. Results for Causality Running from GDP to Energy Consumption

The results for homogeneous non-causality (HNC) and homogeneous causality (HC) for the causal relationship running from GDP to energy consumption ($Y \rightarrow E$) are presented in the second and fourth columns of Table 4. If we fail to reject the HNC hypothesis (F_{HNC} statistic smaller than the critical F value), we conclude that there is no causal relationship from GDP to energy consumption. Table 4 demonstrates that in HNC hypothesis is rejected for all lags. In other words, for at least one province in the panel GDP Granger causes energy consumption. Then, we proceed with the HC test. The resulting F_{HC} statistics are greater than the critical F values, and therefore we reject the null hypothesis of homogeneous causality relationship running from GDP to energy for all lags. Accordingly, we conclude that panel heterogeneity is observed.

Next, we run HENC hypothesis tests. The results for each province are presented in the second, third, and fourth columns of Table 5. We base our conclusions for a significance level of at least 5 percent. 19 out of 30 provinces exhibit heterogeneous causality as the F^{i}_{HENC} statistics are greater than critical F values. Figure 2 displays these provinces on the map. It is recognized that these provinces are scattered across the country but do not include central-eastern provinces. In the second step of the HENC hypothesis test, we test the joint hypothesis of no causality for these 19 provinces. The results of this test are presented in the second column of Table 6. The results indicate that HENC hypothesis is rejected when these 19 provinces are grouped. For the remaining 11 provinces HENC hypothesis is not rejected, i.e., there is no Granger causality running from GDP to energy consumption.

5.3.2. Results for Causality Running from Energy Consumption to GDP

The results for homogeneous non-causality and homogeneous causality for the causal relationship running from energy consumption to GDP ($E \rightarrow Y$) are presented in the third and fifth columns of Table 4. HNC hypothesis is rejected since F_{HNC} statistics are greater than the critical F statistics for all lags. HC hypothesis is also rejected since F_{HC} statistics are larger than critical F values. These results indicate panel heterogeneity. As a consequence, we examine causality relationships at the individual province level and proceed to heterogeneous non-causality (HENC) tests.

We present the results for the HENC hypothesis by provinces in the fifth, sixth, and seventh columns of Table 5. Based on individual HENC tests, we conclude that 14 provinces exhibit heterogeneous causality since the null hypothesis of HENC is rejected. Grouping these provinces we also tested the joint hypothesis that there is no causality for these 14 provinces. The results presented in the third column of Table 6 reveal that HENC hypothesis is rejected for these provinces as a group. Figure 3 displays the 14 provinces that exhibit HEC on the map. It can be easily recognized that these provinces are located in the coastal eastern part of the country where industrial activities are more developed than the rest. Therefore, the availability of energy ensures higher GDP in these provinces. For the remaining 16 provinces, HENC hypothesis is not rejected, i.e., there is no Granger causality running from energy consumption to GDP.

5.3.3. Categorization of Provinces

Based on the results from the causality tests, the provinces of China can be categorized into the following four categories.

(i) *Uni-directional causality from energy consumption to GDP*: Guangdong, Guangxi, Hainan, Hebei, Henan, Hubei, Hunan, Shandong. In these eight provinces, economic activities are dependent on the availability of energy. Other than Guandong, Shandong and Hebei, these provinces are located in the central-eastern region and their economic development level is in between the developed eastern coast and relatively poor western and central provinces.

(ii) *Uni-directional causality from GDP to energy consumption*: Anhui, Beijing, Chongqing, Gansu, Guizhou, Jiangsu, Liaoning, Ningxia, Qinghai, Shaanxi, Tianjin, Xinjiang, Yunnan. For these 13 provinces, the availability of energy does not cause GDP but rather higher GDP requires higher energy use. In these provinces, energy conservation should bring cause no harm to the provincial GDP. It is noticeable that apart from Anhui, Beijing, Jiangsu, Liaoning, Tianjin, these remaining eight provinces are located in the relatively poor western and central parts of the country.

(iii) *Bi-directional causality between GDP and energy consumption*: Fujian, Inner Mongolia, Jiangxi, Jilin, Shanghai, Zhejiang. Energy consumption and GDP are interrelated and cause each other in these six provinces. Higher GDP requires more energy and the availability of energy ensures higher GDP. These six provinces are located in the eastern coastal region and in the north and a common characteristic of these provinces, except for Inner Mongolia, is their relatively advanced industrial sectors.

(iv) *No causality between GDP and energy consumption*: Shanxi, Heilongjiang, Sichuan. For these three provinces, there is not causality relationship in either direction.

6. Conclusion and Policy Discussion

In this paper, we examine the causality relationship between energy consumption and GDP in China using panel data covering 30 provinces for the period 1986-2008 and extend the conventional Granger causality analysis by taking into account panel heterogeneity using a causality technique developed for panels with fixed coefficients. Previous studies focused on cointegration and the conventional Granger causality tests where implicit assumption is made for homogeneity of the panel members.

Our panel that consists of 30 Chinese provinces is characterized by panel heterogeneity and homogeneous causality tests fail. Heterogeneous causality and non-causality tests for the causality running from GDP to energy show that 19 provinces exhibit heterogeneous causality and 11 provinces exhibit heterogeneous non-causality. For the causality running from energy to GDP, 14 provinces exhibit heterogeneous causality and 16 provinces exhibit heterogeneous non-causality.

Although it is difficult to devise policy recommendations from a causality analysis, the results suggest that the Chinese government should incorporate a regional perspective while formulating and implementing energy policies. In general, though with exceptions, we find relatively advanced provinces appear to fall into the groups of unidirectional causality relationship running from energy to GDP or bi-directional causality. The relatively poor provinces located in north-west and south-west appear to fall into the group of uni-directional causality relationship running from GDP to energy. Therefore, the recent energy shortages and conservation policies more likely exert impacts on relatively advanced provinces in China. Given the fact that the relatively advanced provinces located in the southeast coastal line are the center of China's economic growth to date, prolonged energy shortages may dampen country's economic growth as a whole. On the other hand, if, accompanied by the rapid economic growth led by industrialization, the relatively poor provinces also move to the causality pattern running from energy to GDP, the Chinese government may face a further difficult policy choice between growth and environment.

The findings of the paper can be enriched in the future by focusing on the different sources of energy. A more disaggregated sectoral analysis may also have important policy implications as well.

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Figure 1: Energy production and consumption, 1978-2008 (unit: million tons of oil equivalent)

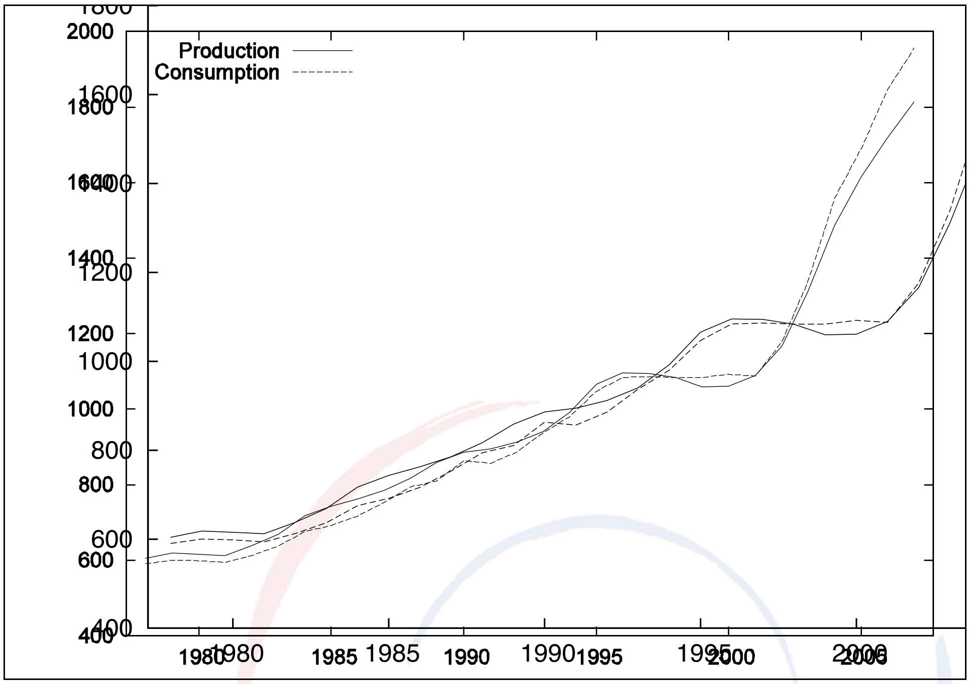

Figure 2: Provinces where GDP Granger causes energy consumption

Figure 3: Provinces where energy consumption Granger causes GDP

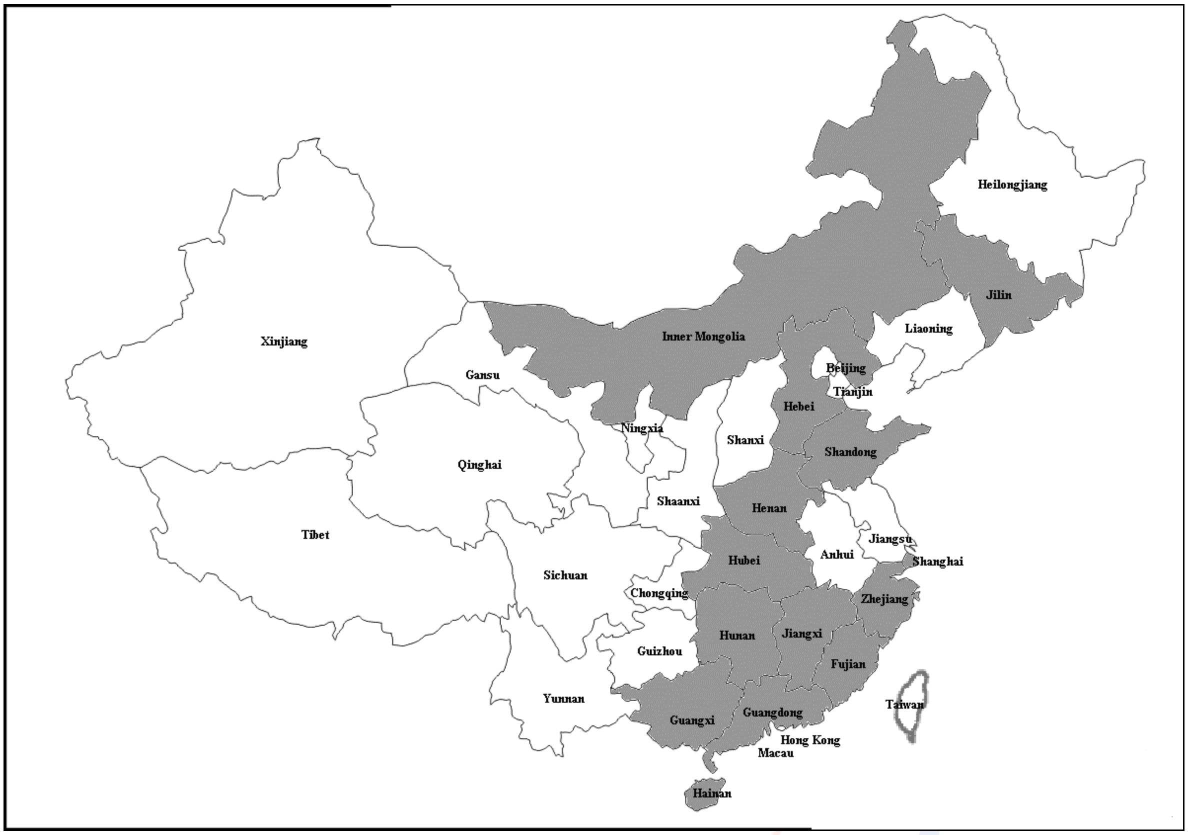

Table 1: Review of recent studies examining the causal relationship between energy consumption and GDP

Authors	*Data set*	*Period*	*Method and result(s)*	*Energy variable(s)*
Wang and Shen (2008)	30-province panel	1999-2005	Causality (Cobb-Douglas production function, Granger)	Electricity consumption
Wang and Zhao (2008)	Time series	1980-2005	Causality (Autoregressive distributed lag, Granger, Toda-Yamamoto)	Total energy consumption
Xu et al (2008)	2 panels: west region (12 provinces), east region (10 provinces)	1986-2005	East region: in both the short and long run; West region: in both the short and long run (error correction model)	Total energy consumption
Yu and Meng (2008)	2 panels: west (10 provinces), east (10 provinces)	1986-2006	East region: in both the short and long run; West region: in both the short and long run (error correction model)	Total energy consumption
Qian and Yang (2009)	Time series	1953-2006	Causality (Granger)	Total energy consumption
Yang and Chi (2009)	Time series	1952-2008	Causality (error correction model)	Total energy consumption
Zhang and Cheng (2009)	Time series	1960-2007	Causality (Toda-Yamamoto)	Total energy consumption
Zhang et al. (2009)	Time series	1953-2007	Causality (vector error correction model)	Coal, crude oil, natural gas
Zhou and He (2009)	Time series	1953-2007	Causality in the long run (demand function, Cobb-Douglas production function, vector error correction model)	Total energy consumption
Ding and Zhou (2010)	Time series	1953-2007	Causality (error correction model)	Total energy consumption
Li et al. (2010)	Time series	1953-2008	Causality (Granger)	Total energy consumption
Ning (2010)	Time series	1965-2006	Causality (Granger)	Total energy consumption
Yang and Yang (2010)	2 panels: west (9 provinces), east (7 provinces)	1999-2007	East region: in both the short and long run; West region: in the long run	Total energy consumption

			(error correction model)	

Table 2: Unit root tests

		Level		First difference	
		Individual intercept	Individual intercept + trend	Individual Intercept	Individual intercept + trend
Y	LLC test	6.305	3.016	-5.744***	-4.283***
	IPS test	13.179	3.769	-7.587***	-4.484***
E	LLC test	4.011	0.281	-6.579***	-7.497***
	IPS test	11.368	1.453	-6.399***	-7.886***

Note: *** significant at 1 percent level, ** significant at 5 percent level, * significant at 10 percent level.

Table 3: Panel cointegration tests

	Statistic	Prob.	Statistic (weighted)	Prob. (weighted)
Common AR coefficients (within-dimension)				
Panel v-Statistic	-1.089	0.862	-2.347	0.991
Panel rho-Statistic	3.332	0.999	3.230	0.999
Panel PP-Statistic	2.769	0.997	2.489	0.994
Panel ADF-Statistic	-1.060	0.145	-0.421	0.337
Individual AR coefficients (between-dimension)				
Group rho-Statistic	4.612	0.999		
Group PP-Statistic	3.730	0.999		
Group ADF-Statistic	-1.265	0.103		

Table 4: Tests of homogeneous non-causality (HNC) and homogeneous causality (HC)

	HNC		HC	
Lag	Y→E	E→Y	Y→E	E→Y
1	6.007***	6.043***	4.387***	4.388***
2	2.955***	3.781***	2.480***	2.427***
3	2.441***	3.438***	2.038***	2.141***

Note: 1. *** significant at 1 percent level, ** significant at 5 percent level, * significant at 10 percent level.

2. E→Y denotes Granger causality running from energy consumption to GDP. Y→E denotes Granger causality running from GDP to energy consumption.

Table 5: Results of heterogeneous non-causality tests

	Y→*E*			*E*→*Y*		
Province	1 lag	2 lags	3 lags	1 lag	2 lags	3 lags
Beijing	1.368^{*}	0.207	0.306	0.011	0.055	0.038
Tianjin	12.365^{***}	6.779^{***}	1.744^{***}	0.773	0.017	0.301
Hebei	0.099	0.750	0.130	4.374^{***}	4.792^{***}	5.216^{***}
Shanxi	0.984	0.764	0.629	1.215	1.224	0.338
Inner Mongolia	9.966^{***}	4.865^{***}	2.233^{***}	11.230^{***}	7.419^{***}	2.782^{***}
Liaoning	7.752^{***}	5.471^{***}	1.593^{***}	0.789	0.758	0.076
Jilin	6.860^{***}	2.168^{***}	0.887	1.615^{**}	0.555	1.603^{***}
Heilongjiang	0.905	1.328^{*}	0.330	1.395	0.151	0.138
Shanghai	3.363^{***}	0.669	0.828	2.650^{***}	3.904^{***}	1.124
Jiangsu	0.312	1.831^{***}	0.232	1.424^{*}	1.163	0.227
Zhejiang	4.434^{***}	2.070^{***}	1.096	5.530^{***}	4.097^{***}	3.280^{***}
Anhui	8.242^{***}	3.551^{***}	1.669^{***}	0.153	0.436	0.003
Fujian	1.679^{**}	1.351^{**}	0.398	22.832^{***}	17.350^{***}	5.863^{***}
Jiangxi	4.655^{***}	1.316^{*}	0.486	2.009^{***}	2.449^{***}	1.897^{***}
Shandong	2.800^{***}	0.900	0.004	3.033^{***}	3.302^{***}	3.858^{***}
Henan	0.007	0.035	0.207	9.567^{***}	9.980^{***}	9.700^{***}
Hubei	1.300	0.690	0.235	1.685^{**}	2.205^{***}	2.984^{***}
Hunan	0.604	0.418	0.014	1.321	1.952^{***}	2.245^{***}
Guangdong	0.911	0.417	0.141	2.018^{***}	1.898^{***}	0.222
Guangxi	1.696^{**}	1.098	0.192	2.771^{***}	1.968^{***}	1.684^{***}
Hainan	0.173	0.481	0.196	2.795^{***}	1.839^{***}	1.084
Chongqing	4.321^{***}	2.667^{***}	2.561^{***}	0.030	0.458	0.400
Sichuan	1.312	1.038	0.371	0.563	0.549	0.983
Guizhou	5.624^{***}	2.939^{***}	0.560	0.825	0.401	0.212
Yunnan	2.877^{***}	0.972	0.710	0.535	1.056	0.135
Shaanxi	1.821^{***}	1.512^{***}	0.932	1.087	0.477	0.911
Gansu	2.839^{***}	1.426^{**}	1.180	0.485	0.717	0.192
Qinghai	9.307^{***}	4.789^{***}	4.034^{***}	0.736	0.153	0.099
Ningxia	2.773^{***}	3.417^{***}	0.718	0.895	0.490	0.191
Xinjiang	2.862^{***}	2.490^{***}	1.318^{**}	0.061	0.045	0.013

Note: 1. *** significant at 1 percent level, ** significant at 5 percent level, * significant at 10 percent level.

2. E→Y denotes Granger causality running from energy consumption to GDP. Y→E denotes Granger causality running from GDP to energy consumption.

Table 6: Tests of heterogeneous non-causality (HENC)

Lag	*Y*→*E*	*E*→*Y*
1	20.324***	18.946***
2	2.173***	4.170***
3	5.111***	6.788***

Note: 1. *** significant at 1 percent level, ** significant at 5 percent level, * significant at 10 percent level.

2. E→Y denotes Granger causality running from energy consumption to GDP. Y→E denotes Granger causality running from GDP to energy consumption.

A Research on Precipitation and Soil Erodibility Factor in Western Mountainous Area of Taiwan

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A Research on Precipitation and Soil Erodibility Factor in Western Mountainous Area of Taiwan

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ABSTRACT

In the mountainous area of western Taiwan, precipitation is mainly caused by typhoon rainstorm. Due to the effects of weak geological characteristics, steep slope, and gangue weathering that soil eroded significantly in the mountainous area studied. At present, the universal soil loss equation (USLE) is the most frequently applied procedure for the estimation of soil erosion in Taiwan. However, the reliability of using the equation in Taiwan mountainous area is rarely practiced. This present study aims to evaluate the relationship between the rainfall event and soil erodibility factor by collecting 59 measured erosion data from 28 experimental sites among the 6 main rivers (Dajia, Wu, Jhuoshuei, Gaoping, Donggang, and Linbien Rivers) in the western part of Taiwan.

From the investigation results, it was discovered that the observed erosion was smaller than the estimation from USLE which implied the overestimation in using the equation. Furthermore, the soil erodibility factors in USLE for different experiment plots were estimated and compared with the suggested by employing regression analysis.

Keywords: Soil erosion, Erodibility factor, USLE, Rainfall

1. Foreword

Taiwan is an island covering 3.6 million hectares, 2.639 million of which are mountains and hills, accounting for 73.3%. As a result, hill slope development becomes inevitable. Due to the characteristic topography and geography, concentrated distribution of rainfall in typhoon season, steep terrains, fragmental geology, and severe soil erosion, how to effectively control loss of soil and reduce soil erosion becomes a crucial issue for soil and water conservation as the development continues.

The USLE (Universal Soil Loss Equation) developed in the US is widely used for most of soil erosion estimations, as well as in many countries for soil loss estimates. However, only overall description of the factors is considered in the equation. In early days, the parameters used in this equation were representative to 2/3 of the eastern US. As time evolves, the accumulated data shaped the equation that is vastly used today.

The soil loss estimate in the hill slope development in Taiwan is still based on the USLE, which is officially included in the soil and water conservation specifications and manuals for the calculation basis in estimating the soil losses. However due to the high variability in the applicable conditions, the estimated soil erosions are quite often far away from the local conditions, and therefore the factors in the equation were extensively studied to establish a database that is specific to Taiwan. For the rainfall erosion index (R), C.T. Huang (1979) and C.C. Fang and K.H. Lu (1993) have come up with the empirical equations unique to Taiwan. Also for the factors such as slope gradient, slope length, crop management and soil and water conservation processing (L, S, C, P), several studies were conducted to propose data for correction. However due to limited measurements, there is no appropriate estimation equation for local conditions for the soil erosion factor (Km). As it is a time-consuming process for in-situ measurement of Km, the Km can only be estimated using the basic property of soil.

S.S. Wann and J.I. Hwang (1989) adopted the nomograph developed by Wischmeier and Smith and collected soil samples from 280 sites around Taiwan for the estimation of soil erodibility factors (SEFs) of Taiwan's hill slopes, which are now included in the soil and water conservation design manual for calculation of soil erosion. However, no specific coordinates were provided for these sampling sites and the data may not be sufficient, and thus the current collection of data still requires further validation for practical application. L.L. Lin and Y.M. Hung (2000) collected 5 soil samples in Miaoli using the block kriging skill, and created the isarithm maps of SEFs at Miaoli block and Jyhu block in Miaoli County. Yet, the limited number of sampling sites suggested that further validation may be needed. L.L. Lin and S.T. Chang (2008) collected soil samples at 50 sites in at Shimen reservoir upstream watershed for laboratory analysis. The comparison made possible by the USLE developed by Wischmeier, the SEF equation developed by the United States Department of Agriculture (USDA) and the empirical equation of Torri et al (1997) revealed that the wider spectrum of factors included in the Wischmeier equation made it a potential equation for extended use. The studies of SEF mentioned above were all conducted to estimate the SEF via lab analysis with soil samples taken on site, but due to the relative relationship between SEF and rainfall, it is unlikely to determine a relatively accurate SEF if only the soil properties are considered.

In light of this, the study was designed specifically for the major river basins in the western mountains of Taiwan. Undisturbed slopes were selected to install soil erosion measurement plots for in-situ measurement of soil erosion depth. 26 plots were established for observation, and rainfall events were carefully documented to investigate the relationship between rainfall events and SEF and the soil erosion characteristics of the western mountains of Taiwan. The result will serve as the basis for estimation of soil losses in the design of soil and water conservation engineering.

2. Methodology

(1) Study sites

The major river basins in the western mountains of Taiwan were selected for in-situ erosion depth measurement. These rivers were, from north to south, Lanyang River, Tanshui River, Tahan River, Wu River, Kaoping River, Tungkang River and Linpien River. In total 26 sites were surveyed as shown in Fig. 1.

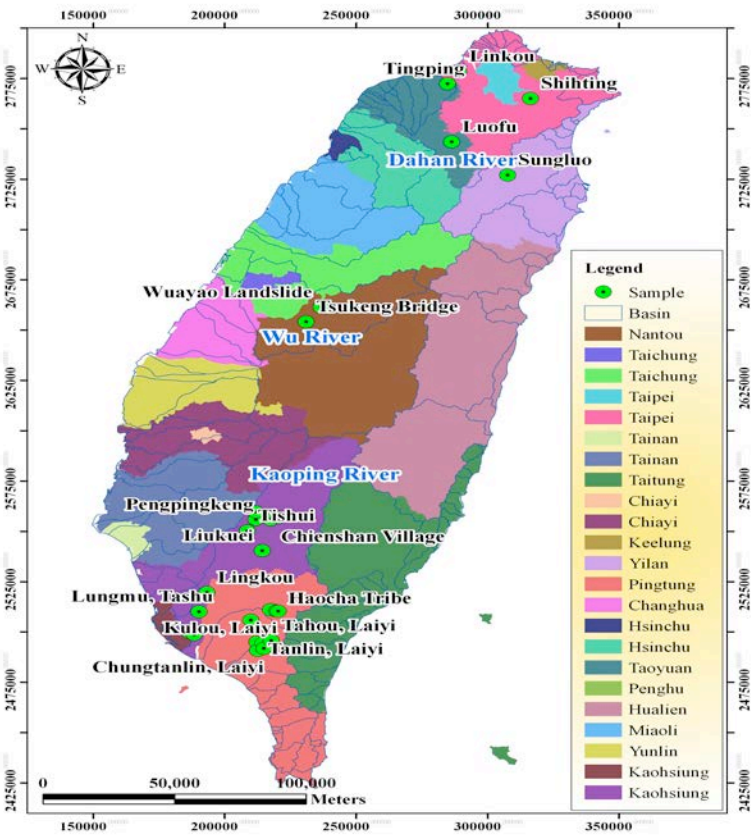

Figure 1 The Sites of Study Interest

(2) Study method

Study flow:

The study flow is shown in Fig. 2.

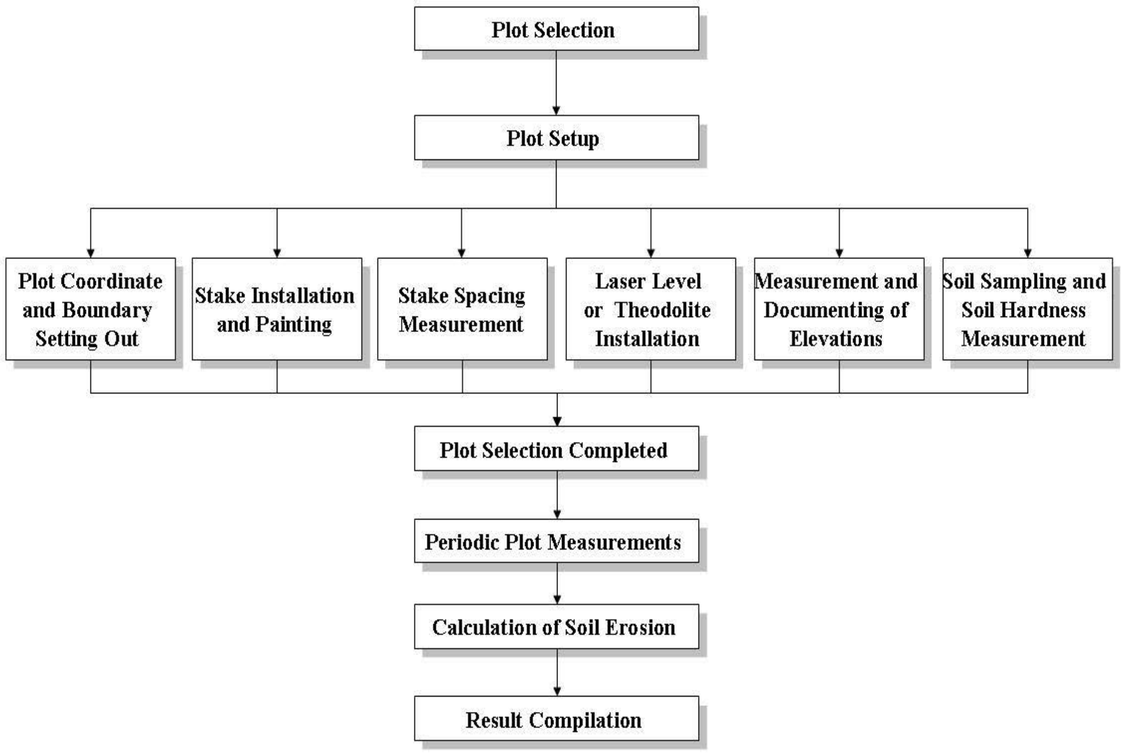

Figure 2 Study Flow

Test plots:

based on in-situ conditions, the size of plot was selected to be 10m long (up to down hill) x 2m wide (lateral) (Fig. 3).

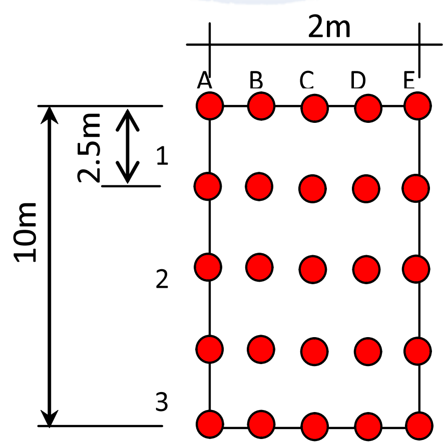

Figure 3 Typical Test Plot

Erosion stake installation:

5 stakes were installed at every transect (2m), i.e. 1 stake/0.5m; longitudinally, a transect was selected at every 2.5m and in total 5 were selected. 25 stakes were installed in every plot. The erosion stake is a round steel bar with 3/8" in diameter and 30cm long. A section of approximately 5cm protruded above ground and was painted in red (Fig. 4).

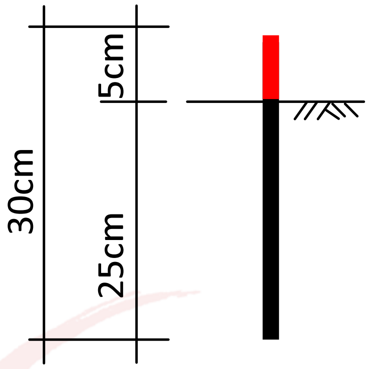

Figure 4 Erosion Stake

Setup and measurement of test plots:

for test plot setup, each of the stakes was driven into soil using a custom-made sleeve, which was precisely machined to a depth of 5cm. The protrusion of stake reached 5cm as soon as the sleeve touched the ground. A caliper was used to measure the height from the ground to the top of stake as the first depth measurement. On the setup of a plot, the elevation was measured using a laser level. The elevation of the top of each stake was measured and documented as the visual height of the measurement spot, and the ground height was determined by subtracting the visual height with the measurement depth. The measurement was carried out at each of the stakes and converted into a record (Fig. 5). For the subsequent measurements, the ground height was determined by observing the protrusion of stake above ground, and thus the sediment depth of the spot was calculated.

The soil hardness was measured and soil samples (5kg) taken around the test plots when the test plots were established. The samples were brought back to the lab for specific gravity test, color chart test, sieve analysis and organic carbon content test.

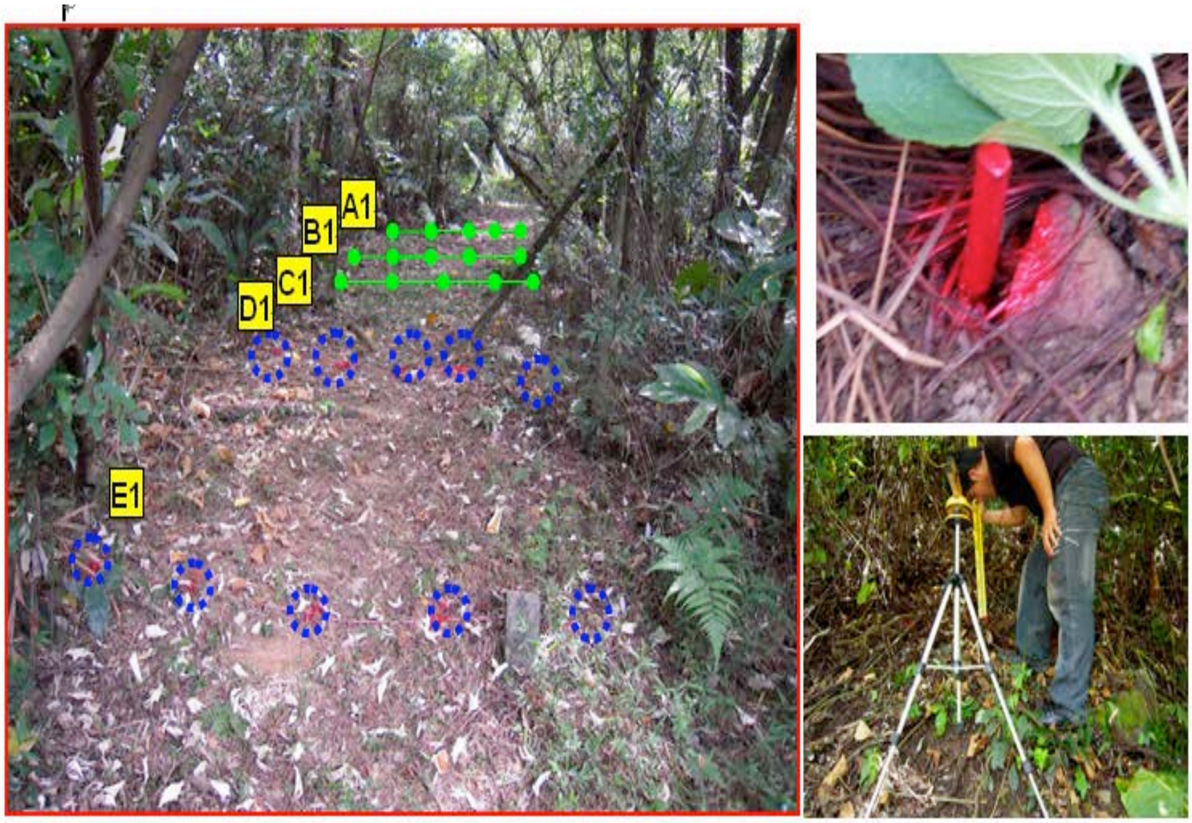

Figure 5 Photos of Test Plot Setup

(3) Estimation of SEF

Determination using SEF nomographs:

Two important findings were discovered in the nomograph analysis that the size of soil particle shall include very fine sand as well as silt, and that the estimates of sand and silt are improved. The determination of SEF using nomographs was rather crude and produced a discouraging accuracy.

Determination using SET equations:

The equation developed by Wischmeier et al (1971)

$$100K = 2.1M^{1.14} \cdot 10^{-4}(12 - a) + 3.25(b - 2) + 2.5(c - 3) \qquad (1)$$

K: $\dfrac{ton \cdot acre \cdot hr}{100 \cdot acre \cdot feet \cdot ton \cdot in}$

Where K: SEF in English units (times 0.137 to convert to SI unit, i.e. Km=0.1317k)

M: silt and very fine sand (0.002-0.1mm) % x (100%-silt %)

a: organic material content % (taken as 4% even it is greater than 4%)

b: soil structure index (see Table 1)

c: soil infiltration index (see Table 2)

Table 1 Categories of soil structure index

Structure category	Soil structure	Particle size (mm)
1	Very fine particles	<1.0
2	Fine particles	1.0~2.0
3	Medium or coarse particles	2.0~10.0
4	Blocks, shale or coarse particles	>10.0

Table 2 Categories of soil infiltration index

Infiltration category	Infiltration	Infiltration rate (mm/hr)
1	Very fast	>125.0
2	Fast	62.5~125.0
3	Medium	20.0~62.5
4	Medium to slow	5.0~20.0
5	Slow	1.25~5.0
6	Very slow	<1.25

Determination using SEF Table

S.S. Wann and J.I. Hwang (1989) adopted the nomographs of Wischmeier and Smith to estimate the SEFs of soil samples collected at 280 sites around Taiwan and compiled the data into a table, from which the values were taken for calculation. However, the estimation is unlikely to be accurate if the soil sample is collected from none of the 280 sites above.

In-situ determination using approximate SEFs

The USDA-SCS developed the SEF table shown in Table 3 in 1978 for the convenience of soil and water conservation engineers to determine the SEFs. This table is practical only for in-situ soil properties, and yields the approximate value of SEFs.

Table 3 Approximate SEFs of Typical Topsoil

Topsoil Property	Km (SI)
Clay, clay loam, loam, silty clay	0.042
Fine sand loam, very fine sand loam, sand loam	0.032
Loamy fine sand, loamy sand	0.022
Sand	0.020
Silty loam, silty clay loam, very fine sand loam	0.049

(Data: SCS, 1978)

3. Result and Discussion

26 representative sites were selected in northern, central and southern Taiwan to collect data

regarding the influence to the SEFs. The SEFs of each site were analyzed to collect the related site distribution and SEF values as shown in Table 4. The relationships between one another at different areas are described as follow:

Table 4 Basic Information of Each Site

Item	Name	County/City	X	Y	Experimental Km	Specification Km	River
1	Chunglin, Neipu	Pingtung County	209844	2505670	0.0258	0.029	Tungkang River
2	Hoping Village, Taiwu Township	Pingtung County	212160	2494873	0.0148	□	Tungkang River
3	Tanlin, Laiyi	Pingtung County	212386	2490754	0.0295	0.0224	Linpien River
4	Kulou, Laiyi	Pingtung County	214507	2494274	0.0193	0.0303	Linpien River
5	Chungtanlin, Laiyi	Pingtung County	214814	2491636	□		Linpien River
6	Tahou, Laiyi	Pingtung County	217606	2495529	0.0218	□	Linpien River
7	Kanglangyuan, Taliao	Kaohsiung County	186471	2499627	0.017	0.0158	Kaoping River
8	Taitienfu, Mingshan, Taliao	Kaohsiung County	188382	2498510	0.0191	0.025	Kaoping River
9	Lungmu, Tashu	Kaohsiung County	190175	2509970	0.0213	0.0408	Kaoping River
10	Lingkou	Kaohsiung County	193186	2519446	0.0206	0.025	Kaoping River
11	Liukuei	Kaohsiung County	214267	2540251	0.0252	0.0408	Laonong River (upstream of Kaoping River)
12	Chienshan Village	Kaohsiung County	217321	2555610	0.0301	□	Laonong River (upstream of Kaoping River)
13	Paolai	Kaohsiung County	220466	2556755	0.0298	□	Laonong River (upstream of Kaoping River)
14	Estuary of Ailiaonan River	Kaohsiung County	217413	2510874	0.0147	0.0171	Ailiao River (upstream of Kaoping River)
15	Haocha 2 Bridge	Kaohsiung	219680	2510329	0.0191	□	Ailiao River

		County					(upstream of Kaoping River)
16	Haocha Tribe	Kaohsiung County	220202	2510125	0.0237	□	Ailiao River (upstream of Kaoping River)
17	Tishui	Kaohsiung County	208567	2550122	0.0255	0.0421	Chishan River (upstream of Kaoping River)
18	Pengpingkeng	Kaohsiung County	211781	2555735	0.0257	□	Chishan River (upstream of Kaoping River)
19	Hsiaopeishihkeng	Kaohsiung County	211789	2559510	0.0236	0.0329	Chishan River (upstream of Kaoping River)
20	Luofu	Taoyuan County	286231	2743474	0.0276	0.0171	Tahan River
21	Tingping	Taoyuan County	284709	2772347	0.0362	0.0237	Nankang River at coastal Taoyuan
22	Wuayao Landslide	Nantou County	236581	2661241	0.0185	0.0474	Wu River
23	Tsukeng Bridge	Nantou County	230858	2654082	0.0194	0.0474	Wu River
24	Shihting	Taipei County	316251	2765037	0.0316	0.0408	Chingmei River of Tanshui River System
25	Linkou	Taipei County	288948	2778431	0.0377	0.0237	Coast of Tanan Bay at coastal Taoyuan
26	Sungluo	Yilan County	307581	2726962	0.0258	0.0132	Lanyang Creek of Lanyang River system

□: the site is damaged beyond measurement;

□: no available data at the vicinity of any site in the specifications.

(1) The river systems of southwestern Taiwan and the range of SEFs

Table 5 shows the SEFs (Km) of the representative site of each river system, and Table 6 and Figure 6 the range of distribution. Geostatistics was used to convert the data obtained into the isarithm maps of SEFs in southwestern Taiwan, as shown in Fig. 7. For the SEF of different river system, there is a range of distribution. The test result shows that the SEFs of southwestern rivers fall between 0.015 and 0.03. The SEF of Laonong River is the highest, indicating less resistance to soil erosion.

The comparison between the SEFs determined using the waster and soil conservation design specification and those obtained from the tests conducted for the study in the same area shows that the SEFs determined from the tests are smaller than those determined using the design specification, whereas the range of SEFs determined using the design specification tends to be larger, i.e. between 0.042 and 0.015.

For the overall relative magnitude of SEFs, the values from tests and those from design specification display a somewhat consistent relationship in relative magnitude for different river systems. The SEFs of Laonong River and Chishan River are higher, while that of Ailiao River is smaller.

Table 5 SEFs of the Representative Site of Each River

Item	Name	X	Y	Experimental Km	Specification Km	River
1	Chunglin, Neipu	209844	2505670	0.0258	0.0290	Tungkang River
2	Hoping Village, Taiwu Township	212160	2494873	0.0148	□	Tungkang River
3	Tanlin, Laiyi	212386	2490754	0.0295	0.0224	Linpien River
4	Kulou, Laiyi	214507	2494274	0.0193	0.0303	Linpien River
5	Chungtanlin, Laiyi	214814	2491636	□		Linpien River
6	Tahou, Laiyi	217606	2495529	0.0218	□	Linpien River
7	Kanglangyuan, Taliao	186471	2499627	0.0170	0.0158	Kaoping River
8	Taitienfu, Mingshan, Taliao	188382	2498510	0.0191	0.0250	Kaoping River
9	Lungmu, Tashu	190175	2509970	0.0213	0.0408	Kaoping River
10	Lingkou	193186	2519446	0.0206	0.0250	Kaoping River
11	Liukuei	214267	2540251	0.0252	0.0408	Laonong River
12	Chienshan Village	217321	2555610	0.0301	□	Laonong River
13	Paolai	220466	2556755	0.0298	□	Laonong River

14	Estuary of Ailiaonan River	217413	2510874	0.0147	0.0171	Ailiao River
15	Haocha 2 Bridge	219680	2510329	0.0191	□	Ailiao River
16	Haocha Tribe	220202	2510125	0.0237	□	Ailiao River
17	Tishui	208567	2550122	0.0255	0.0421	Chishan River
18	Pengpingkeng	211781	2555735	0.0257	□	Chishan River
19	Hsiaopeishihkeng	211789	2559510	0.0236	0.0329	Chishan River

□: the site is damaged beyond measurement;

□: no available data at the vicinity of any site in the specifications.

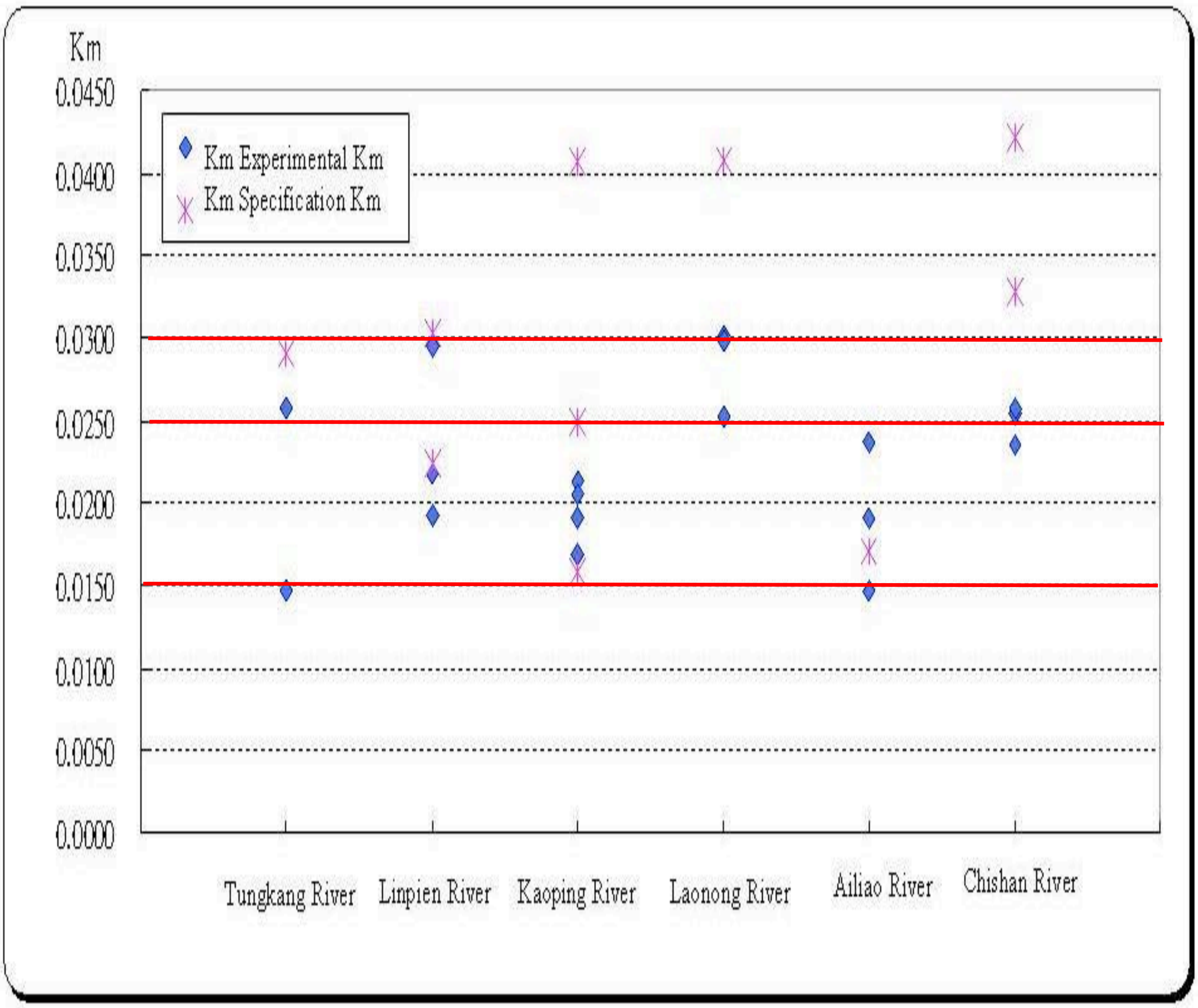

Figure 6 SEF Distribution of Southwestern River Systems

Table 6 Approximate SEFs of Southwestern River Systems

Item	River	Specification Km	Experimental Km
1	Tungkang River	0.029	0.015~0.026
2	Linpien River	0.022~0.03	0.019~0.03
3	Kaoping River	0.016~0.041	0.017~0.021
4	Laonong River	0.041	0.025~0.03
5	Ailiao River	0.017	0.015~0.024
6	Chishan River	0.033~0.042	0.024~0.026

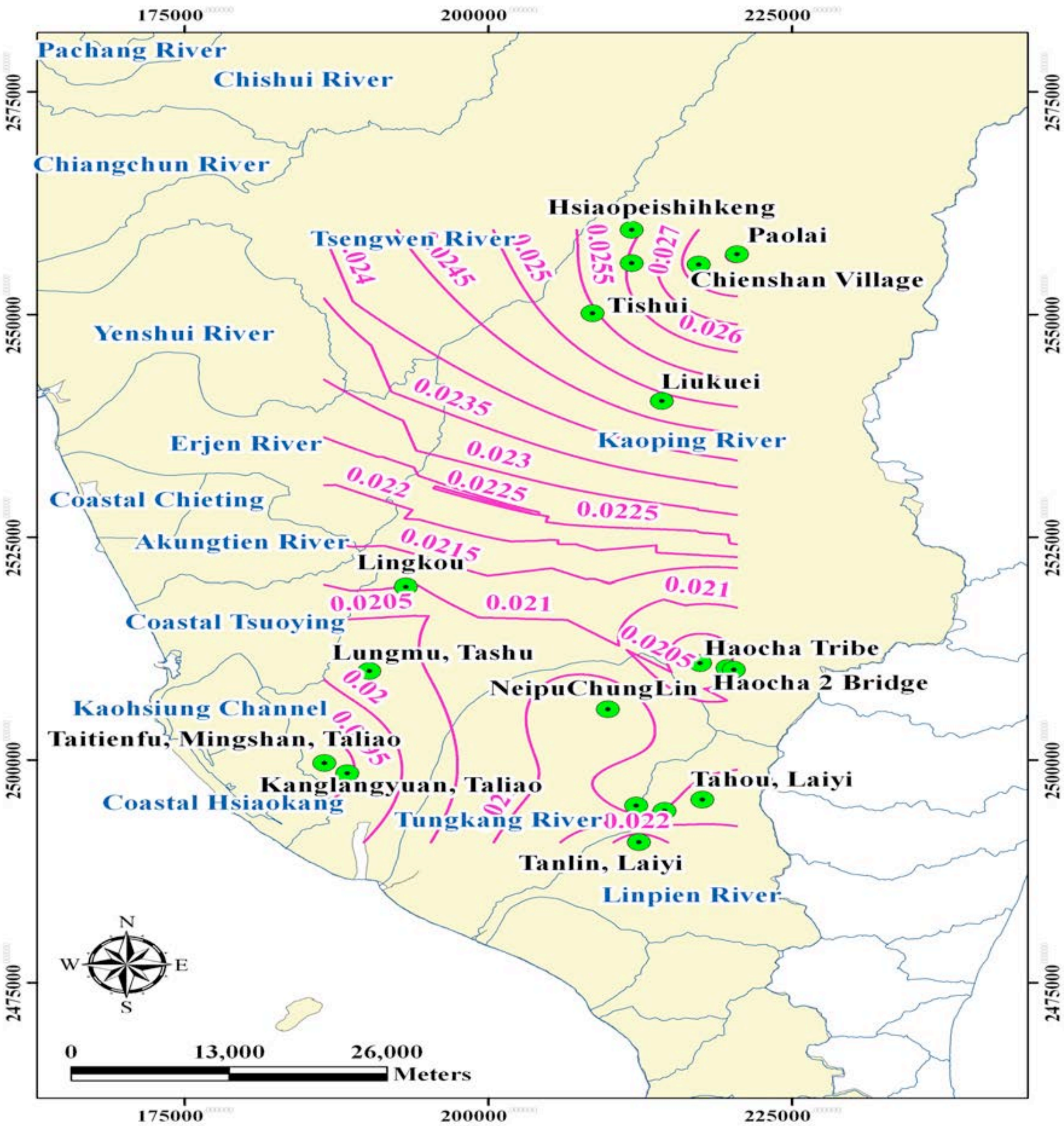

Figure 7 Isarithm Maps of SEFs for Southwestern River Systems

(2) Different southwestern soil properties and the range of SEFs

The basic soil properties and SEFs of each plots are shown in Table 7. By categorizing the

SEFs based on different soil texture, the result is obtained and shown in Figure 8.

In general, the soil erodibility should be in reverse proportion to the soil texture, i.e. the coarser the texture, the higher the soil erodibility , and the lower the SEFs (Km). However, the test result shows that by comparing the SEFS of sand and loam taken from southwestern Taiwan, the SEFs of sand are greater than those of loam; for other soil textures, they fit the general trait of SEFS, that is, the coarser the texture, the smaller the SEFs.

The test result of the SEFs of the southwestern soil was compared with the SEF table developed by USDA-SCS in 1978, and the result is shown in Table 8. Apart from the reverse trait of clay and sand, the traits of other soil textures are roughly consistent; for the SEF of type 5 soil, the result obtained from this test exhibits a wider range between 0.016 and 0.042, whereas the same SEF is a single value of 0.049 in the USDA-SCS table.

Table 7 Soil Textures of Each Plot

Item	Name	X	Y	Experimental Km	Specification Km	River	Soil Texture
1	Chunglin, Neipu	209844	2505670	0.0258	0.0290	Tungkang River	Sandy loam
2	Hoping Village, Taiwu Township	212160	2494873	0.0148	□	Tungkang River	Loamy sand
3	Tanlin, Laiyi	212386	2490754	0.0295	0.0224	Linpien River	Sandy loam
4	Kulou, Laiyi	214507	2494274	0.0193	0.0303	Linpien River	Loamy sand
5	Chungtanlin, Laiyi	214814	2491636	□		Linpien River	
6	Tahou, Laiyi	217606	2495529	0.0218	□	Linpien River	Loamy sand
7	Kanglangyuan, Taliao	186471	2499627	0.0170	0.0158	Kaoping River	Silty clay loam
8	Taitienfu, Mingshan, Taliao	188382	2498510	0.0191	0.0250	Kaoping River	Silty loam
9	Lungmu, Tashu	190175	2509970	0.0213	0.0408	Kaoping River	Silty loam
10	Lingkou	193186	2519446	0.0206	0.0250	Kaoping River	Silty loam
11	Liukuei	214267	2540251	0.0252	0.0408	Laonong River	Sand

12	Chienshan Village	217321	2555610	0.0301	□	Laonong River	Sandy loam
13	Paolai	220466	2556755	0.0298	□	Laonong River	Sandy loam
14	Estuary of Ailiaonan River	217413	2510874	0.0147	0.0171	Ailiao River	Loam
15	Haocha 2 Bridge	219680	2510329	0.0191	□	Ailiao River	Sandy loam
16	Haocha Tribe	220202	2510125	0.0237	□	Ailiao River	Sandy loam
17	Tishui	208567	2550122	0.0255	0.0421	Chishan River	Silty clay loam
18	Pengpingkeng	211781	2555735	0.0257	□	Chishan River	Silty loam
19	Hsiaopeishihkeng	211789	2559510	0.0236	0.0329	Chishan River	Silty clay loam

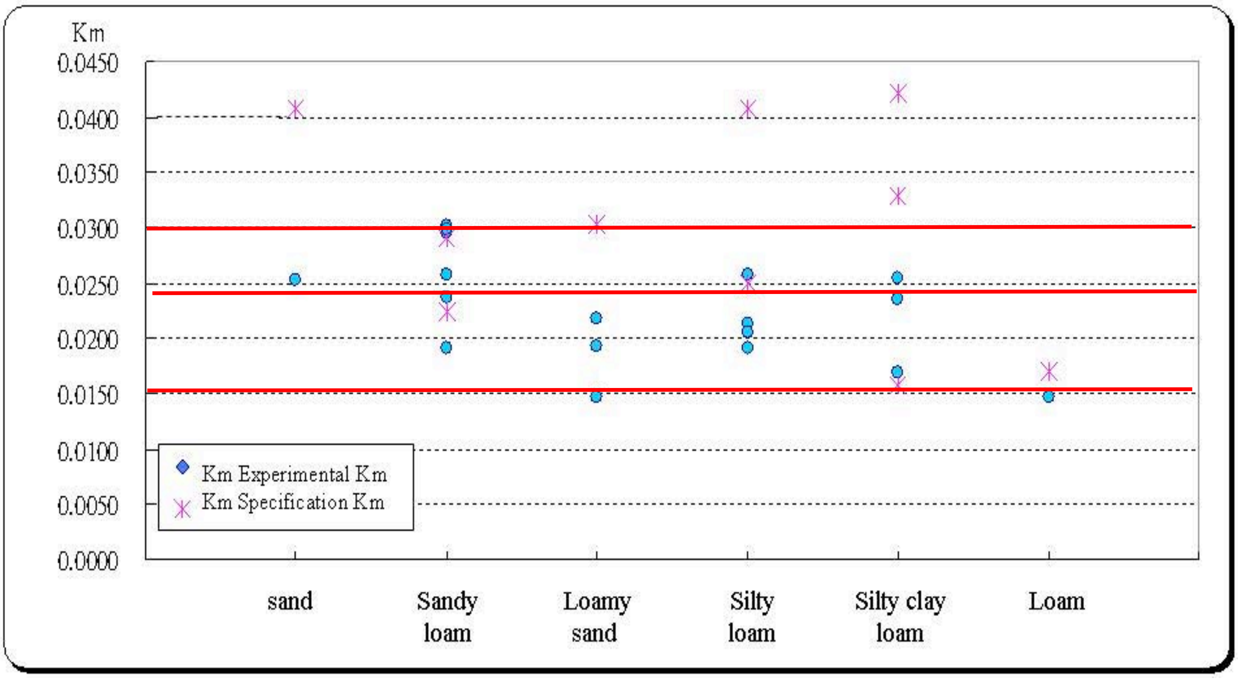

Figure 8 SEF Distribution of Soil Samples Taken from Southwestern Taiwan with Various textures

Table 8 Approximate SEFs of typical soil textures in southwestern Taiwan

Type	Topsoil Texture	USDA Km	Southwestern Taiwan Km

1	Clay, clay loam, loam, silty clay	0.042	0.017
2	Fine sand loam, very fine sand loam, sand loam	0.032	0.019~0.030
3	Loamy fine sand, loamy sand	0.022	0.015~0.022
4	Sand	0.02	0.04
5	Silty loam, silty clay loam, very fine sand loam	0.049	0.016~0.042

(3) The southwestern SEFs and their relationship with other parameters

Table 9 shows the Km obtained from the test for the test plots of southwestern Taiwan and that obtained from SEF table vs. organic material content in soil (a), silt and very fine sand content percentage (d) and coarse sand percentage (e).

Figure 9 shows the correlation result from the analysis of the individual influence factors and SEFs. The result shows that for the result from the test conducted on soil samples from southwestern Taiwan, the silt and very fine sand content (b) has a higher correlation with SEF. Overall, the relationship between the Km obtained from the test and the factors is more significant that that between Km from SEF table and the factors.

Table 9 SEFs vs. Factors Having Influence to SEFs

Name	Y(N)	X(E)	Km	Specification Km	Rm	a	b	c	0.002~0.1(d)	0.1~2(e)
Kanglangyuan, Taliao	2499627	186471	0.0170	0.0158	13650	6.49	3	3	53.06	31.19
Taitienfu, Mingshan, Taliao	2498510	188382	0.0191	0.0250	13650	4.58	3	3	47.97	33.33
Lungmu, Tashu	2509970	190175	0.0213	0.0408	20000	4.63	2	3	59.01	34.92
Lingkou	2519446	193186	0.0206	0.0250	25000	5.75	3	4	44.80	44.65
Tishui	2550122	208567	0.0255	0.0421	25000	5.26	3	4	63.66	17.76
Chunglin, Neipu	2505670	209844	0.0258	0.0290	18909	4.36	3	4	61.43	14.99
Pengpingkeng	2555735	211781	0.0257	□	21028	3.14	3	5	58.36	0.42
Hsiaopeishihkeng	2559510	211789	0.0236	0.0329	21028	3.66	3	3	65.56	4.80
Hoping Village, Taiwu Township	2494873	212160	0.0148	□	44712	5.18	3	3	49.73	12.89
Tanlin, Laiyi	2490754	212386	0.0295	0.0224	21854	3.82	3	3	70.69	14.13
Liukuei	2540251	214267	0.0252	0.0408	20000	5.58	4	4	62.41	4.41
Kulou, Laiyi	2494274	214507	0.0193	0.0303	21854	7.49	4	4	51.02	14.07
Chienshan Village	2555610	217321	0.0301	□	25000	4.91	3	4	71.18	15.43
Estuary of Ailiaonan River	2510874	217413	0.0147	0.0171	24556	6.78	3	5	29.21	23.37
Tahou, Laiyi	2495529	217606	0.0218	□	21854	4.83	4	5	42.32	3.79

Haocha 2 Bridge	2510329	219680	0.0191	□	24556	4.95	4	4	44.53	4.07
Haocha Tribe	2510125	220202	0.0237	□	24556	2.03	4	5	37.86	9.66
Paolai	2556755	220466	0.0298	□	20000	2.13	4	3	62.81	5.66

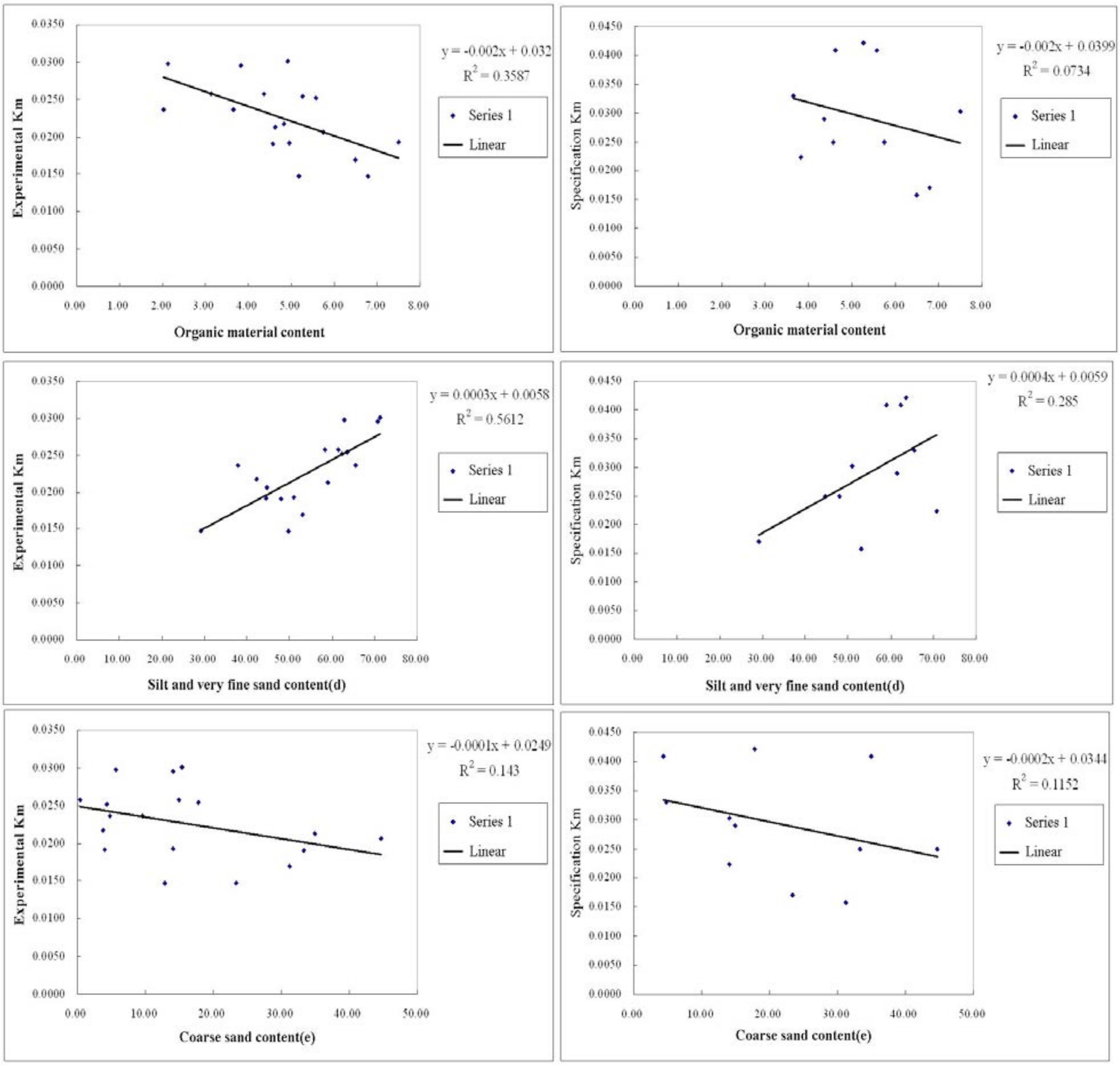

Figure 9　Km Estimated Using Different Methods vs. Various SEFs

(4) SEFs of western soil and their relationship with rainfall

11 representative plots were selected in northern, central and southern Taiwan. The table in the soil and water conservation design specification (Method 1), soil test (Method 2) and regression with in-situ measurement of erosion (Method 3) were employed to obtain SEFs. The cumulated rainfall from Apr to Jul 2010 was collected for comparison shown in Table 10.

In general, the SEFs have higher correlation with soil texture and parent rock, and rainfall is susceptible to rainfall erodibility index (Rm). However, the relationship between SEFs obtained in different methods and the cumulated rainfall, as shown in Tables 10-12, suggests that the SEFs obtained from Method 1 has a greater correlation with the cumulated rainfall, followed by Method 2 and Method 3.

The result obtained using Method shows a certain level of correlation, but it relationship with SEFs decreases, not increase, with the cumulated rainfall.

Table 10 Km Obtained Using Various Estimate Methods vs. Cumulated Rainfall

County	Plot	Km from table (Method 1)	Km from soil test (Method 2)	Km calculated from stake measurements (Method 3)	Cumulated rainfall from Apr to Jul 2010 (mm)
Taoyuan	Luofu	0.0171	0.0276	0.0007	632
Taoyuan	Pingting	0.0237	0.0362	0.0036	527.5
Nantou	Wuayao Landslide	0.0474	0.0185	0.012	1013
Nantou	Tsukeng Bridge	0.0474	0.0194	0.0028	939.5
Kaohsiung	Tishui	0.0421	0.17	0.0872	1587
Kaohsiung	Hsiaopeishihkeng	0.0329	0.0206	0.0431	1547
Pingtung	Tanlin, Laiyi	0.0224	0.0147	0.0028	998
Pingtung	Hoping Village, Taiwu Township	0.0303	0.017	0.0052	998
Taipei	Shihting	0.0408	0.0316	0.0091	668
Taipei	Linkou	0.0237	0.0377	0.0046	527.5
Yilan	Sungluo	0.0132	0.0258	0.0081	849

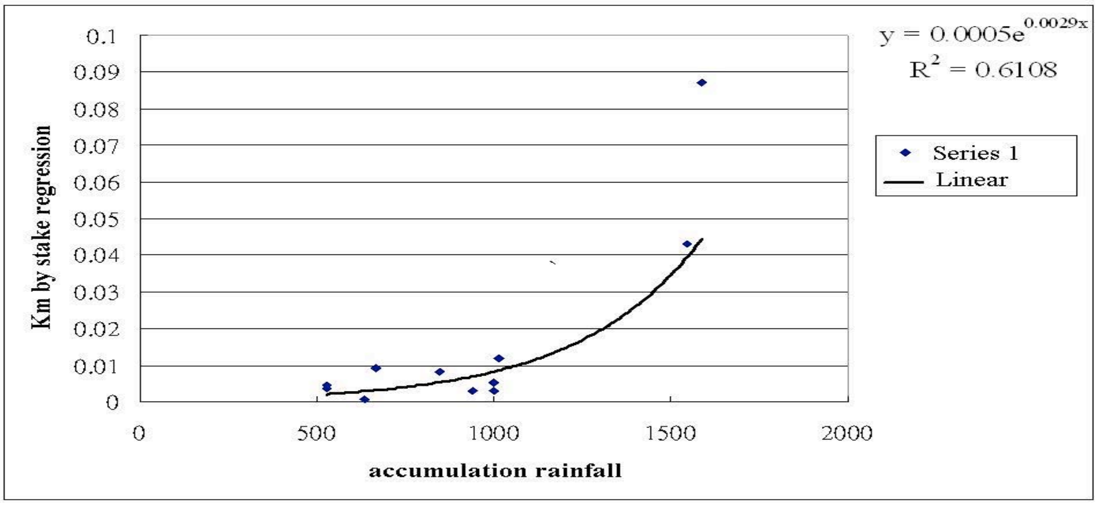

Figure 10 Km Obtained from Regression with In-situ Measurement of Erosion vs. Cumulated Rainfall

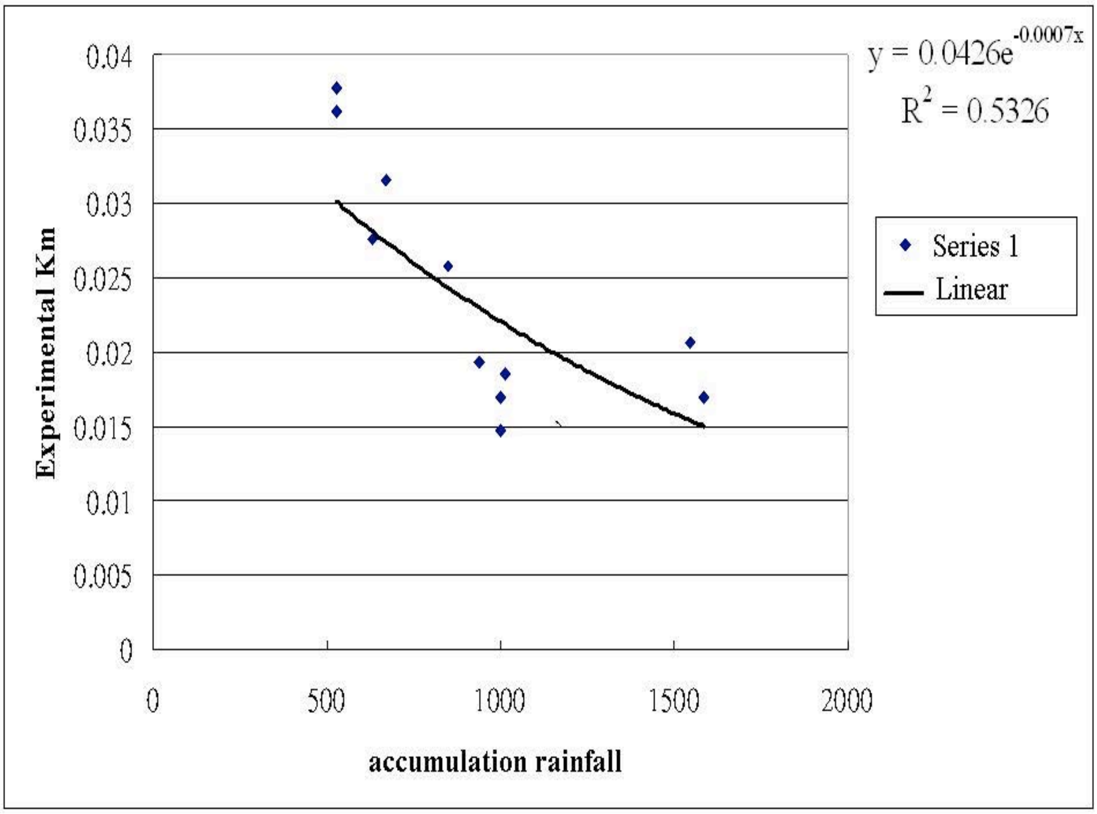

Figure 11 Km Obtained from Soil Test vs. Cumulated Rainfall

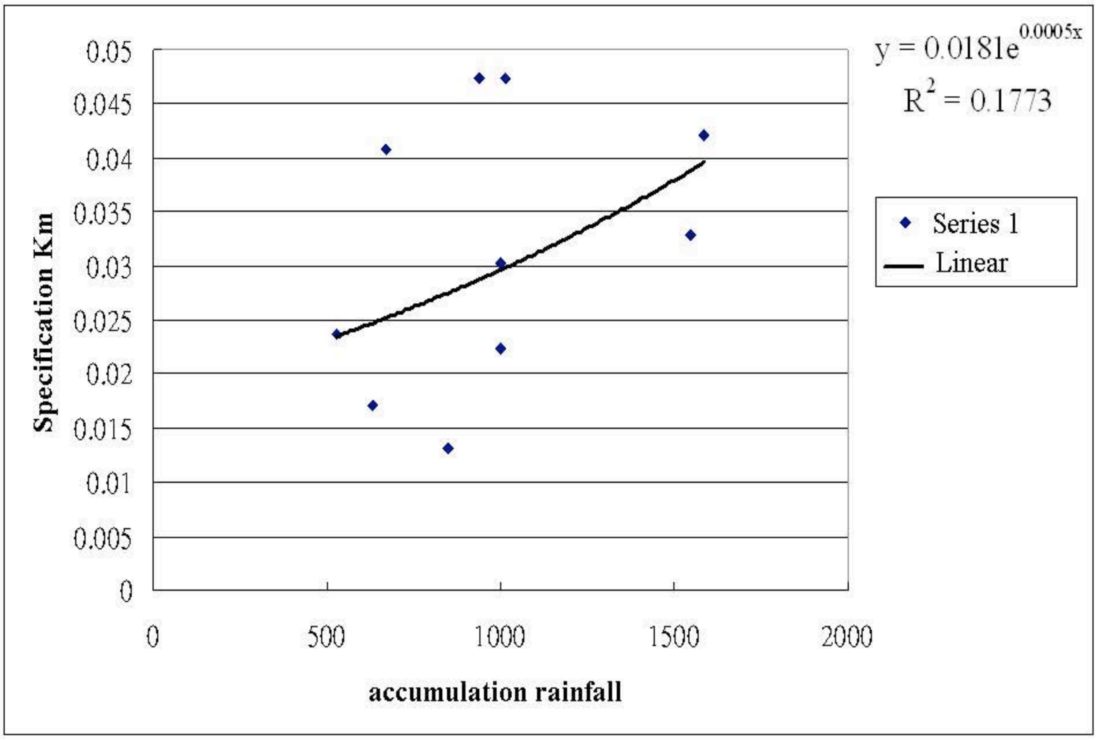

Figure 12 Km Obtained from SEF Table in the Design Specification vs. Cumulated Rainfall

4. Conclusion

(1) The relationship between rainfall events and SEFs was investigated. In general, the SEFs are relatively susceptible to soil texture and parent rock, while rainfall is susceptible to the rainfall erodibility index (R). However, the relationship between the SEFs obtained from various methods and the cumulated rainfall suggests that the correlation between the SEFs estimated using regression with in-situ measurement of erosion and the cumulated rainfall is the greatest, whereas that between SEFs obtained using the SEF table in the soil and water conservation design specification and the rainfall is the lowest.

(2) The measurement result shows that the soil erosions estimated using the USLE provided in the soil and water conservation design specification (2003) are mostly greater than those measured in-situ, which suggests a revision of the equation to better meet the local conditions.

(3) The SEFs estimated using the soil test results and the cumulated rainfall are somewhat correlated, and the SEFs decrease with the cumulated rainfall instead of increasing.

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A Study on Potential Use of Pulverized Oyster Shell as A Cementing Material in Civil Engineering

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A Study on Potential Use of Pulverized Oyster Shell as A Cementing Material in Civil Engineering

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ABSTRACT

Oysters are one of the major costal economic products in Taiwan. The oyster shells are usually deserted after oysters being collected. This research intends to study the cementing potential of the shell on Pozzolanic reaction with fly ash and soil stabilization. Different ratios of pulverized oyster shells are mixed with lime, fly ash, and soil to study the strength of the specimens. The main concept in the study is to reutilize the Calcium in the deserted shell in soil stabilization and Pozzolanic reaction with fly ash.

Soil which is classified as CL in the USCS system, commercialized pulverized oyster shell, F-type fly ash, and lime are mixed with different weight percentage. Five sample groups are made to study the compressive strength of the cubic lime cubes with W/B around 0.45 and the compacted soil under the standard Procter compaction respectively.

The results show that more POS added, lower the strength will get both in the soil specimen and lime cubes. In a 56-day period, the compressive strength of the lime cubes containing fly ash increases evidently. The soil specimen containing fly ash gradually gain strength as curing proceeds, though the strength of the compacted soil is low in early stage of the test. It suggests that mixtures of POS and fly ash do not process any Pozzolanic reaction nor help to raise the unconfined strength of the compacted soil through the 2-year-period curing. Apparently, the CaO in the pulverized oyster shells is not feasible in Pozzolanic reaction with fly ash for the time being.

Keywords: soil stabilization fly ash pulverized oyster shell lime

1. Foreword

Surrounded by ocean, Taiwan is rich in marine resource. Along the west coast of Taiwan, the oyster farming is one of the important production activities for marine economy. In general, most of oyster shells are discarded with no further use once the flesh is stripped off, except that a small amount is used for art creation [1, 2]. As a result, oyster shell piles are common at areas of oyster production with no further utilization. The primary ingredient of oyster shell is CaO [3], similar to that of lime, which has been used for soil stabilization [4]. The expandable nature of clay is reduced by the ion exchange from the interaction between calcium ions and clay. Quicklime creates coagulation if added with water. Thus, calcium ions are used generally as the primary component in the clay stabilization. There is no known chemical reaction between soil and lime except the ion exchange. In other studies for potential use, the shells are mostly used as additive or replacement of part of cement in concrete. However, the lime contained in the shells does not provide improvement of concrete strength as the Pozzolanic products of concrete already contain lime, and therefore no positive effect is detected for concrete strength. No concrete strength increase was found by adding sintered and pulverized oyster shells to concrete [5]. As a result, the use of pulverized oyster shells as concrete additive or cement replacement often needs to be combined with other bonding materials, such as fly ash or slag. Only the Pozzolanic between SiO_2 in the fly ash or slag and CaO in the pulverized oyster shells, along with the addition of water reducer or superplasticizer, can improve the strength of pulverized oyster shell added concrete. Two major parts in the research are to investigate, firstly, the Pozzolanic reaction between F type fly ash and the pulverized oyster shell, and secondly, for the improvement of soil strength, the combination of pulverized oyster shells, clay and sand can effectively improve the physical properties of soil such as strength [4]. However, most of soil stabilization is done by in-situ mixing, paving and compacting. It is unlikely to obtain good control as it does in concrete mixing.

2. Specimens in the tests

5×5×5 cm cubic specimens (Photo 1), which are named lime cubes in the following, were made for testing the Pozzolanic potential of fly ash and the oyster shell. There are five groups of cubic specimens with different proportions of lime, fly ash, and pulverized oyster shell. Each group contains 3 specimens. The W/B 0.45 and 40% weight of lime are chosen in mixture of specimens. The lime is originally proposed to provide the adhesion for fixing the cubes, due to its low strength after hardening, in case that the Pozzolanic reaction between fly ash and the oyster shell dose not occur. However, the lime, when mixed with fly ash, becomes a main character providing the compressive strength of the cubes at the end of the study. The ratios of the ingredients, shown in table 1, are conveniently chosen since the study mainly focuses on the reaction between fly ash and the shell but does not concern about the optimum ratio of the ingredients.

Photo 1. Cubic specimens in the study

Table 1. Weight Proportion of ingredients in cubic specimens

group	lime	fly ash	POS*
A	40	40	20
B	40	20	40
C	40	30	30
D	100	--	--
E	--	50	50

* pulverized oyster shell

A USCS classified CL soil is used in the compaction. The analysis of basic physical soil properties in the laboratory revealed that the plastic limit was 11% and liquid limit 25%, resulting in the plasticity index of 14%, which classifies the soil used to be low plasticity soil according to the unified soil classification. The soil contained approximately 90% of fine particles, as the size of most particles was smaller than 2.75 mm (i.e. #4 sieve). Only 2% of particles were greater than 2.75 mm in size. The specific weight of soil particles was 2.63.

The Proctor (ASTM D698-91A) standard compaction test was selected for soil dynamic analysis. Cylindrical soil specimens of 7.5ϕ×15cm were prepared for unconfined compression test in order to find out the influence of pulverized oyster shells to the compression strength of soil. If the soil specimens were taken from the compacted soil in a standard compaction mold using thin tube, the sampling would create excessive disturbance affecting the test result. Considering the minimization of disturbance to soil specimens, the standard compact mold was not used for compaction in the specimen preparation. Instead, a steel concrete specimen mold of 7.5ϕ×15cm was chosen for compaction. Two steel molds were connected with screws (Photo 2) to allow complete filling of soil in the mold. The number of hammering was calculated based on the compaction energy received per soil volume in the standard compaction test.

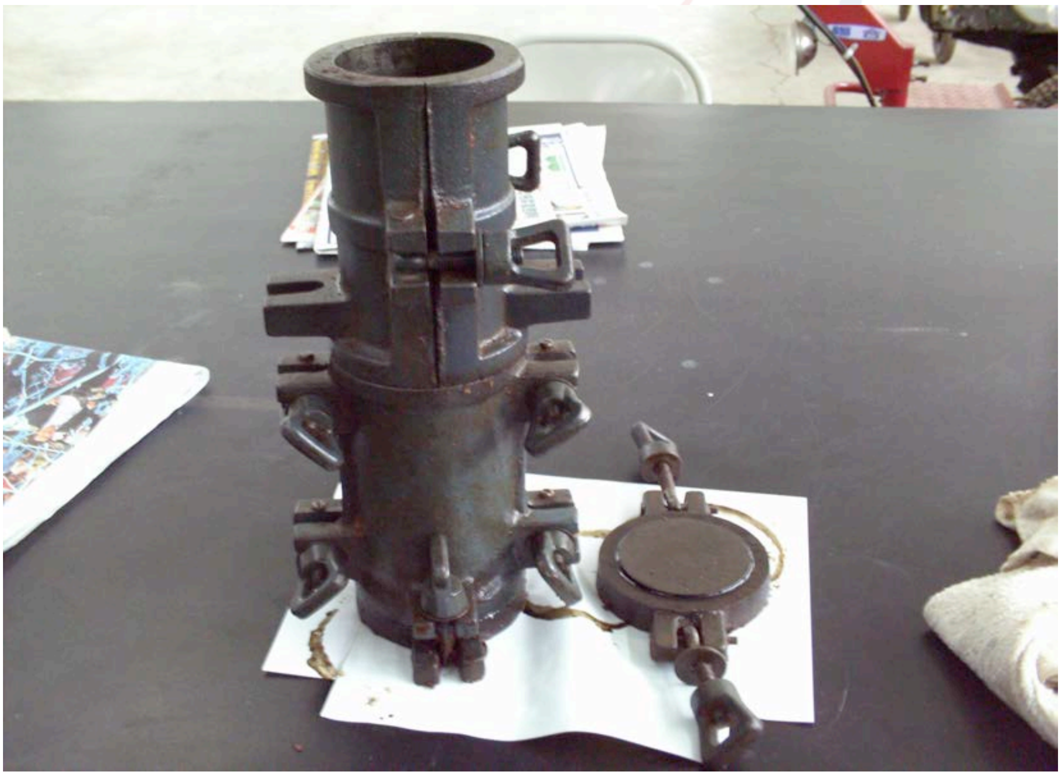

Photo 2: Soil compaction mold assembly modified from concrete specimen mold

Specimens were produced with repeated compactions. 1.2 kg of soil was used to fill the mold in three layers. 8 compactions were exercised for every layer. Specimens were produced at a height of roughly 16 cm based on the soil weight and procedure. The part of soil hanging outside of the mold was carefully removed using a steel saw, thus resulting in cylindrical specimens of 7.5ϕ×15cm (Photo 3) and eliminating the disturbance that sampling with thin tube would have caused, in the hope to minimizing test error.

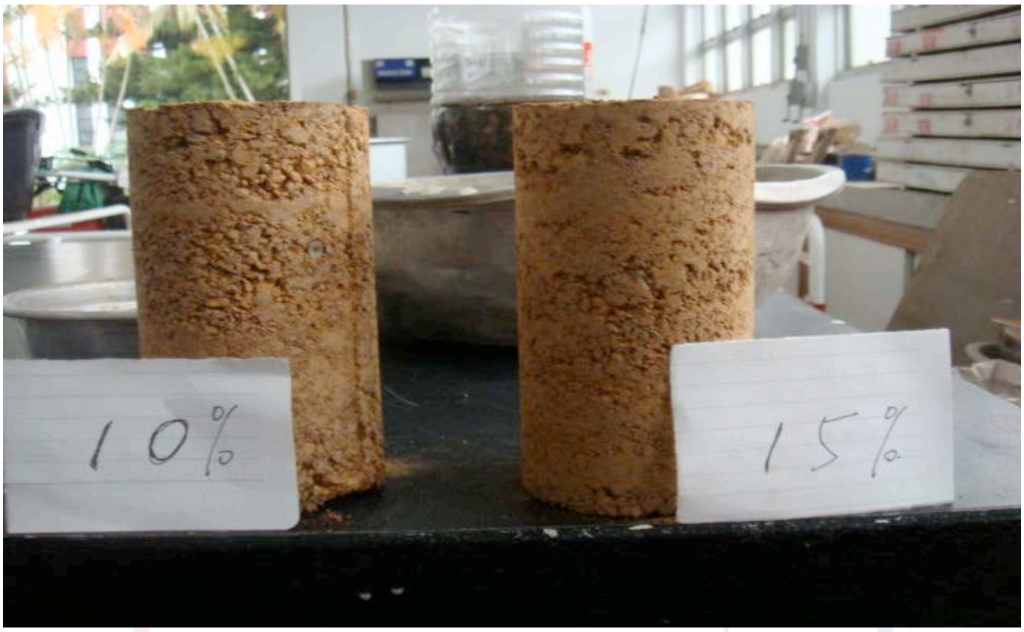

Photo 3: Compacted soil specimens

Specimens were separated in 5 groups, in each of which different proportions in weight of pulverized oyster shells and fly ash were added in place of partial soil for specimen production. The purpose was to investigate the influence of pulverized oyster shells and fly ash to the compression strength of soil. The composition of each group shown in table 2

Table 2. Weight Percentage of ingredients used in soil specimens

group	soil	fly ash	POS*
A	100	--	--
B	95	--	5
C	85	--	15
D	95	5	--
E	85	7.5	7.5

* pulverized oyster shell

The compression test was carried out on day 7, 28, 60 and 90 to investigate the changes of unconfined compression strength at different days.

3. Water in the compacted soil

The maximum dry density of soil sample and the difficulty of removing the specimens from mold must be considered, as the specimens produced for the study were not made in the standard mold. The soil of each group was compacted according to the compaction energy and soil weight determined previously. The compaction result of some of the soil is shown in Figure 1to Figure 3.

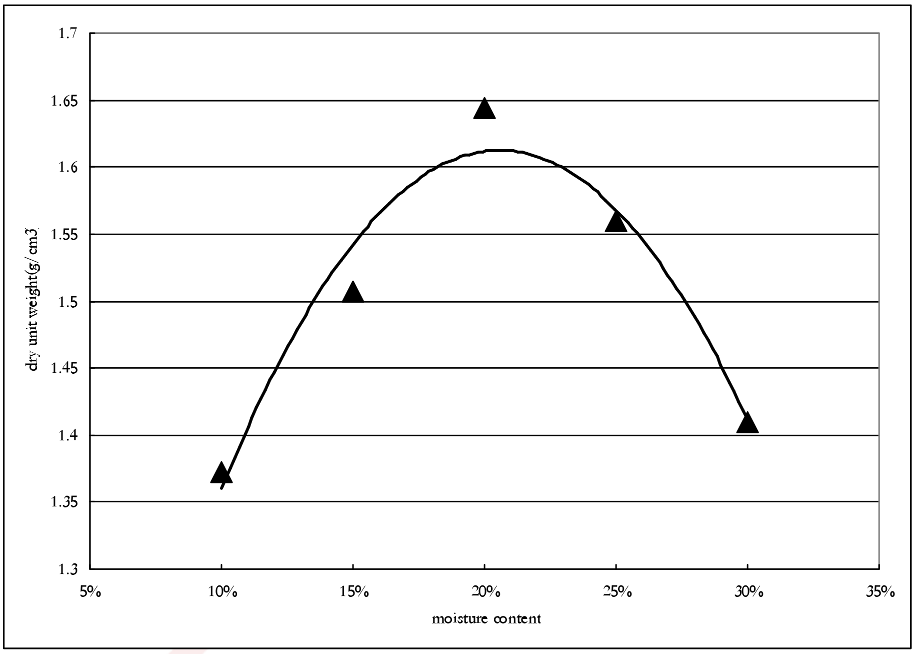

Figure 1 Compaction curve of soil group A.

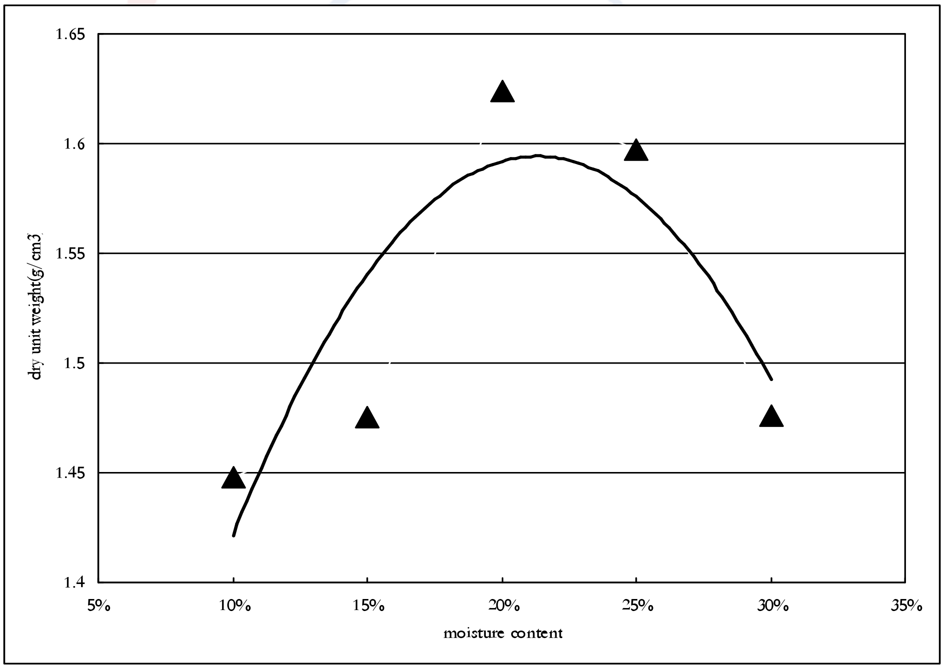

Figure 2 Compaction curve of soil group B.

From the above, it is found that the addition of pulverized oyster shells improved the optimal moisture content in the soil from 20% to nearly 25%. Therefore, the soil was less sensitive to water, allowing the increase of moisture in soil without making the soil too soft. As non-standard procedure was adopted for the compaction test, it is necessary to consider how to keep the specimens intact when removing them from molds, and the soil strength, as well as the test result, is susceptible to moisture content. By considering both factors above and conducting trial and error, it is realized that it is the easiest to remove the specimens from the molds at the content of 20%. As a result, the moisture content of 20% was used for the compaction of specimens. The changes in the strength of each group of specimens at the maximum dry density are not covered in this study.

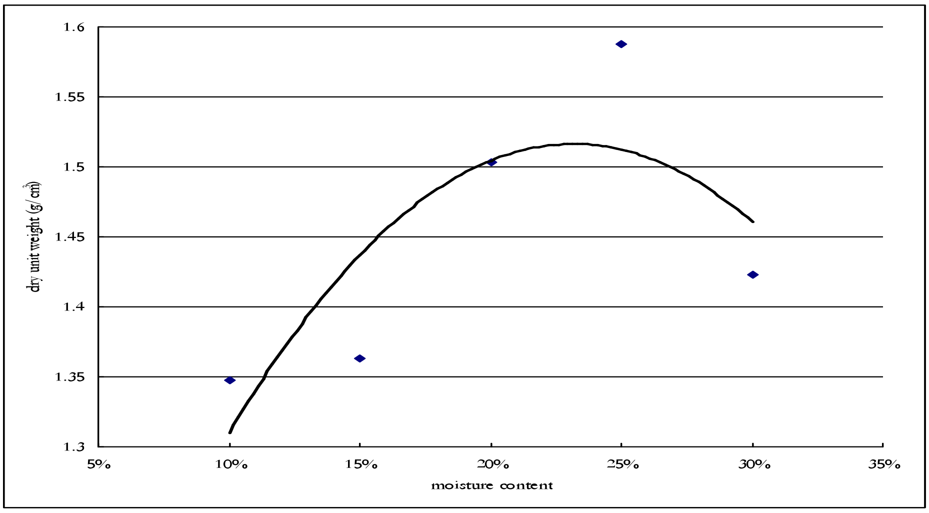

Figure 3 Compaction curve of soil group C.

The wet specific weight of specimens obtained in the compaction test was calculated based on 30 specimens taken from each group, and is shown in Table 3, which indicates that the homogeneity of the specimens produced was satisfying with the specific weight of all specimens at 2.04 g/cm^3 for maximum (Group A) and 1.87g/cm^3 for minimum (Group E). The error of the maximum and minimum specific weights of the soil specimens relative to the average specific weight felt between 2.27%~2.64% with the largest difference of 4.16% occurring in Group E. At a specific weight of 2.2, the addition of pulverized oyster shells decreased the specific weight of soil specimens, suggesting that the specific weight of soil specimens decreases with the increase of addition of pulverized oyster shells, dropping from 1.97g/cm^3 for pure soil to 1.94g/cm^3 with the difference in specific weight at only 1.8%.

Table 3 : Specific weights of soil specimens by group

Group / Project	A	B	C	D	E
Average	1.97	1.97	1.94	1.97	1.95
Standard deviation	0.03	0.02	0.02	0.02	0.03
Max（Homogeneous difference%）	2.04（3.73）	2.02（2.47）	1.99（2.60）	2.01（1.75）	2.01（2.64）
Minimum（Homogeneous difference%）	1.91（3.24）	1.92（2.43）	1.89 2.27	1.92（2.64）	1.87（4.16）

4. Specimen curing and compression test

To prevent water in the specimens from vaporizing, the specimens were wrapped in plastic film when produced (Photo 4) and placed in large plastic bags. Small amount of water was sprinkled in the plastic bags every week to keep the specimens properly moist, keeping in mind not to allow excessive moisture in them to ruin the result of compression test to come.

The unconfined compression test (i.e. the uniaxial compression strength test) was carried out at day 7, 28 and 75 of specimen curing to investigate the long-term influence of pulverized oyster shells and fly ash to the compression strength of compacted soil. The moisture content was measured after the compression test to determine the effect of curing method to the moisture maintenance in soil.

Photo 4 : Compacted soil specimens wrapped for curing

5. Test result

The lime cubes were then tested on the 7th, 28th, and 56th day. The results are shown in table 4, figure 4, and figure 5. It shows that Pozzolanic reaction between fly ash and POS does not occur as expected. The strength of cube A gets higher as the curing time elapses, while cube E only gets slight increase in strength. It is reasonable to conclude that the strength of cube A is mainly gained from the Pozzolanic products from lime and fly ash. Also, the compressive strength of the cubes is smaller as the weight percentage of pulverized oyster shell increases (figure 5). The compressive strength of the D and E cubes eventually becomes the same at any curing age. It suggests that, for the time being, the commercialized pulverized oyster will not have too much help in Pozzolanic reaction with fly ash.

Table 4 Compressive strength of lime cubes

Time (day)	Compressive strength (N/cm^2)				
	A	B	C	D	E
7	48.3	26.1	32.5	33.7	28.4
	54.5	23.9	33.0	33.0	25.8
	43.1	25.5	32.1	40.3	-
average	48.6	25.2	32.5	35.7	27.1
8	192.5	29.7	63.2	46.0	34.2
	159.5	28.1	83.4	47.2	33.0
	221.8	17.1	-	40.6	-
average	191.3	24.9	73.3	44.6	33.6
56	324.2	32.8	-	-	39.3
	402.0	44.3	122.1	37.8	35.8
	436.5	42.0	179.2	27.4	-
average	387.6	39.7	150.7	32.6	37.6

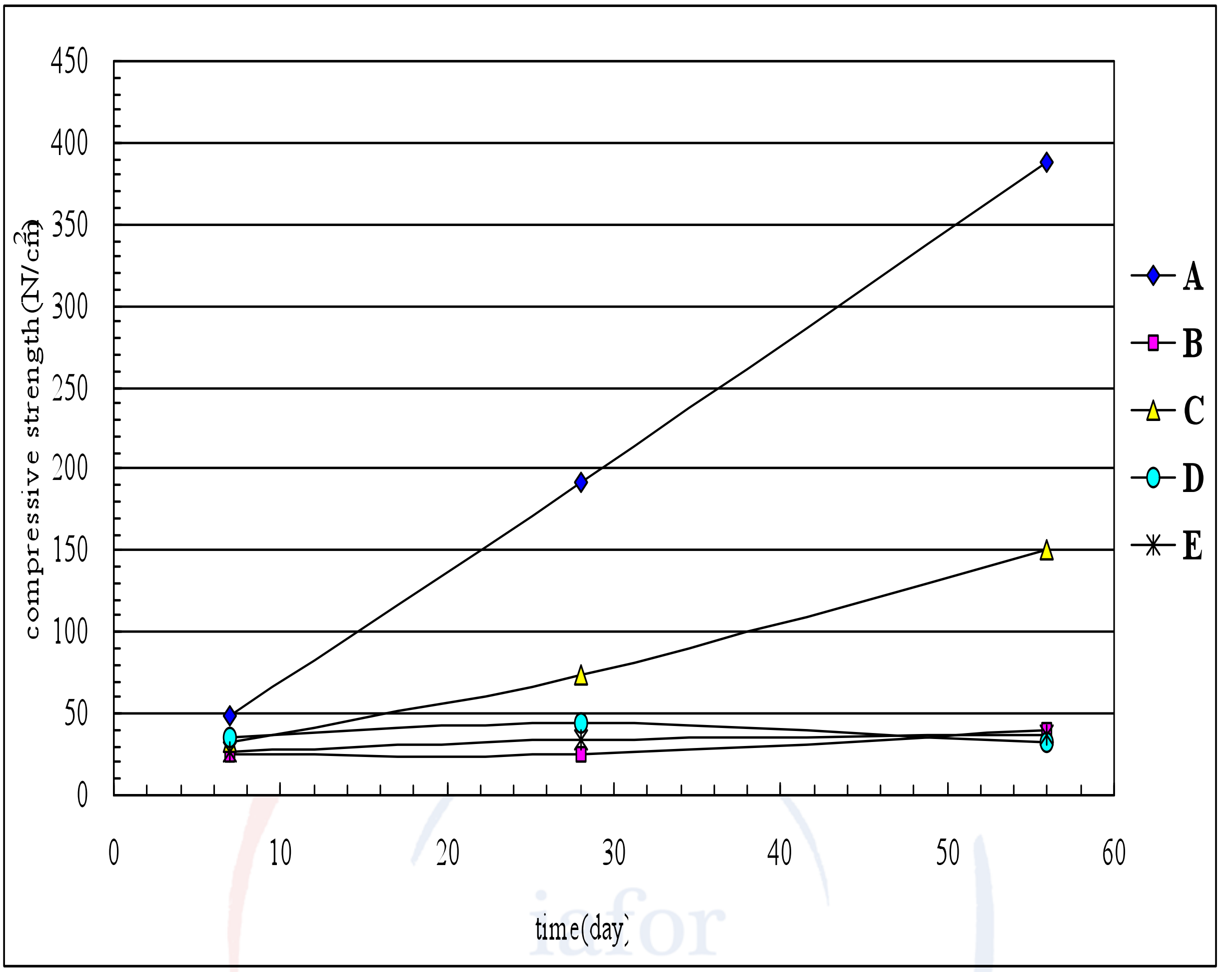

Figure 4 Strength development of lime cubes

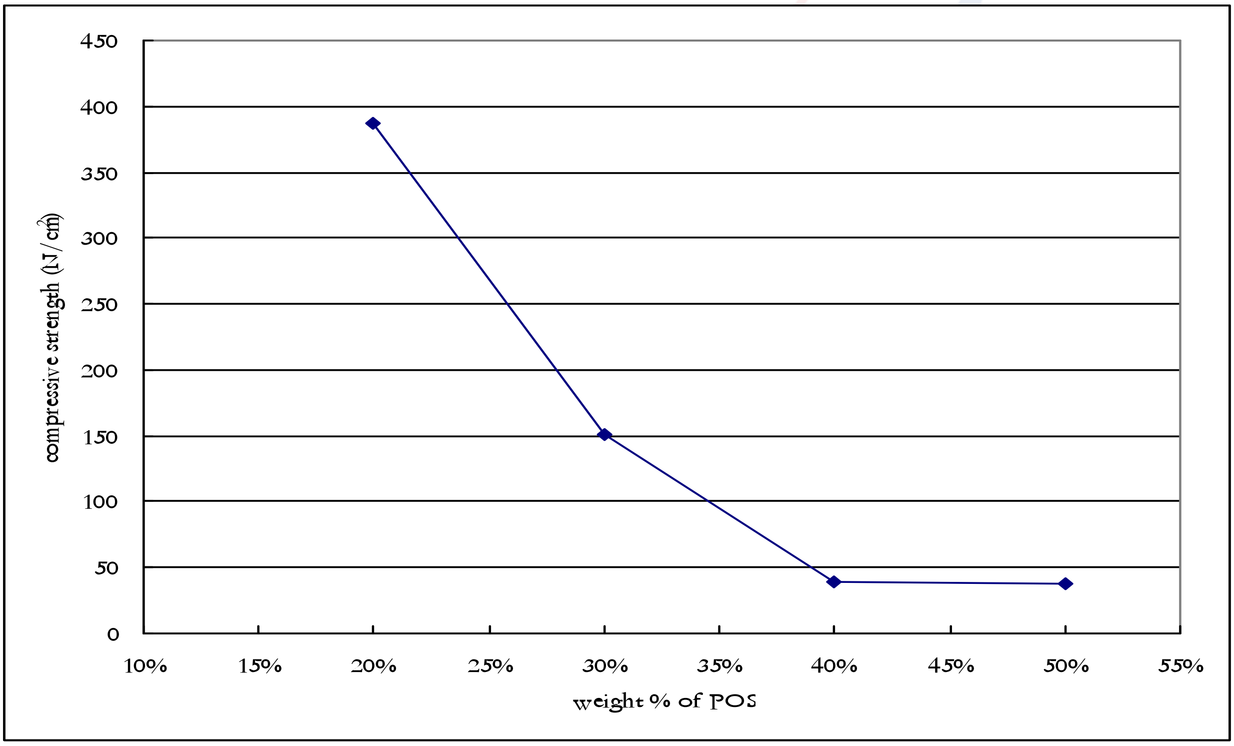

Figure 5 Strength of lime cubes versus weight percentage of pulverized oyster shell

The compressive strength test on compacted soil specimens was scheduled at day 7, 28, 60 and 90. However due to equipment servicing, it was rescheduled at day 7, 28 and 75 of specimen age. Table 5 shows the strength of each group of specimens vs. curing time, whereas Figure 6 gives the maxima of compression strength at each of the days.

Table 5: Unconfined compression strength of soil specimens for group with different age.

Time (day)	Compressive strength (N/cm2)				
	A	B	C	D	E
7 day	22.1	23.5	20.7	15.6	21
	25.7	26.2	17.4	17.4	16.5
	28.2	17.2	20.2	19	12.2
average	25.3	22.3	19.4	17.3	16.6
28 day	27.5	21	15.9	23.5	20.9
	29	17	17.5	22.8	19.4
	27.2	21.4	21.9	23.5	17.5
average	27.9	19.8	18.4	23.3	19.3
75 day	28.1	19.6	16.8	21.6	17.5
	27.3	18.1	18.5	27.5	16.1
	31.9	20.1	19.6	25.9	18.4
average	29.1	17.3	18.3	25	17.3

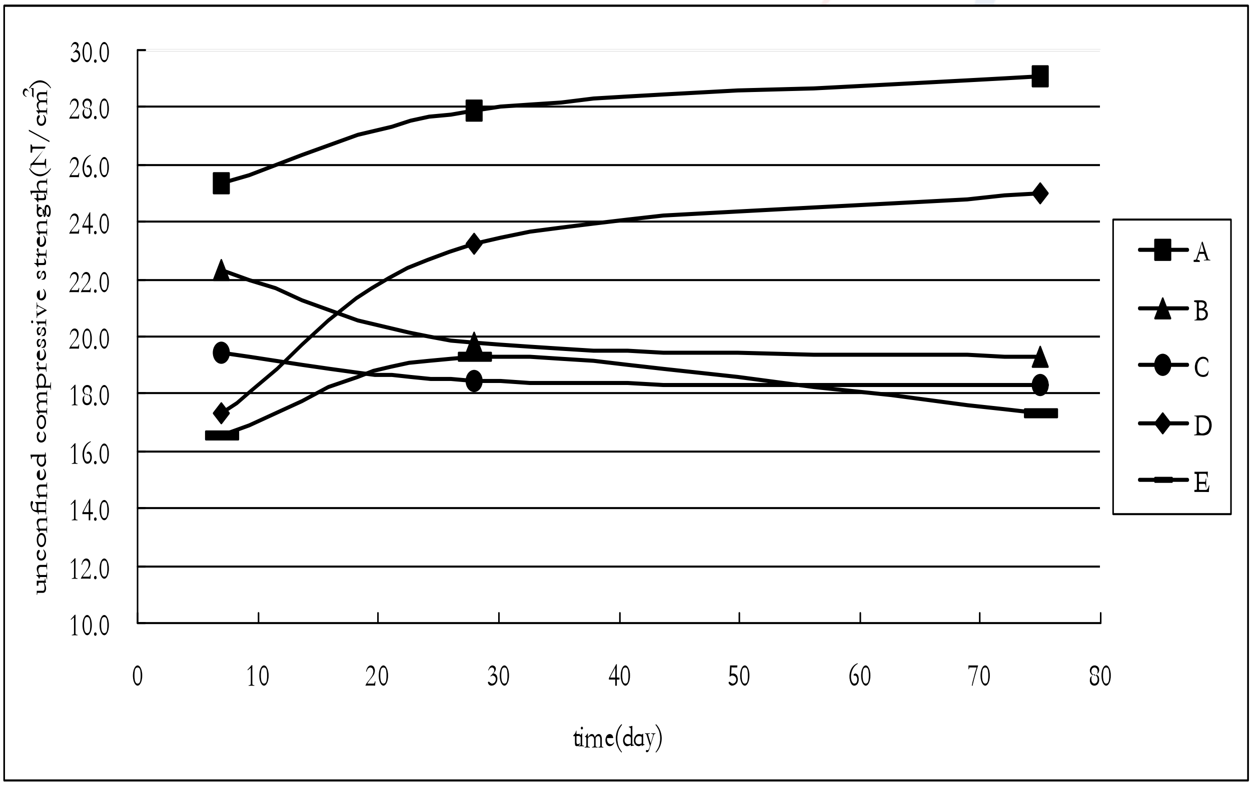

Figure 6 Unconfined strength of compacted soil

From the tables and figures above, it is clear that the addition of pulverized oyster shells gave no significant improvement for the compacted red soil taken from the campus of the Pingtung University of Science and Technology in terms of the unconfined compression strength. The comparison of Groups A, B, C and E in Figure 6 shows that the strength decreased significantly with the increasing addition. It is possible that no ion exchange occurred between the pulverized oyster shells chosen for this study and the clay, or the soil samples taken for this study might not be expansive, leading to no obvious iron exchange.

The addition of fly ash also led to decrease in the compression strength of the soil used in the study. However, its compression strength displayed a gradual increase. The addition of both pulverized oyster shells and fly ash in soil did not provide the improvement in soil strength as the addition of only pulverized oyster shells did. It is concluded that the addition of both pulverized oyster shells and fly ash in Group E specimens did not improve the compression strength of soil by inducing the Pozzolanic reaction as expected.

Figure.7 and 8 show the stress-strain curves for each group of specimens at day 7, 28 and 75 in the compression strength test. The result suggests that the stress-strain curves become less steep with the decrease of strength. Also, the compacted soil becomes soft and susceptible to displacement with the increasing addition of pulverized oyster shells.

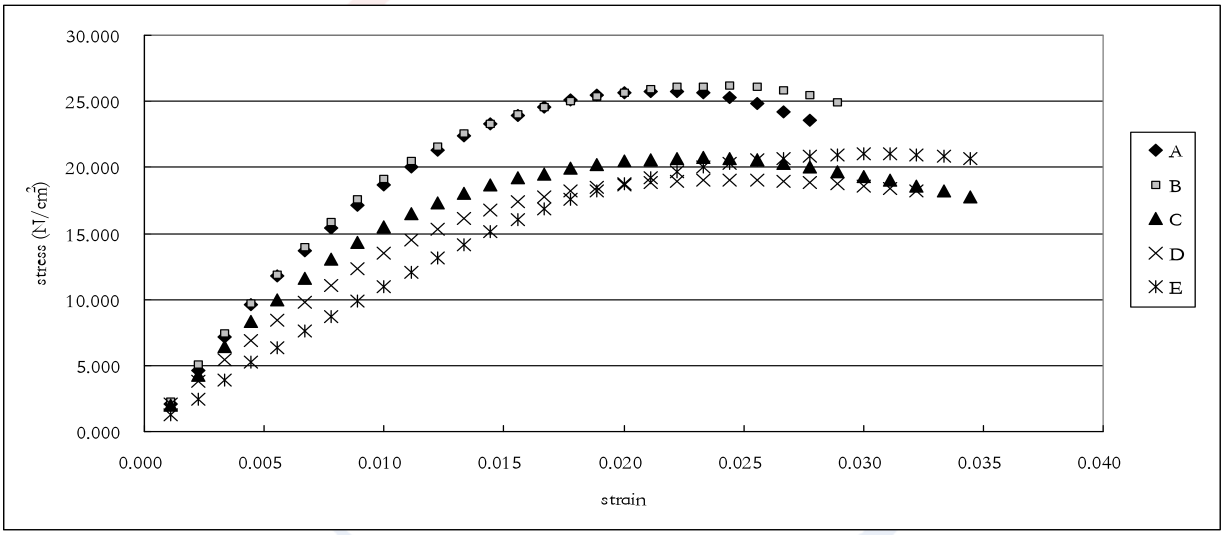

Figure 7 Stress and strain of the compacted soil at 7 days

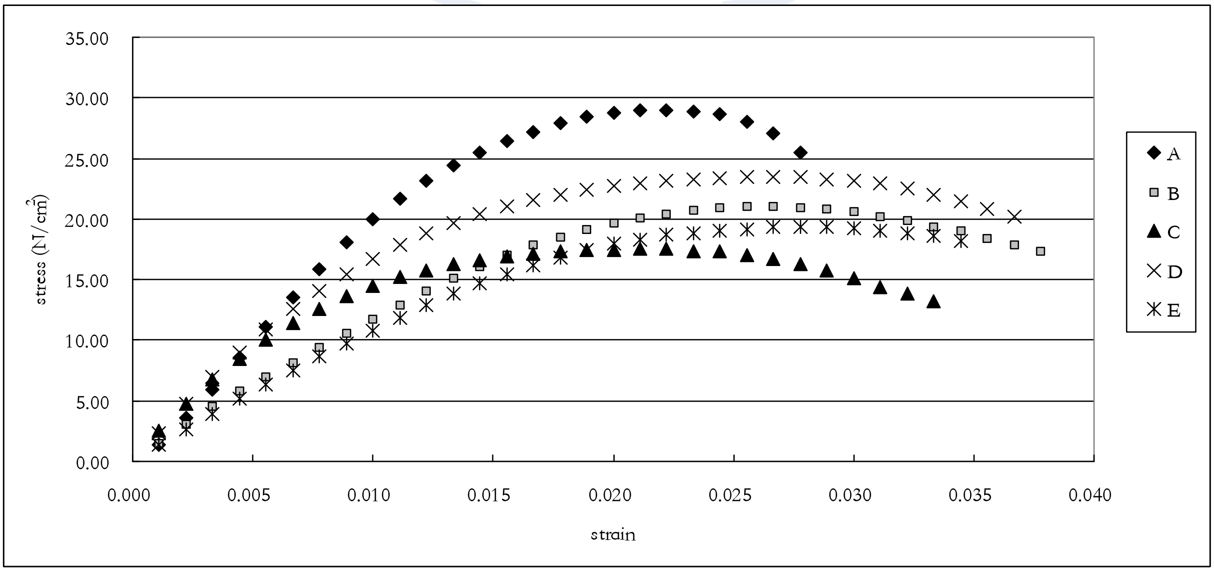

Figure 8 Stress and strain of the compacted soil at 28 days

6. Conclusion and suggestions

1. Standard molds were not used for the compaction. However, the test result shows that the compaction is reasonable, and the specific weight of compacted soil suggests consistency of soil result. Therefore, the compaction selected for this study is feasible.
2. The addition of pulverized oyster shells improves the optimal moisture content in the soil, i.e. decreases the sensitivity of soil to moisture content. However, at a specific weight of 2.2, the pulverized oyster shells do not improve the maximum dry density of the soil when added.
3. The market-available pulverized oyster shells used in the study do not improve the compression strength of compacted soil in the experiment, and the drop of compression strength grows increasingly clear with the increase of addition.
4. The test result suggests neither significant Pozzolanic reaction between the pulverized oyster shells used and the fly ash nor improvement of soil strength by adding both pulverized oyster shells and fly ash.
5. The application of lime is a common and viable practice in soil stabilization and Pozzolanic reaction with fly ash. However, the strength improvement in compacted soil and lime blocks using lime-rich pulverized oyster shells perhaps is limited to the fineness and activity of pulverization, soil type and aggregates. The same conditions do not apply to all test configurations.
6. It is probably feasible to use pulverized oyster shells for their lime-rich nature in soil stabilization or in reaction with fly ash. However, the study did not yield the expected compressive strength increase in both compacted soil and lime blocks. How to improve the practicality of using pulverized oyster shells in soil stabilization remains to be investigated.
7. The soil used in this study does not expand, resulting in lack of expected outcome. Test conducted on expandable clay may be considered to determine the suitability of pulverized oyster shells.

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The Asian Conference on Sustainability, Energy and the Environment
June 2011

Mutual Dependence of Social and Environmental Sustainability in Offices

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Abstract

Studies of US and Japanese office work and workplaces dramatize the three-way interactions of environmental, economic, and social aspects of sustainability. Half the employment in advanced economies occurs in office settings, and the 2000-2010 decade has seen strong initiatives toward environmental and economic sustainability of office buildings. Social relations in these workplaces co-evolve with such initiatives. Suitable engagement of all actors, as in the "integrated design" process found in certain of the cases, has shown potential for qualitative, not just incremental advance in both environmental and economic results, indicating that interactions at the scale of individuals significantly condition outcomes of large-scale policies in this sector, and social sustainability is a vital ingredient for significant environmental progress, not just a desirable effect.

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Mutual Dependence of Social and Environmental Sustainability in Offices

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1. Offices and sustainability

Office work in its various forms accounts for roughly half of US employment and a similar fraction in Japan.[1] Such a major segment of life cannot fail to intersect all three aspects of sustainability—environmental, economic, and social. Offices provide vital economic information and coordination. Environmentally, office workers have low individual impacts but large when taken together, especially through the construction and servicing of the buildings they occupy. For the less well defined social aspect of sustainability, we are guided by Littig and Griessler's formulation:

> Social sustainability is a quality of societies. It signifies the nature-society relationships, mediated by work, as well as relationships within the society. Social sustainability is given, if work within a society and the related institutional arrangements
> • satisfy an extended set of human needs
> • are shaped in a way that nature and its reproductive capabilities are preserved over a long period of time and the normative claims of social justice, human dignity and participation are fulfilled.[2]

Offices as work settings clearly engage human needs and claims of justice, dignity and participation in significant ways. Our particular concern is with the relation between office work and office buildings. Though not an early environmental priority, buildings have attracted considerable effort over the past 20 years, primarily in a mode which disconnects environmental from social sustainability. We will describe that mode, with some of its successes and limitations, and will show how reconnecting the environmental and the social is enabling much needed progress toward sustainability in offices. Our emphasis is on the United States, with important examples and confirmations from Japan. Though environmental sustainability touches many issues, for simplicity we will focus on energy.

2.1 Physical and social sustainability—an early disconnect

After a false holiday during the 1980's, environmental consciousness reawakened in the US and Japan in the 1990's. For buildings, the reigning mode gave the initiative to engineers, architects, and builders. They naturally took the problems as primarily physical ones, calling for physical solutions. If buildings were heavy energy users, one should seek lower-energy materials and equipment—better insulation, window glass that allowed visible light to pass but kept heat inside, more efficient air conditioning, and so on, always with an eye on cost. During the 1990's there was considerable technical developments of this kind. However, the activities that occur in buildings were largely not questioned. They were surveyed and taken as inputs to engineering study, but not considered changeable, nor much studied for their relation to the effectiveness of technical improvements, nor indeed much considered as involving human persons possessed of agency, values, or autonomy. Occupants were represented only as behavioral statistics. Occupants in turn, whether employees or managers, learned to expect buildings to provide a certain generic comfort which neither required nor invited their participation. The result was a tacit agreement by all parties that office work and office buildings should evolve separately.

This mode of making and operating buildings saw important steps taken during the 1990's. Landmark US projects such as the Energy Resource Center of Southern California Edison and the Oberlin College Lewis Center established that full-scale green projects were possible and successful at least in terms of basic functioning.[3] Key elements of intellectual and organizational infrastructure also began to appear, most notably the Leadership in Energy and Environmental Design (LEED) rating system with its promise of a broadly agreed, relatively transparent, comparative scale for "green" building projects.[4] LEED also provided a needed base for capacity building in the design and construction industry, by defining which topics would count, and how, toward placement on the rating scale. It grew rapidly. The pilot version appeared in 1998; registrations (projects intending to be rated) had reached 1794 by the end of 2005; the number of "accredited professionals" approved as project advisors reached 19,000 in 2005, four years after the approval examination launched.[5]

Japan pursued a distinct but parallel path. There were well-publicized proof-of-concept buildings, such as Tokyo Gas Company's Earth Port and Kansai Electric Power's Osaka office, and a university/industry/government consortium developed a Japan-oriented rating system, the Comprehensive Assessment System for Building Environmental Assessment (CASBEE).{Vare:to} In addition to providing a way of comparing flagship projects, several major Japanese cities require projects to report CASBEE scores and in some cases provide incentives for high scores, but do not set minimum levels of achievement. Results for Nagoya down to 2007 are typical: a few excellent buildings and a large mass of conventional ones.[6] The transition from early adopter to mainstream practice has not occurred yet in either country.

Each building project is unique in its specifics, but there have been many common elements in the green building practice of this decade—increased use of daylight, with controlled balancing by artificial light; more complex control of air conditioning to reduce supply at unneeded times and places; higher efficiency in such systems; windows which admit daylight but block heat flow; heat recovery from outgoing ventilation air; thicker insulation; computer simulation. Interestingly, the last has primarily a societal, not a technical function—to develop confidence among designers, builders, and owners that the physical measures would work properly, i.e. get high environmental performance without departing from conventional comfort standards.

LEED-rated buildings in 2000-2010 typically estimated 20-40% energy savings over comparable conventional buildings. The later years of the decade also brought the first solidly based performance data.[7]The results are still under debate[8][9]; they do not clearly demonstrate high performance by the LEED-rated group. What they do clearly demonstrate is very wide variation within the group: measured energy use per square foot within the group went from 20 to 140 kBtu/sf, and when comparing measured use to design-phase estimates, buildings ranged from three times better than estimated to more than three times worse.[7]

While some of this scatter may be due to undigested new methods, it is not different in range from what one finds for conventional buildings, which also vary widely.[10] How can there be such large variation among physically similar buildings performing similar functions? A look at the human interactions involved in creating and operating these buildings suggests some answers.

3. Actor Groups and Building Energy

Offices of this era depend on electrical and thermal energy for all key functions. Heating, ventilating and air conditioning (HVAC) is much the largest category, followed by lighting and the steadily growing demands of computer and other office equipment. (Figure 1[11])

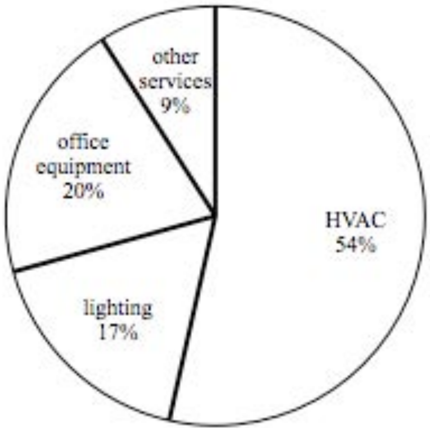

Figure 1. Office energy uses. Source: EIA

These energy functions all require human attention. There are at least five kinds of relevant actor—building owners, architects, mechanical engineers, building operating staff, and building occupants. The first three set the specifications, acquire the equipment and install it; the last two, plus of course the owner, arrange and experience the ongoing performance of the system.

HVAC installations are quite inflexible, except within their design specifications, so energy management is strongly channelled by actions of owner, architect and engineer when the building is being designed. The role of operating staff has typically only been to keep equipment in running order, respond to complaints, and contain costs.

In conventional office buildings, occupants are not directly involved in a building's HVAC performance. However, it is they who primarily manage lighting, hot water for restrooms or kitchen spaces, water coolers, vending machines, and most importantly computers and other office equipment. Building staff and an organization's managers do some structuring, through setting hours of operation and policies for providing and maintaining equipment and lighting. In the end, however, it is occupants who turn things on and off.

Given this multiplicity of actors and divergent roles and interests, wide variation in building performance is not surprising, and suggests that actually achieving the good performance that is possible technically will require understanding human as well as technical dynamics.

3.1 Roles and perspectives of actor groups

Each of the energy-related actor groups has socially constructed and enforced role definitions; they contain considerable latitude for variation, but in the period 1950-2000 have had a fairly settled, stable general character in both the US and Japan. As Schön and Rein usefully put it, there has been an well established frame for this work.[12] We approach this status quo heeding Biggart and Lutzenhiser's caution,

> Problems of environment and technology are "constructed" and "framed" by social movements and organizational interests. In the instance of the commercial and institutional built environment, a strongly economistic social problem frame is used by environmental movement organizations, efficiency industry firms, federal officials, national laboratory scientists, state policy agencies, and energy advocacy groups. Social scientists have pointed out that this frame fails to appreciate the complexity and uncertainty of the world of commercial real estate.[13]

The proper frame here needs to go beyond economic behavior to include differentiated motivations, perceptions, and tolerances of the actor groups. New office projects in the 1950-2000 period began with building owners stating functional requirements. Architects then devised a suitable physical form, usually employing specialist consultants for handling technical matters such as structure, lighting, landscape, and most importantly HVAC. Engineers could handle whatever spaces the architects chose, for they had reliable ways of gauging the capacity of HVAC systems, lighting, and so on.

This division of labor has at least two strong advantages, both operating at a social-symbolic level: it allocates responsibility in a tidy-looking way, and it is animated by a vision of mechanistic control. Clear responsibility is important in the US, where lawsuits over extra costs and the like are a common way of doing business. The vision of control is perhaps even more important. The idea that an organization is a machine and management is for controlling it is deeply entrenched in US business[14], and applies with extra strength to an organization's buildings. In this view, buildings are utilities, not ends in themselves; they should simply provide good conditions reliably and inexpensively. Engineering culture agrees: the task is to develop the right clear specifications for building performance, and then to select reliable means of meeting them. Ideally, choice will be "optimal," i.e. settled by the highest value of some objective measure of fit between specifications and predicted performance. Human involvement in buildings is not much welcome to mechanistically minded managers or engineers. Usually, they feel, an appliance can be found that does the specified job better and cheaper. For both owners and engineers working in this mechanistic-utility frame, the ideal building is plug-and-play: it is ready on time and under budget, and occupants need merely walk in and turn it on.

Architects have largely been happy with this way of approaching buildings. It certainly simplifies their job, and liberates time for more interesting matters, such as visual form. In fairness, equipment has become increasingly complex and specialized, partly in pursuit of energy savings, so some division of labor is unavoidable.

The plug-and-play ideal has also been acceptable to occupants and building staff. Occupants can count on unvarying indoor environments, provided without their involvement by hidden machinery and nearly hidden staff. Instead of fine-tuning indoor environments for individual comfort, as at home, the available actions are telephoned complaints. Building operators, in turn, often judge whether their settings are correct by whether complaints about temperature roughly balance between "too hot" and "too cold". Often coming from engineering or technical backgrounds, many building operators have liked regarding their job as machine-tending (the building as machine) rather than as providing service to occupants (building as supporting environment). Occupants become simply squeaky wheels. Complaints are data, rather than messages from fellow human beings. In their turn, many occupants are willing to regard operators impersonally, too—equivalent to balky control equipment, not persons.

The degree of personal satisfaction for both occupants and staff in this social arrangement is low; how could its participants have an interest in maintaining it? A sufficient answer comes from Simon's concept of satisficing: a sub-optimal situation can be an acceptable problem solution if the expected cost of finding a better one is high.[15] Office workers and office operating staff are commonly under constant pressure for productivity in their primary roles, so the cost of making and maintaining human relationships across role boundaries can seem high, with the prospects for improved conditions low. The result in office buildings has generally been acceptance of a generic kind of comfort. An inflexible physical arrangement, put in place by firm social construction of roles, considered as mere infrastructure by top management, and run by staff and users without shared values or traditions of workplace community, performs according to accidents of personalities, talents, and interactions, sometimes favorable, sometimes not. Under these circumstances, generic comfort is an achievement and wide variation in secondary characteristics like energy use is to be expected.

3.2 Productivity as a sustainability variable

Research in the 2000-2010 decade began to show, however, that generic comfort of this kind was a good deal less than ideal. For example, when a large sample of British building occupants was asked if any physical aspects of their building, such as temperature, lighting or noise, cause them discomfort, typically 85-90% of users said yes. Even in the best 5% of buildings, 65% of occupants say they experience some discomfort.[16] US results were similar.[17]

Such results came at a welcome time for proponents of sustainability. From early on, the perception that green building is costly has been a major hindrance. The data shows steady downward trends from generally modest initial premiums to parity or sometimes cost savings, but the perception of high costs became established before the buildings went up, and has proved resistant to correction. Thus proponents have needed arguments that put the issue in a new frame. User experience is half an answer. The other half is the insight that employee wages and salaries are orders of magnitude higher than the typical costs of energy saving and other green measures, and that even modest increases in employee productivity might have considerable dollar worth, arguably well more than the cost of greening.[18], [19] Where might productivity come from? From improved daylighting, individual control over workplace air, and other measures emerging from the search for energy savings. An influential study of the positive influence of classroom daylight on reading scores in California schools,[20] was important support for this idea, and correlations of self-reported productivity gains with certain green design elements, such as more natural light, fewer synthetic odors, or outdoor views have consistently supported it.

4. Advanced sustainable design and social sustainability

The elements mentioned, such as outdoor views, may not seem closely connected with energy. In the mechanistic-utility frame, they are not. But prospecting for energy savings has led to a number of measures which reach into the work setting and begin to reconnect environmental and social sustainability in a synergistic way. We illustrate with some specific examples.

Takenaka Corporation, a major Japanese design-construction company, wanted a new headquarters building which would bring together dispersed units in a high efficiency, high quality workplace with much reduced environmental impact at low cost. The resulting building has 30,000 m^2 (320,000 sq ft) of floor area over seven floors and has the highest CASBEE rank (S). It opened in September 2004 and in the first year used 15% less energy than the average Japanese office.

Photo:OGAWA Taisuke

Figure 2. Takenaka Corporation Tokyo Head Office

On top of its environmental performance, the project is significant for intensive work flow and work space consultations among all company units involved, in the design phase and afterward. Takenaka has a goal of continued improvement in energy saving, cost control, and usability. In addition to regular problem-solving meetings, they conducted post-occupancy evaluations of the whole building in 2004, 2005, and 2007, which uncovered work life issues such as lack of meeting space as well as energy saving opportunities. The building now runs at 23% below the national average.[21]

Photo credits: Gabe Hanson

Figure 3. Terry Thomas Building (Weber Thompson office)

The Seattle architectural firm Weber Thompson wanted a new building which would be viable as an investment, healthy and productive as a workplace, and environmentally responsible. The result meets all these goals in a four story, 6000 m^2 (64,000 sq ft) structure which opened in 2008 and achieved the LEED Gold level (with its interior fittings scoring even higher). It makes such extensive use of natural ventilation and daylighting that it needs no conventional HVAC, and in its first year used 44% less energy than average for its type.[22]

The firm uses half the floor space and rents out the rest. The savings from reduced equipment allowed the project to be financed by conventional means. Since the owner is the main occupier, design could include extensive consultation with future occupants, whose cooperation has been essential in choosing the details of ventilation and daylighting, and in the considerable adjustments needed during the first year to get all systems working properly together.

Both these existing buildings perform well environmentally, thanks to successful interplay with social processes in the two organizations. The interplay is even clearer in our third example, the energy saving measures considered for an unpublished, very advanced project now nearing the end of design.

The design engineers' report lists 18 measures for energy saving relative to the city's current requirements.[1] We will consider them in two groups, non-participative and participative. The former are measures where building occupants have little or no role in their effective operation. An example is central heating/cooling equipment, housed in a basement or special space, and only known to occupants by the warm or cool air it makes possible. Participative measures, by contrast, depend importantly on occupant cooperation or informed involvement. A straightforward example is the reduction of "phantom loads." These are electric energy used when equipment is idle, e.g. computers left on overnight.[2]

[1] Brian Court, personal communication

[2] Different observers might make somewhat different judgments as to participative character, but the following argument would lead to much the same general conclusions.

Figure 4 lists the 18 proposed measures, with non-participative measures on the left, accounting for 42% of estimated savings, and participative on the right, at 58%. The typefaces are sized to indicate the relative size of energy savings for the given measure. (Each increase in font size represents roughly a three-fold larger contribution, so the largest font represents roughly 100 times more energy saving than the smallest.

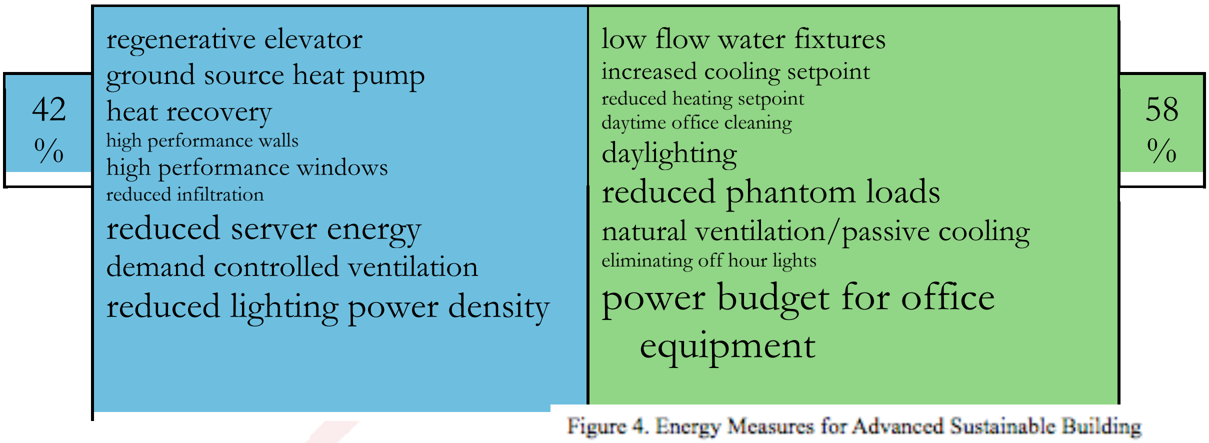

Figure 4. Energy Measures for Advanced Sustainable Building

The non-participative group (left side) has some items that may be familiar, such as high performance walls or windows. Interestingly, these give relatively low savings for this project. One reason is the improvement in standard walls and windows over the past 10-25 years, such that the additional improvement from using even better ones is now relatively small.

The middling contributions from the non-participative list, especially heat recovery and ground source heat pumps, are not very new, either. Heat recovery is the use of warm, stale outgoing air to pre-heat incoming fresh air, thereby reducing the additional heating needed for winter comfort. The principle and its engineering have been familiar for a long time; because of the search for energy savings, demand has increased and costs have come down in classic production trajectory manner. Ground source heat pumps, which use a technology very similar to refrigeration to extract heat from the ground under and around a building to provide heat inside, are a very similar story.

Together, the small and middling non-participative savings (all items except server and lighting) contribute 19% of the estimated total. These are also the ones which fall most squarely in the traditional engineering paradigm, which emphasizes machines, predictability, and control, and strives to replace human energy and attention as much as possible, freeing it for more important things. *This engineering approach, valuable as it has been thus far, can now only account for a small portion (19% in this example) of attainable progress toward environmental sustainability for buildings. Greater potential progress (80% in this example) depends on new degrees of human involvement.*

The largest two non-participative contributions, amounting to 23% of total savings, are both primarily technical, but both have a key human ingredient. Reduced lighting power density is simply the use of newly available high efficiency light sources together with a willingness to have lower illumination levels where tasks or activities do not require more. Stairways do not have to be as well lit as desk surfaces, for example. Reduced server energy makes use of advances in server software such as virtualization, which pay off in this case when all building tenants agree to use the same server.

Agreement on lower illumination or sharing a server—these are occupant decisions, not lab test results or expert judgments. The lighting and server measures are non-participative because once installed they run without occupant involvement, and because the decisions to implement them are made once and for all at the design stage. But they both engage significant features of what Littig calls "work and the related institutional arrangements." In other words, they engage social sustainability. One anecdote is enough to show the engagement is non-trivial. Designers of the new Port of Portland headquarters (Portland, Oregon; completed 2010) had to abandon the energy savings from motion-actuated lights in an attached parking structure because consultation convinced them that too many employees would be frightened to enter a dark multi-floor structure at night. In this case, the willingness to have reduced illumination was not present, because a basic need (the feeling of security) would not be met.

Turning now to participative measures, which account for nearly 60% of energy savings in this advanced design, we will see that they ask even more of occupants. We start with the largest, the power budget for office equipment. The advanced building's designers find that 30% of all expected savings can come from judicious shifts or restrictions in power-using equipment, such as laptops instead of desktop computers, or having fewer food-area refrigerators, microwaves, and dishwashers per floor. All of these moves act directly on occupants as they work and take breaks; insofar as they affect productivity, they also intersect with practices of supervision, pay, and advancement. Achieving the estimated energy savings requires that ordinary employees understand these measures and at least cooperate with them. Moreover, implementing such shifts or restrictions in rented space calls for negotiating leases which impose a monthly or yearly energy budget, and thus impinges on the usual separation of authority between landlord and tenant. Again, these energy savings are entangled with social and cultural arrangements.

Reduced phantom loads, the next largest entry on the participative side, depend entirely on equipment users switching them off when not using them, or not bypassing automatic equipment set to switch them off. Moving further down the list, to daylighting, we come to an area of great importance to green designers, and again of direct impact on occupants' working environment. In addition to offering quite significant energy savings, most occupants find increased daylight to be a great benefit. Including it in a package of green design elements thus increases the acceptability of the whole, and the likelihood of compliance with good practice.

5.1 Interplay of physical and social elements in sustainability of buildings

A fascinating picture of the interplay between physical and social elements of workplace sustainability comes from Leaman and Bordass's study of factors related to reported productivity improvements in green buildings in the Building Use Survey database[23]. They find five variables strongly associated with productivity:

1. Comfort, including personal control.
2. Responsiveness to need, including comfort (from 1.), but a host of other ways in which needs should be met effectively.
3. Ventilation type, which also encompasses attributes such as size, building depth and other allometric properties (i.e. how size affects shape, volume, services etc.).
4. Workgroups and their layout in the space plan.
5. Design intent, and how this is communicated to users and occupants.[23]

Workers report higher productivity when they feel comfortable, but comfort is not a purely physical or physiological matter, but also involves a degree of personal control over temperature, air flow, and the like. This finding, confirmed by extensive lab and field studies[24], intimately connects work, human needs, and participation. And the same studies show that when a degree of control is provided—as simple as an openable window, an adjustable vent, or (as in the successful Japanese "Cool Biz" campaign[25]) a relaxed dress code—workers accept a wider range of temperatures than when there is none. That translates into meaningful energy savings, because it allows less heating or cooling without bad effects on morale or productivity.

Next comes responsiveness to need. The needs in question are at the day to day level—temperature, failed lightbulbs, cleaning a spill, mail handling, and the like. Workers who report getting timely responses which are sensitive to conditions also report increased productivity. Building design and engineering bear on this matter indirectly, through making responses easy or hard, but the direct effects concern the organization's culture and procedures.

Occupant productivity does best with "mixed mode" ventilation systems, i.e. natural ventilation when outside conditions are favorable, but dehumidified and cooled air in hot, humid summers. This has strong implications for both engineers and architects, as natural air circulation does badly with deep floor plans. Workgroups and their layout get quickly drawn into play, as natural ventilation favors open plan offices. So does daylighting. Office layout touches organizational life very deeply. In the Port of Portland headquarters, top management support for the proposed high degree of natural ventilation and daylighting came partly from a strong conviction that the organization needed open plans. Getting this accepted required an extended series of information sessions and discussions, a number of key small-scale physical adjustments (e.g. to the height of transparent screens between desk and lobby areas), and ultimately accepting that one division (lawyers) would not relinquish its commitment to closed offices. The Takenaka head office project also merged work organization and environmental gain.

The last of the Leaman-Bordass variables, design intent, may be quite surprising. How can the designer's image of what is supposed to happen in a building affect the productivity of people who work there? It is beyond our scope to do more than suggest some possibilities. One is that a sense of participation in a joint project often has an enlivening effect, and engenders acceptance of conditions which otherwise would be undesirable. Another is that understanding what is supposed to happen in a building helps occupants distinguish favorable and unfavorable ways of adjusting it to their satisfaction. A simple example is the trickle vent, a narrow adjustable opening underneath a window, intended to admit a small, steady flow of fresh air without drafts. In one early green office with trickle vents, new tenants redecorating the interior painted them shut unknowingly. Such a change unbalances air flows and generally leads to needless use of heating/cooling equipment, or less comfort, or both.

Making design intent effective involves good communication between designers and users. The conventional pattern of 1950-2000—design/build/occupy as separated stages carried out by separate actors—acted to block communication. It is no accident that many of the best-performing office buildings of 2000-2010, like the Takenaka and Weber Thompson examples mentioned above, are occupied by their designers. It was natural in those cases to have the discussions and do the collective thinking which lead to real understanding of design intent. Though the situation of designer-occupier will always be the exception, these histories point the way toward a possible and valuable revision of the institutional arrangements within which office work is performed. Perhaps, as with the Port of Portland headquarters, design of a new office can be a moment for an organization to stage wide discussion of its work and work life, out of which a shared understanding of the intent and function of its new building can readily flow.

6. Conclusions

Our aim has been descriptive, not prescriptive, and part of our hope has been to complexify, not simplify the understanding of sustainability, by looking in some detail at a number of conceptual and pragmatic tendencies bearing on sustainability in this one segment of modern industrial societies. The central point, however, is about framing: understanding buildings as machines blocks proper recognition of the mutual dependence of social and environmental sustainability that takes place in them. We have shown how significant future energy saving in offices depends heavily on occupant participation, how energy saving approaches carry the promise of significant improvements in the needs satisfied by workplace environments, how good workplace environments are linked with high productivity, with productivity in turn generating the finance behind energy saving measures.

Because the human actors in this mutually dependent situation possess agency, good results are not guaranteed in the mechanistic, single-factor way imagined by technocrats. Instead they flow from the detailed choices and moves the actors make, and on the frameworks of understanding they use. The histories that ensue may be indiffferent, bad, or good. The work to achieve the latter will be largely local, not ruled by global theories, but we suggest that a perspective of mutual dependence will greatly clarify the nature of local possibilities, and their relation to larger social, economic and environmental developments.

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Decentralization and Environmental Governance: Insights from the Experiences of Selected Lakeshore Communities in the Philippines

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1. Introduction

Decentralization and participatory governance may probably standout in the realm of good governance for these two concepts have been at the core of governance discourses and development debates in the past few decades. Decentralization has always been associated to democracy, responsiveness, and efficiency (de Oliveira, 2008; Wu & Wang, 2007; Ribot, 2004; Cheema & Rondinelli, 1983). The growing interests to shift towards decentralization may have been due to the perceived failures of the central governments to implement policies. It is now viewed as a great alternative approach to perform the complicated tasks of the government particularly on achieving policy objectives and to effect changes at the local level. If decentralization is properly managed (WRI, 2003), it promises to bring good outcomes, such as: (1) better opportunities for local people to participate in decision-makings, (2)increases the efficiency in the delivery of public services, (3) public services are sensitive to local needs, (4) reliance on local knowledge enhances social and economic development, (5) allows greater political representation, (6) increases transparency and accountability, (7) provides attractive grounds for new ideas, and (8) increases political stability and foster sense of community ownership on public decisions.

Participatory governance seems inseparable from decentralization. The main premise on reforms towards decentralization by a number of governments worldwide was basically anchored to the idea that it will strengthen democratic process (Asante, 2007). The goal of decentralization is to bring government closer to the people to increase public interests to get involve in governmental affairs (Wu & Wang, 2007). Catenacci (2010) shares the same idea claiming that the proximity of the local governments to the citizens provides the latter the best positions to take appropriate, and to some extent, best actions tailored to the local needs. In addition, the value of decentralization is that it leads to a more flexible, innovative, and creative administration in consonance to local conditions which in so many ways different from other parts of the country (Cheema & Rondinelli, 1983).

Apparently, the looming environmental problems and rapid deterioration of natural resources in many countries, especially those developing ones, are indicatives of inferior performance of central governments to flex their respective legal and political instruments at the community level. Thus, decentralization seems promising to improve the quality of environmental governance – a function which will be taken away from the traditional domains of central governments. Decentralization, in a way, slowly changes the terrain of environmental governance worldwide.

In the Philippines, the passage of the Local Government Code (RA 7160) in 1991 was a defining point for the advancement of decentralization and deeper civil society engagement in government affairs. The Local Government Code was an essential take off point in decentralized environmental governance since environmental management functions have been devolved to Local Government Units (LGUs) along with other sectors, i.e. health, social services, and agriculture, among others. One of the most interesting features of the RA 7160 is the promotion of citizen-government relationships particularly the Non-Government Organizations (NGOs) and the People's Organizations (POs). For the past 20 years since its adoption in 1991, it is then compelling to provide a picture on how this decentralization efforts have impacted the current trend of environmental governance at the local level.

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The freshwater resources in the Philippines, specifically the inland fishery and aquatic resources subsectors, are profoundly lacking of serious studies. The inland fishery subsector in the Philippines is considered as a major economic and food base for rural communities where majority of the people live way below the poverty threshold (Israel, 2006). It is then imperative to understand the inland coastal communities and look at the prevailing practices, processes, and approaches relative to the country's environmental governance. Although environmental policies are still within the central government, much of implementation activities are now in the hands of the LGUs. Thus, it is necessary for us now to understand the policy implementation process at the local level to unravel the emerging trends and practices, to determine the strengths of the new system, as well as to identify the current and potential challenges. This study, however, is focused on the experiences of seven selected lakeshore municipalities located in three major lakes (Lake Mainit, Lake Buluan, and Lake Sebu) in the island of Mindanao, Southern Philippines.

The data were collected from different primary and secondary sources. Primary data were mainly taken from interviews; focus group discussions; fieldwork notes, and documents from LGUs. Secondary sources, on the other hand, were made up of online and printed academic journals, reports of national government offices posted on their respective websites, online newspapers clippings and other printed materials. Fieldworks were carried out in March 2010 and September-November 2010. A total of 36 key informants were interviewed using informal interview with the guidance of semi-structured questionnaire. These 36 individuals were composed of the following: 3 Municipal Mayors; 1 Vice Mayor; 18 Heads of relevant municipal offices. The remaining 14 key informants were field personnel from various municipal offices and as well as officers of NGOs and POs. There were 2 Focus Group Discussions carried out: one in Lake Mainit area and the other one in Lake Buluan area. The methods used to analyse and interpret the data were the following: Pattern-matching, Cross-case synthesis, and Triangulation. The major strength of this study is the use of multiple sources of data. The primary advantage of using multiple sources of evidences is the opportunity to use triangulation process (Yin, 2009), i.e. cross checking (a) data sources and (b) data collection methods, to increase accuracy and credibility of the findings (Patton, 2002, p. 247).

2. Issues and concerns on Philippine inland fisheries and aquatic resources

The Philippines has a total of 18 major river basins and 421 principal river basins (NWRB, 2008). It also has 79 lakes (Greenpeace, 2007) with a total area of roughly 200,000 hectares (dela Cruz, n.d.) mostly utilized for fish production. Additionally, the country has about 30,000 hectares of reservoirs (dela Cruz, n.d.). Most of these freshwater bodies are intended for fishery, recreation, and supply for manufacturing processes (EMB, 2006).

Despite abundance, freshwater resources are facing various pressing problems. These challenges were brought by rapid increase of country's population and the corresponding increased of economic activities (Rola, 2004). The Environmental Management Bureau (2006) identified the point sources of freshwater water pollution as follows: (1) domestic wastewater accounts 33%; (2) 29% are due to agricultural waste; (3) 27% for industrial waste; and (4) the remaining 11% is from other sources.

The country's aquaculture production is one of the world's biggest making the Philippines 10^{th} largest producer in the world in 2007 (BFAR, 2008). According for Food and Agriculture Organization, inland fisheries production in 1992 was recorded at 229, 973 tons but fell to 136, 347 tons in 2001. Philippine fishery shares less than 3% of the GDP and the inland fishery subsector covers 13.3% of total fishery production (Israel, 2006). Inland fishery and aquatic resources may not have significantly contributed to country's national economy, but Israel (2006) stresses out that this sector remains to be a major economic and food base for rural communities, especially those households located along the coasts and banks of inland waters. Furthermore, he argues that many of the people in rural communities live in absolute poverty and this subsector is an important issue to combat poverty. Inland waters serve as major food resource among coastal villages because inland aquaculture is mainly using low-value fish species (Israel, 2008). FAO validates this claim of Israel that, in spite of low quantity of Philippine inland fishery production, this subsector remains economically important as subsistence livelihood to marginal fishermen.

Assessing the issues and concerns that affect Philippine lakes is extremely difficult due to lack of studies and researches. While Laguna de Bay has been intensively studied, other lakes in the countryside have been scarcely studied at all (Haribon Foundation, n.d). For Israel (2006), the inland fisheries and aquatic resources in the country, generally, are neither well understood nor well researched. While the lakes heavily support coastal communities which primarily depend on subsistence fishing and other lake resources, pollution poses threats to these ecosystems. Laguna de Bay, for instance, serves as a mega sink for Metro Manila and its surrounding provinces – receiving all kinds of pollutants dumped into it including various toxic substances (Elazegui, 2004). Occurrences of algal bloom, proliferation of water hyacinth, presence of invasive alien species, observed fish diseases, siltation, and sedimentation are considered as the most serious concerns among fisherfolks in Laguna de Bay (Israel, 2007). Invasive alien species (IAS) have affected most of the lakes in the Philippines (Joshi, n.d.).

It is widely known that deforestation in the country is one of the major environmental problems that directly and seriously affect watershed areas. Additionally, mining operations in the upstream areas affect the lakes' tributaries. For example, the Western Mining Corporation[3] in South Cotabato, and a number of mining companies in north-eastern Mindanao threaten the environmental health of Lake Buluan and Lake Mainit, respectively.

Looking at the above-mentioned scenarios, one can conclude that freshwater resources and ecosystems are indeed facing serious threats. Other than the physical and biological threats, there are five areas of concerns that confront Philippine freshwater ecosystem: (1) absence of a national policy framework for the sustainable use of the country's freshwater ecosystem; (2) need to harmonize development plans/ activities in areas affecting freshwater ecosystems; (3) need to institutionalize a mechanism for integrated water management; (4) degradation of water quality and freshwater ecosystems; and e) need for water resource assessment (Israel, 2003). Israel (2006) further argues that policies that may take advantage the potentials of inland fisheries and aquatic resources in the country are practically lacking.

3. Reforms towards decentralized environmental governance

The Local Government Code of 1991 was a major turning point towards decentralized environmental governance. The Code enumerates encompassing functions and powers of Local Government Units (LGUs) relative to the management over environment and natural resources. The major roles LGU as mandated by the LGC are summarized as follows:

1. natural resource conservation and habitat protection measures[4]
2. formulation of development, land use, zoning plans[5]
3. intergovernmental collaboration and cooperation[6]
4. private sector participation[7]
5. LGU partnerships with and assistance to NGOs and POs[8]
6. formulation of appropriate regulatory instruments[9]
7. adopt solid waste management[10]
8. conduct research and extension services[11]
9. enforcement and execution of environmental laws[12]

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[3] This is an Australian mining company owned by BHP Billiton and is one of the largest in the worlds. Its operation in the Municipality of Tampakan and adjacent areas has stirred controversies on the development agenda of the national government and the legality of LGUs to ban open bit mining within their respective political jurisdictions.
[4] Local Government Code, Sect. 17(a)(2)(i), 444(b)(3)(vii)447(a)(1)(vi), 447(a)(5)(i)
[5] Local Government Code, Sect. 20(c),444(b0(1)(ii), 447(a)(2)(vii), 447(a)(2)(ix), 447(a0(4)
[6] Local Government Code, Sect. 3(f) and 33
[7] Local Government Code, Sect. 3(l)
[8] Local Government Code, Sect. 17(a)(3)(i), 34, 35, 36 and 149
[9] Local Government Code, Sect. 444(b)(3)(iv), 447(a)(3)
[10] Local Government Code, Sect. 17(a)(2)(vi), 447(a)(5)(xii)
[11] Local Government Code, Sect. 17(a)(2)(i), 17(a)(3)(i)

There are other national environmental laws related to inland fishery and other freshwater resources that clearly outline the roles of municipal LGUs, especially those laws that were legislated after the enactment of Local Government Code in 1991. In fact, all of the inland fisheries and freshwater resources in the country fall under municipal waters. Some larger lakes like Laguna de Bay, Lake Lanao, and Lake Mainit are shared by two or more provinces but the ***Philippine Fisheries Code*** clearly stipulates that municipal/city local governments have the jurisdiction over these municipal waters. This Code provides that "municipal/city government, in consultation with the Fishery and Aquatic Resource Management Council (FARMC), shall be responsible for the management, conservation, development, protection, utilization, and disposition of all fish and fishery/aquatic resources within their respective municipal waters"[13].

The coverage of responsibilities of municipal LGUs, however, is not limited to the mandates of Philippine Fisheries Code. The ***Clean Water Act*** stipulates that LGUs have the responsibility in the management and improvement of water quality within their respective jurisdictions. LGUs are tasked to take appropriate actions for the establishment and protection of critical habitats as well as in the conservation of species endemic to their areas as provided in the ***Wildlife Resources Conservation and Protection Act***. Also, LGUs have the primary responsibility for the implementation and enforcement of ***Ecological Solid Waste Management Act***.

Meanwhile, the ***Agriculture and Fisheries Modernization Act*** puts on the shoulder of the LGUs the following duties: (1) prepare land-use and zoning plans, (2) assist the implementation of AFM Plan, (3) extend credit assistance, research, and extension services, as well as (4) assistance to design and implement non-farm employment programs. The ***Indigenous Peoples Rights Act*** encourages LGUs to incorporate the indigenous people's rights in the formulation of local policies and development plans. The role of LGUs is crucial in the implementation of ***National Integrated Protected Areas System Act*** at the local levels. The ***Executive Order 240*** requires municipal LGUs to take the lead in the establishment of Fisheries and Aquatic Resource Management Councils at the *barangay* and municipal levels. The ***DILG-DENR-DOJ Joint Memo Order No. 2*** harmonizes the various guidelines for the devolution process of country's forestry sector. LGUs may also be deputized to carry out specific functions or activities to govern the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources as provided by ***Water Code of the Philippines***. Finally, the ***Philippine Environmental Code*** establishes a broad framework for concerned government agencies that includes LGUs for a comprehensive environmental protection and management measures.

The above-mentioned national laws are in no way exhaustive. There are several other laws that do not specify the role of LGUs wherein the local authorities could still refer to. What is clear for now is that LGUs have direct responsibilities in the enforcement of environmental laws after the passage of Local Government Code.

4. The current challenges

Weak Technical, Financial, and Institutional Capabilities of Local Government Units (LGUs). Obviously, lakeshore municipalities are not prepared to respond and fulfil the environmental responsibilities devolved to them. Except the LGU-Lake Sebu, the rest of the lakeshore municipalities are technically inadequate especially in designing environmental plans and actions. Also, financial resources of the LGUs are notoriously insufficient hindering significant local actions for the implementation of national mandates. Institutional capabilities of all the lakeshore LGUs require much support for improvement. In particular, there is a need to capacitate these LGUs in establishing good information management system. Presently, LGUs have very poor ability to collect and consolidate local data.

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[12] Local Government Code, Sect. Sect. 3(i), 17(a), 17(a)(2)(i), 17(a)(3)(iii), 4444(b)(2)(iii), 447(a)(1)(vi), 447(a)(1)(xii), 447(a)(1)(xiii)

[13] Fisheries Code, Sect. 16.

Fragmentation, Overlapping Functions, and Conflicting Interests among Multiple Government Agencies. As already stressed out in a number of previous studies on the country's natural resource governance – mainly on forestry and marine coastal environment, there have been so much fragmentation in managing these resources. It is particularly pronounced in freshwater governance (Barba, n.d.). The inherently complicated issues surrounding the management of water resources, in which inland fisheries and aquatic resources is substantially part of, the regional and provincial offices of national agencies were functioning only on very specific project in limited areas. Thus, this led to piecemeal development approach. As an illustration for this fragmentation, the Bureau of Fisheries and Aquatic Resources (BFAR) is under Department of Agriculture which focuses on the development of fishery technologies; the Environmental Management Bureau is under the Department of Environment and Natural Resources (DENR) simply monitors the water quality; the Forest Management Bureau is also under the DENR that works on the forestry and watershed management; the Department of Public Works and Highways (DPWH) performs flood control and mitigation measures. At first glance, there seems to have very good division of responsibilities. In reality, however, they seldom coordinate with one another.

Oftentimes, overlapping of functions lead to duplication of actions. But as experienced, government agencies with overlapping mandates have literally done less and blamed each other for inactions. For example, fisherfolks expected BFAR for regular fish seeding in Lake Mainit but these fisherfolks were dismayed with the evident failures of the BFAR regional office. The BFAR's excuse for this was that the LGUs have to ask them for their services because their agencies functions are limited only to technical components of fishery development. The LGUs, on the other hand, blamed BFAR's inactions and for grossly neglecting their functions as mandated by the Philippine Fishery Law. Also, BFAR washes its hands on the enforcement claiming that this responsibility has already been devolved to LGUs.

While fragmentation is already a problem, another contributory factor to the challenges is the conflicting interests of national agencies on the use of freshwater water resources. The National Irrigation Administration wanted to have the biggest share to increase agricultural productivity. The Department of Energy is looking for more sources of hydroelectric power while the Mines and Geosciences Bureau is exploring for prospective mining areas. One of the glaring conflicts of interests is the current position of national government favoring the mining industry. Lake Mainit and Lake Buluan are currently facing severe environmental threats as their respective tributaries originate from large mining areas. All of these obstacles, in one way or another, can be attributed to the partial devolution of environmental authority to the local government units. For Lavińa (2002) as cited by Gollin & Kho (2008), "decentralization to LGU is highly incomplete, and is sometimes characterized as a tug of war between national and local government authorities".

Problems on Accountability, Legitimacy, and Transparency. In the implementation of national environmental laws and policies in the country, the most prevailing stumbling block is the issue of accountability. The Clear Water Act of 2004, in fact, provides that "local government officials concerned shall be subject to administrative sanctions in case of failure to comply with their action plan accordance with the relevant provisions of R.A. No. 7160"[14]. In spite of obvious failures of all local governments in compliance to the provisions of the said law, none of them was reprimanded or sanctioned at all. The only accountability mechanism functioning right now is the voting power of the public to "punish" or "reward" the local politicians during local elections. In principle, this electoral accountability seems sufficient enough but in current practice, it is practically inadequate.

The legitimacy of local institutions and local authorities had been eroded due to politicalization in the creation of local enforcement bodies. It is particularly applied in the selection and appointment of some deputized fish wardens. The processes of widening "public involvement" were strongly questioned by the locals. Furthermore, the trust and confidence of the public continued to decline as they perceived that even local organizations – NGOs and POs – were conniving with LGUs and shunning away from the ideals of transparency.

Weak Civic Environmentalism. Local actions and concerted effort from local residents to

[14] Philippine Clean Water Act of 2004, Sect. 29.

protect and preserve their fragile environment remains relatively poor at the moment. On the positive side, local residents are substantially knowledgeable of and have good understanding on the problems and threats that endanger their very source of living. On the negative side, they failed to initiate for collective engagements to counter further environmental degradation. Awareness and actions are two different things.

Civic environmentalism may have already taken off in several areas in the country but not in the lakeshore communities surrounding the three lakes covered in this study. Self-mobilization and self-initiated environmental actions is extremely rare. Juinio-Meńez (n.d.) offers two possible answers to this: (1) local communities are disempowered and (2) they are not accustomed to initiate changes for they are used to external mobilizers to lead them.

Prevailing Traditional Politics. The local politics are largely captured by the elites. Most of the elected local leaders are predominantly traditional politicians and thriving on culturally clientilistic electorates. There are some LGU personnel who are technically qualified and have the eagerness to introduce environmental measures. However, these creative individuals have frequently encountered discouragements as their proposals always turned down by Municipal Mayors. For these politicians, the introduction of unpopular environmental measures may encounter wide public opposition which may endanger their political bid in the next elections.

Political conflicts also hampered inter-municipal cooperation as experienced in Lake Mainit. The delineation of municipal boundaries remains a stumbling block for the adoption and eventual implementation of Unified Fishery Ordinance. Political interventions during enforcement have greatly affected the cascading confidence of the public on the sincerity of the LGUs in the implementation of environmental policies. Politicians sometimes bend the laws to favour some law offenders who happened to be loyal supporters in the preceding elections. These local authorities are, in effect, become selective in dispensing justice to accommodate political favors. Furthermore, there were several instances in the past where good projects have been politically abandoned during the change of administration. Hence, there were so much wastage on the meager resources for discontinuation of promising plans and programs initiated by previous elected leaders. Summing these up, the unhealthy traditional politicking undermines the compliance and enforcement implementation in particular and the sustainability of the environment in general.

5. The prospects

Sufficient Legal Framework. The country has sufficient national environmental laws. Similarly, there had been important functions and responsibilities already devolved to LGUs to effectively govern local natural resources and critical ecosystems - which include inland fisheries and aquatic resources. What the local communities truly need is a strong political will and environmental leadership from the elected leaders and government authorities. Also, the national government has to strictly enforce the administrative accountabilities of local authorities so as to ensure the attainment of policy objectives. It is noteworthy to emphasize that despite some legal and administrative limitations, LGUs still have much to take advantage of the authorities currently afforded to them.

Strengthening and Sustaining Public Participation. Farmers, fisherfolks, indigenous people, women, youth, and other civic organizations as well as religious groups of different faiths are exponentially increasing even in the countryside. Many of those organizations instituted by LGUs still exist in spite of dormancy for a long time. Nevertheless, these small community groups have immense potential to help the government only if mobilized and supported properly. They can be effective change agents in increasing awareness and civic environmentalism among their ranks. The experience of Cooperative of Women for Health and Development (COWHED), a small NGO, is a proof to this. COWHED's participation in environmental initiatives in Lake Sebu is relatively young. Nonetheless, it has already delivered significant milestones and the on-going collaboration with LGUs may bear more positive outcomes in the next few years. As a grantee of USAID financial support for its innovative sanitation projects, COWHED can already use this track record to secure more foreign fundings.

Other than strong political will of local leaders, as wished by enforcement volunteers in Lake Mainit area, their actions would be more aggressive only if they are provided with proper security – i.e. health insurance and legal support in the event of court battle. Fortunately, the Local Government Code clearly stipulates that municipal government may "provide group insurance or additional insurance coverage for *barangay* officials, including members of *barangay tanod* brigades and other service units with public or private insurance companies, when finances of the municipal government allow said insurance"[15]. Additionally, LGUs have to "provide legal assistance to *barangay* officials who in the performance of their official duties or on the occasion thereof, have to initiate judicial proceedings or defend themselves against legal action".[16]

Intensifying Compliance Promotion, Monitoring, and Enforcement. Some important compliance and enforcement strategies are already in place. What the LGUs need to do is to further intensify these and adopt some stringent enforcement mechanisms i.e. filing and pursuing court cases. To set precedence may discourages future violations and provide public impression that authorities are doing serious business. The authorities must not be selective in dispensing appropriate sanctions so as enforcement becomes more predictable. The LGUs can capitalize on the strong "texting culture" or the use of cellular phones among Filipinos. It is a potent force to empower the locals to become community watchdogs without expecting financial rewards. Additionally, the public may exercise the power of citizen's arrest against law breakers as practiced in San Miguel Bay in apprehending commercial trawlers (Juinio-Meńez, n.d.).

LGU-Academe Partnership. Academe has always been a repository of knowledge and latest information. Oftentimes, they are at the forefront of generating innovative ideas, skills, and techniques. Fostering LGU partnership with academic institutions makes technical inadequacies more manageable. For example, University professors need research and extension activities for them to gain required applied professional experiences to qualify for higher ranks. These academics have excellent records in winning research funds. In fact, much of the major researches in Lake Mainit were conducted by Mindanao State University researchers with funding coming from external resources. They were also able to train LGU personnel to become local research partners.

All of Higher Educational Institutions (HEIs), i.e. both public and private universities and colleges, are required to carry out the National Service Training Program (NSTP)[17]. These HEIs can provide massive human resources to carry out environmental projects under Civic Welfare Training Service (CWTS)[18] component. As experienced in Davao Oriental Province, the Davao Oriental State College of Science and Technology (DOSCST), where the author is currently employed, had utilized thousands of its students to do tree planting activities in some denuded areas. The only counterpart of the LGUs was limited to transportation of the students and faculty supervisors.

Replication of Local Innovations and Best Practices. The alliance forged by municipal and provincial LGUs, and regional offices of national line agencies has set an excellent example in creation the Lake Mainit Development Alliance (LMDA). The alliance has relatively succeeded in its quest for a more concerted effort in addressing varied issues and concern common to them. The apparent institutional shortcomings of LGUs are increasingly complemented by local institutions like the LMDA and the COWHED. Both the LMDA and the COWHED could be credited for major achievements in development efforts in Lake Mainit and Lake Sebu, respectively - especially

[15] Local Government Code, Sect. 447(a)(1)(xiii)
[16] Local Government Code, Sect. 447(a)(1)(xii)
[17] RA 9163 is known as the "National Service Training Program (NSTP) Act of 2001. Retrieved from http://lawphil.net/statutes/repacts/ra2002/ra_9163_2002.html.
RA 9163, Section 3 (a) "National Service Training Program (NSTP)" is a program aimed at enhancing civic consciousness and defense preparedness in the youth by developing the ethics of service and patriotism while undergoing training in any of its three (3) program components. Its various components are especially designed to enhance the youth's active contribution to the general welfare.
[18] RA 9163, Sect. 3 (d) "Civic Welfare Training Service" refers to programs or activities contributory to the general welfare and the betterment of life for the members of the community or the enhancement of its facilities, especially those devoted to improving health, education, environment, entrepreneurship, safety, recreation and morals of the citizenry.

by attracting foreign donors for environmental investments.

The LMDA, in fact, was a major actor in preparing the proposed Unified Fishery Ordinance which is enthusiastically considered by local leaders to implement. The alliance was also instrumental for winning huge amount of foreign funds for several alternative livelihood projects in upland areas adjacent to the lake. Furthermore, it has demonstrated its pivotal role in harmonizing fragmented municipal plans, programs, and projects and succeeded in breaking the political barriers among traditionally competing LGUs. It has also displayed its creativity in pooling and maximizing meager financial resources of every alliance member. The LMDA, a politically created body, is not at all free from political disturbances. Nevertheless, the Project Management Office was still able to pursue worthwhile efforts for common benefits of every alliance member. Thus, the LGUs surrounding the Lake Buluan could greatly learn from LMDA experience to further improve its sustainability plans and measures for their common fishing grounds.

6. Conclusion

This study was a preliminary attempt to investigate the complicated and encompassing issues on environmental governance in the context of decentralization. As Philippines explicitly welcomed decentralization as a major reform in early 1990s, it is then imperative to have a more concrete understanding on how this bold reform has impacted at the local communities. Specifically, this study closely investigated how the local government units, particularly the municipal governments, have responded to their new authorities, responsibilities, and challenges in governing their respective fragile environment and valuable natural resources. This paper concludes the following:

Firstly, it is very clear that the country has sufficient environmental laws to abate further deterioration of environment and natural resources in the countryside. There is a wide array of national environmental laws with positive provisions supporting the primacy of LGUs in providing environmental leadership. These advances in governance reforms, unfortunately, were not fully utilized by the local leaders to their own advantage. As enshrined in the Local Government Code, environmental responsibilities have been devolved to the LGUs. However, they still have to make the most of the decentralization opportunities provided. *Secondly*, it has confirmed the findings of earlier studies on natural resource governance, i.e. marine coastal environment and the forestry sectors, that LGUs in the country were struggling in terms of technical, financial, and institutional capabilities. *Thirdly,* decentralization can be described as a mechanism in adjusting the existing relationships among government agencies (Saito, 2008). This mechanism is two-fold: (1) it necessitates division of functions and (2) it requires coordination. In the experiences of the lakeshore municipalities, division of responsibilities and proper coordination among LGUs with other involved government agencies are two of the major challenges which have to be carefully addressed. *Fourthly*, the innovations and creative practices of LGUs have defined their potentials in providing effective environmental leadership within their respective localities. Particularly, intergovernmental cooperation and public collaboration with LGUs could be potentially replicated in other areas in Mindanao, e.g. Lake Buluan and Lake Lanao; as well as in other sectors, e.g. marine coastal environments and forestry. The LMDA experience, despite some shortcomings, has exemplified that LGUs could make significant milestones without depending from the national government. *Finally*, the challenges in decentralizing the responsibilities and functions over environment and natural resources are evidently enormous. Nevertheless, the available options are equally overwhelming. It is then incumbent upon the local leaders as well as the civil society at the grassroots level to boldly act and make a difference by taking advantage of the initial gains of decentralization in the Philippines.

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Draft (Please do not cite)

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Consumer Willingness to Pay for Energy Conservation: The Case of Taiwan

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May 2011

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Paper prepared for The Asian Conference on Sustainability, Energy & Environment, June 2-5, Osaka, Japan.

Consumer Willingness to Pay for Energy Conservation: The Case of Taiwan

I. Introduction

Global warning and climate change have been the most important issues over the next decades. As the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the possible effects of climate change cover many types including freshwater, food, agriculture, human health, coastal areas and ecosystems. The negative impacts will be substantial if adequate policy interventions do not meet the challenge of growing demand for decreasing greenhouse emissions. One of the policy options is attributed to energy uses. The increasing energy efficiency and conservation have long been the majority methods to the issues of the energy uses.

Recently, Gillingham et al. (2009) mentioned the importance of information programs in discussing the energy efficiency policy. However, the effectiveness of the information program is varied by their methods and implementations. Levine et al. (1995) found that the program of Energy Guide product labeling has little effect in increasing energy-efficient investments. On the contrary, Webber et al. (2000) found that the voluntary Energy Star label has significant effect on energy saving by increasing energy efficiency. Howarth et al. (2000) found that the Green Light program has shown its effect in increasing energy-efficient investments.

The purpose of this paper is to discuss the effectiveness of voluntary Energy Efficient Label program in Taiwan. By far one of the most widely used methods is the hedonic price method. This method models an individual's demand for product characteristics by estimating the relationship between the prices of product and its characteristics. It utilizes observed differences in the amounts of characteristics observed across different products and estimates the individual's willingness to pay for the product's characteristics.

Previous studies have examined whether consumers are willingness to pay price premium on energy-efficiency products. For example, Wallander (2008) examined the price premium for the Energy Star label on residential clothes washers and found that there is no significant eco-label price premium based on the hedonic price function and a 10% positive but statistically insignificant price premium on the quasi-experiment estimation. The results show that Energy Star program may not have its effect on the policy of energy efficiency. Furest and McAllister (2009) investigates the effects of LEED and Energy Star program on the US commercial office properties and found that there is approximately 6% rental price premium for the eco-certified buildings. Shen and Saijo (2009) conducted a hypothetical experiment analysis on the China Energy Efficiency Label program and found that consumers are willingness to pay more amounts for more energy efficiency refrigerators than those for more energy efficiency air-conditioners.

Although previous studies have examined the effect on the energy efficiency label, however, there are no consistent results about the issue. In this paper, we will use the air-conditioners data collected in Taiwan to examine whether consumers pay more value on the higher efficiency standard or eco-label products. The outline of this paper is as follows. In section 2 we discuss the framework for estimation. Our data is described in more detail in Section 3. Section 4 contains the empirical results. Section 5 gives a brief conclusion of the paper.

II. The Model

Consider the individual demand framework found in Rosen (1974), the model assumes that an individual's utility depends on the consumption of the numeraire goods, X, and one unit of purchased goods, Y in a given period of time horizon. The utility function can be described as:

$$U = U(X, Y)$$

where the purchased goods of Y can be further described as a vector of its characteristics, $Q = q_1,....,q_j$. That is, the utility function is defined as $U = U(M - P_Y, q_1,...,q_j)$ where M is denoted as the individual's income. The solution of the utility maximization yields that the individual would choose the level of each characteristics to satisfy the first-order condition: $(\partial U / \partial q_i)/(\partial U / \partial X) = \partial P_Y / \partial q_j$. This obtains an indifference curve or bid function, called a hedonic function, that reflects an individual's maximum marginal willingness to pay for q_j, holding utility constant. Under the Rosen (1974) framework, the hedonic price function depends on the determinants of the purchased goods' characteristics markets.[1] The marginal implicit price curve reflects the individual's inverse demand function.

The most general form to estimate the hedonic price function is attributed to the Box-Cox functional form proposed by Goodman (1978) and Halvorsen and Pollakowski (1981). The form is:

$$P^{[\lambda]} = \alpha_0 + \sum_{i=1}^{k} \alpha_i z_i^{[\theta]}$$

where i index the characteristics and λ and θ are transformation parameters estimated from the data. The feature of the Box-Cox form gives a flexible functional form that indicates the linear, semi-log, log-log form as λ and θ approach 0 or 1. In this paper, we would provide the estimation results of semi-log form of hedonic price function first, then provide the estimation results of general form of Box-Cox transformation.

III. Data

1 Rosen (1974) also discuss the supply side of the purchased goods and

The data used in this study are derived from two public sources. The sale prices and its characteristics of air-conditioner are derived from the PChome online. The energy efficient product data are obtained from the "Energy Efficient Label" program conducted by Bureau of Energy, Ministry of Economic Affairs, Taiwan. A total of 363 observations with full information were employed in the hedonic price estimation. These observations can be separated into two groups by the standard whether the products offered an energy efficient label or not. The energy label group includes 198 observations, whereas the non-energy label consists of 165 observations. Table 1 reports the statistics for selected variables used in the estimation.

IV. Empirical Results

Estimates of the parameter and the associated t-values of the hedonic price equations by using the OLS estimation method are presented in Table 2. The hedonic price equations were estimated as the semi-log form in the regression. Four specifications of the model were estimated. Those models were separated by the brand dummies and energy efficient standard. Model (1) of Table 2 shows the results for including the variables of energy efficient ratio (EER) and Japanese-related brand dummy (JAP). All parameter estimates were significantly different from zero. As expected, the coefficient of EER is positive and of the square term is negative. The results indicate that the higher the EER the higher the prices but the slope is decreased. It implies that consumers are willingness to pay NT$23,700 for an additional unit of energy efficient ratio. The value of the coefficient of the inverter type of air-conditioners is 0.15, which means that consumers are willingness to pay an additional NT$7,360 to buy such products. Comparing with the window type air-conditioners, the positive coefficient of split variable indicates that prices of split-type products are higher about NT$18,000. The air-conditioners with warm function also have the higher prices on average NT$4,000. In addition, the products with Japanese brand have the higher prices on average NT$10,000.

Comparing with Model (1), Model (2) shows the results for including corporation brand dummies. Five major corporation brands are employed, including TATUNG, SANYO, HITACHI, PANASONIC and TECO. All characteristics variables are statistically significant from zero except the square term of capacity (Cap^2) and the volume of product ($\log(Involume)$. The magnitudes of coefficients are slightly different from the estimates in Model (1), however, all values are as expected. For those brand dummies, we found that the variables of HITACHI and PANASONIC, two famous Japanese brands, have positive and significant coefficients. The results indicate that consumers are willingness to pay addition NT$ 13,000 and NT$4,000 to buy HITACHI and PANASONIC air-conditioners. The results are as expected, the HITACHI products are most welcomed air-conditioners in Taiwan although the products have the higher prices but also have the higher energy efficient ratio with high quality.

Model (3) and (4) show the results based on the use of the variable of energy efficiency label. The positive and highly significant coefficients of the variable LABEL indicate that consumers pay more values on the air-conditioners with the Energy Efficient Label. With the label, consumers are willingness to pay more on the average of NT$ 3,500~NT$3,700.

Table 3 reports the estimation results based on the Box-Cox transformation. All estimated parameters are also expected, however, the coefficients obtained from the non-linear form gave slightly different magnitudes of the parameters comparing with those in OLS estimation. However, the estimated consumer's willingness to pay for the product characteristics are not change a lot. For example, consumers are willingness to pay more on the average of NT$ 3,220~NT$3,800 with the Energy

Efficiency Label.

V. Conclusion

The path of increasing carbon emissions and global warnings has called public attentions to its impacts on economic activity. Much attentions has been on the issues of the energy uses. This also leads to concern whether consumers prefer to buy energy efficiency products in the market. Estimating the relationship between product prices and the demand for the energy efficiency characteristics not only provide the evidence for product makers as part of information for decision-making, but also offer the useful measure for policy makers to design available instruments for the issue of global warming.

In this study, we uses the air-conditioners market data to estimate the impact of energy efficiency standard as well as energy efficiency label on prices on the demand of air-conditioners in Taiwan. Our empirical results indicate two major findings: First, consumers are willingness to pay more amounts on the products with higher energy efficient ratio or with the energy efficiency label. Second, the Japanese-type brand or manufacturer of air-conditioners, in particular for HITACHI, have price premium in Taiwan market.

One of important limitations to our study is that it does not consider the household ownership and utilization decisions. Pursuing related research would be useful to get further realization on the impact of increasing energy prices. Collecting individual data on the purchases' decision as well as air-conditioner utilization will get more insights to this topic. All of these are attributed to further efforts.

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Table 1. Descriptive Statistics for Selected Variables

	With Energy Efficient Label		Without Energy Efficient Label	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
Price (NT$)	45,033	15,844	41,848	19,859
EER	3.57	0.43	2.68	0.29
AREA(Ping)	8.66	3.23	10.52	5.26
KCAL	3,824	1,576	4,667	2,722
KW	4.20	1.62	5.31	2.76
Observations	165		198	

Table 2. OLS Estimation Results

	Model (1)		Model (2)	
Variable	coefficient	T-value	coefficient	T-value
Constant	5.880 (0.980)	6.00***	7.200 (1.052)	6.84***
EER	0.549 (0.123)	4.47***	0.343 (0.134)	2.55**
EER^2	-0.065 (0.017)	-3.78***	-0.045 (0.018)	-2.39**
Inverter	0.157 (0.030)	5.31***	0.190 (0.032)	5.86***
Ping	0.047 (0.019)	2.49**	0.084 (0.021)	4.09***
$Ping^2$	-0.001 (0.0001)	-1.72*	-0.002 (0.001)	-2.31**
Cap	0.145 (0.033)	4.44***	0.060 (0.036)	1.67*
Cap^2	-0.005 (0.002)	-2.44**	-0.002 (0.002)	-1.02
log (Involume)	0.123 (0.052)	2.36**	0.077 (0.056)	1.38
Heat	0.088 (0.025)	3.42***	0.122 (0.027)	4.52***
Split	0.339 (0.068)	4.97***	0.361 (0.072)	5.01***
Split×Many	0.280 (0.039)	7.23***	0.215 (0.044)	4.89***
JAP	0.214 (0.020)	10.71***		
TATUNG			0.006 (0.034)	0.18
SANYO			-0.002 (0.055)	-0.03
HITACHI			0.262 (0.032)	8.26***
PANASONIC			0.093 (0.037)	2.54**
TECO			-0.037 (0.053)	-0.69
F-value	145.02		97.83	
R^2	0.8398		0.8268	
Adj-R^2	0.8340		0.8183	
Obs.	345			

Table 2. OLS Estimation Results (continued)

	Model (3)		Model (4)	
Variable	coefficient	T-value	coefficient	T-value
Constant	5.955 (1.047)	5.69***	7.323 (1.089)	6.72***
Label	0.082 (0.026)	3.17***	0.078 (0.028)	2.84***
Ping	0.082 (0.023)	3.52***	0.130 (0.024)	5.31***
$Ping^2$	-0.002 (0.001)	-2.65***	-0.003 (0.001)	-3.62
Cap	0.090 (0.046)	1.96*	-0.023 (0.049)	-1.27
Cap^2	-0.001 (0.003)	-0.32	0.006 (0.004)	1.56
Power	-0.00004 (0.0008)	-0.62	0.0001 (0.0001)	1.84*
$Power^2$	-4.93e-10 (1.47e-08)	-0.03	-2.6e-08 (1.51e-08)	-1.72*
Log(Involume)	0.173 (0.057)	3.03***	0.100 (0.059)	1.68*
Heat	0.197 (0.026)	7.70***	0.232 (0.026)	9.04***
Split	0.483 (0.074)	6.56***	0.467 (0.075)	6.20***
Split×Many	0.233 (0.045)	5.16***	0.156 (0.048)	3.22***
JAP	0.211 (0.022)	9.51***		
TATUNG			0.014 (0.036)	0.38
SANYO			0.075 (0.058)	1.29
HITACHI			0.298 (0.033)	9.04***
PANASONIC			0.105 (0.040)	2.64***
TECO			0.031 (0.058)	0.54
F-value	110.24		81.55	
R^2	0.7975		0.7972	
Adj-R^2	0.7902		0.7874	
Obs.		349		

Table 3. Box-Cox Estimation Results

	Model (1)		Model (2)	
variable	coefficient	Chi^2	coefficient	Chi^2
constant	6.351		8.941	
eer	0.324	22.094***	0.177	2.297
inverter	0.131	30.733***	0.260	39.244***
ping	0.225	22.094***	0.658	41.231***
cap	0.344	29.255***	0.180	3.065*
involume	0.099	2.810*	0.032	0.539
heat	0.076	13.105***	0.168	23.147***
split	0.249	19.321***	0.436	20.533***
split×many	0.199	37.747***	0.235	17.136***
jap	0.169	95.751***		
tat			0.041	0.909
san			0.007	0.010
hit			0.368	74.474***
pan			0.139	8.744***
taco			-0.034	0.257
LR Chi^2	623.00		610.51	
lambda	-0.018		0.027	
sigma	0.138		0.228	
Obs.	345			

Table 3. Box-Cox Estimation Results (continued)

	Model (3)		Model (4)	
variable	coefficient	Chi^2	coefficient	Chi^2
constant	6.652		8.227	
label	0.097	12.812***	0.108	8.336***
ping	0.318	12.831***	0.768	40.913***
cap	0.363	14.277***	0.010	0.006
power	-0.039	0.623	0.059	1.107
involume	0.144	7.505***	0.062	1.979
heat	0.220	58.406***	0.332	77.681***
split	0.509	37.186***	0.642	32.911***
split×many	0.235	23.968***	0.200	9.211***
jap	0.229	80.942***		
tat			0.019	0.157
san			0.096	1.455
hit			0.436	84.357***
pan			0.144	6.879***
taco			0.033	0.170
LR Chi^2	552.07		560.66	
lambda	0.009		0.035	
sigma	0.206		0.268	
Obs.	349			

Spatial Drought- Distribution in the Northwestern Part of Bangladesh

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Submission Category:
Environmental Sustainability and Environmental Management-Freshwater, Oceans ad Seas

Spatial Drought- Distribution in the Northwestern Part of Bangladesh

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Abstract

Bangladesh is one of the most disaster-prone countries in the world. High spatial and temporal climatic variability, extreme weather events, poor institutional capacity, inadequate financial resources, and poor infrastructure have made Bangladesh highly vulnerable to disaster. Drought is a recurrent feature of the climate and it is common in Bangladesh. It is related to a deficiency of precipitation over an extended period of time, usually for a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Drought affects people's access to food and water. Monsoon rains normally sweep Bangladesh from June to September gets more than 80 percent of its annual rainfall during this period. The amount of rainfall varies considerably from year to year and from region to region. In some areas in the northwestern part of the country, the amount of annual average rainfall may be as low as 130 mm whereas in the north-eastern part, average annual rainfall may be as high as 500 mm. So the northwestern part of the country is vulnerable to drought and is recognized as drought-prone region of the country. This paper deals with spatial and temporal distribution of meteorological drought in the northwestern part of Bangladesh over last 5 decades (1960-2008) by Standardized precipitation index method. GIS is used to map the spatial extents of droughts in different time steps. The Standardized Precipitation Index (SPI) series of different time scales have been calculated and used for drought analysis.

Keywords: Bangladesh, Drought, SPI, GIS

INTRODUCTION

Drought is an intense climatological event which is the deficiency of precipitation and scarcity of water supply over quite an extended period of months and years resulting in significant non-structural damage and adverse environmental impacts on human, vegetation and animal. Meteorological drought is considered the first ring in the chain of droughts and is analyzed in water resource planning and management studies. It is usually defined based on the degree of dryness and the duration of the dry period. Main drought characteristics include the onset, termination time, severity and frequency (Loukas and Vasiliades, 2004).

Drought is in fact an extensive phenomenon which occurs in a variety of frequencies in many parts of the world (Seilar et al., 2002). It is a permanent feature of climate and is restricted to low rainfall regions. Since there is no universal definition for drought it is not possible to develop widespread drought monitoring systems. There were many attempts in the past to develop indicators that would follow drought occurrence in certain sectors and certain climate as accurately as possible. Numerous drought indices have been proposed to quantify droughts. The most commonly used meteorological drought indices are Palmer drought severity index (PDSI) (Palmer, 1965), deciles (Gibbs and Maher, 1967), and the standardized precipitation index (SPI) (Mckee et al., 1993). Loukas and Vasiliades (2004) used SPI for the identification and the assessment of drought events. The SPI is defined as a number of standard deviations that the cumulative precipitation at a given scale (usually 1, 3 or 6 months and 1 or 2 years) deviates from the long term mean.

Bangladesh is one of the most disaster-prone countries in the world. High spatial and temporal climatic variability, extreme weather events, high population density, high incidence of poverty and social inequity, poor institutional capacity, inadequate financial resources, and poor infrastructure have made Bangladesh highly vulnerable to disaster (Ahmed 2004). Drought is a recurrent phenomenon in some parts of Bangladesh. It has attracted far less scientific attention than floods or cyclones (Alexander 1995; Brammer 1987). However, losses from drought are likely to be more severe than from floods in Bangladesh. On the global level, impact of natural hazards and disasters are staggering. In Bangladesh, the major natural hazards are also in line with global patterns. In the context of global warming, most of the climatic models project a decrease in precipitation in dry season and an increase during monsoon in south Asia (TPCC 2007). This will cause a cruel combination of more extreme floods and droughts in the region. Due to the land use changes within the country and in neighboring country, Bangladesh has already shown an increased frequency of droughts in recent years (National Drought Mitigation Center 2006). Concern among scientists has grown on changes of precipitation and frequent occurrence of droughts in Bangladesh. Therefore, drought hazards, vulnerability, and risk assessment is essential for implementing mitigation to reduce drought impact in Bangladesh.

STUDY AREA

The Study Area is in the north western region of Bangladesh. It actually covers two of the administrative divisions of Bangladesh: Rajshahi and Rangpur. The Region is located in 25° 0′ N and 89° 0′ E and it has an area of 34513 km^2. A main river the Padma, which is originated from the Ganges, borders the region on the south and another major river the Jamuna lies across the eastern border. Rajshahi division shares a border with West Bengal province of India in the North and West. This section is little higher than the central and southern part of alluvial plain land. The soil in this region is mostly red and hard. Drought commonly occurs here for the rivers being dried out in the dry season and the short of fertility of the soil. On the other hand it is affected very frequently by the flood in the monsoon for the excess of river water released from the barrages that overflows the land. Precipitation data of 5 districts are collected from Bangladesh Meteorological Department. The common record length of the study extends from 1961 to 2006 which is adequate for drought studies.

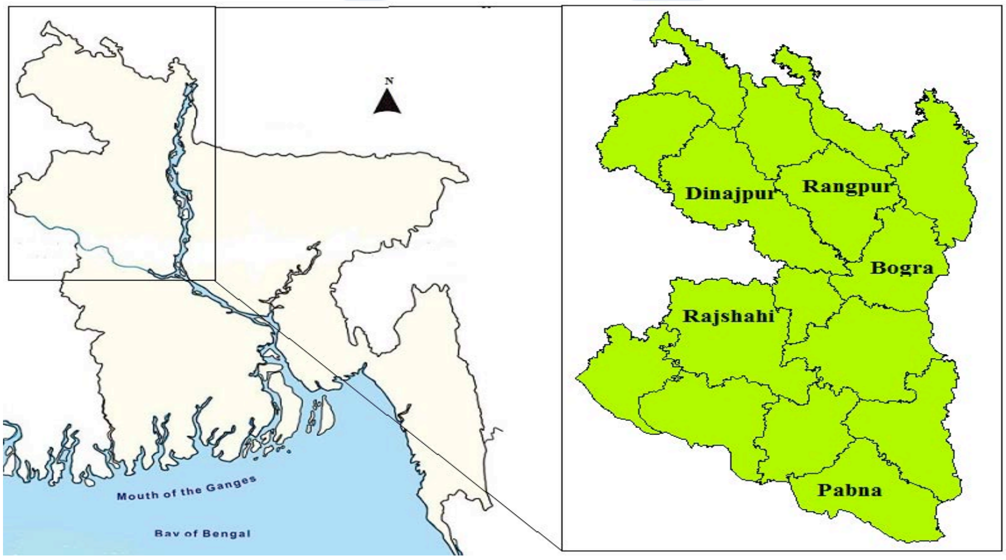

Figure 1: Study area

METHODOLOGY AND SPI

Precipitation data for the five stations has been collected to analyze the precipitation pattern of the area and calculate SPI. Standardized Precipitation Index (SPI) has been used to monitor meteorological drought. SPI offers a quick, handy, simple approach with minimal data requirements (Komuscu, 1999).

The procedure in the calculation of the SPI requires first to determine a probability density function that describes the long-term series of cumulative precipitation sums. Once this distribution is determined, McKee et al. (1993) uses a two parameter gamma density function, and then it is converted into standard normal distribution with a mean of zero and standard deviation of one so the values of the SPI are really in standard deviations (Edwards and McKee 1997). Considering that SPI is normalized, dry (negative values) and wet (positive values) periods can be shown at the same way.

McKee et al. (1993) and McKee et al. (1995) originally used an incomplete gamma distribution to calculate the SPI. Efforts are now in progress to standardize the SPI computing procedure so that common temporal and spatial comparisons can be made by SPI users (Guttman 1998).

Table 1: Drought categories defined for SPI values

SPI value	Drought category
0 to −0.99	Near normal or mild drought
−1.00 to −1.49	Moderate drought
−1.50 to −1.99	Severe drought
−2.00 and less	Extreme drought

Although McKee *et al.*, (1995) in the original classification scheme proposed 'mild drought' for SPI values less than 0.00, in the modified SPI classification scheme of Agnew (1999), there is a straight jump from 'no drought' to 'moderate drought'. In the present study, SPI maps have been classified using the modified scheme of Agnew (1999) to represent various meteorological drought intensities, however, 'mild drought' has been recognized corresponding to the SPI values less than -0.50, which has a probability of occurrence 0.309 (Agnew, 1999).Since drought is a regional phenomenon, SPI values of the rain-gauge stations have been interpolated using interpolation technique in ArcGIS 9.3 to demarcate its spatial extent.

RESULTS

Average Precipitation of North-western region of Bangladesh varies from 1600-2200 mm per year. Rangpur has got the highest and Rajshahi has got the lowest precipitation in this region. Almost 80-85% precipitation usually occurs during monsoon season.

Figure 2 shows the precipitation pattern of the study area. Monitoring and confirming intensity and spatial extent of drought are one of three basic elements (monitoring and early warning,

risk assessment, mitigation and response) of possible plans for struggle against drought (Wilhite and Svoboda, 2000). Appearance of drought is happening every time when SPI is negative and its intensity comes to -1.0 or lower.
Theoretically, drought stops when SPI is positive. The duration of every drought appearance is determined by negative index values. Accumulated totals of negative values of SPI could also be used as a measure of drought severity.

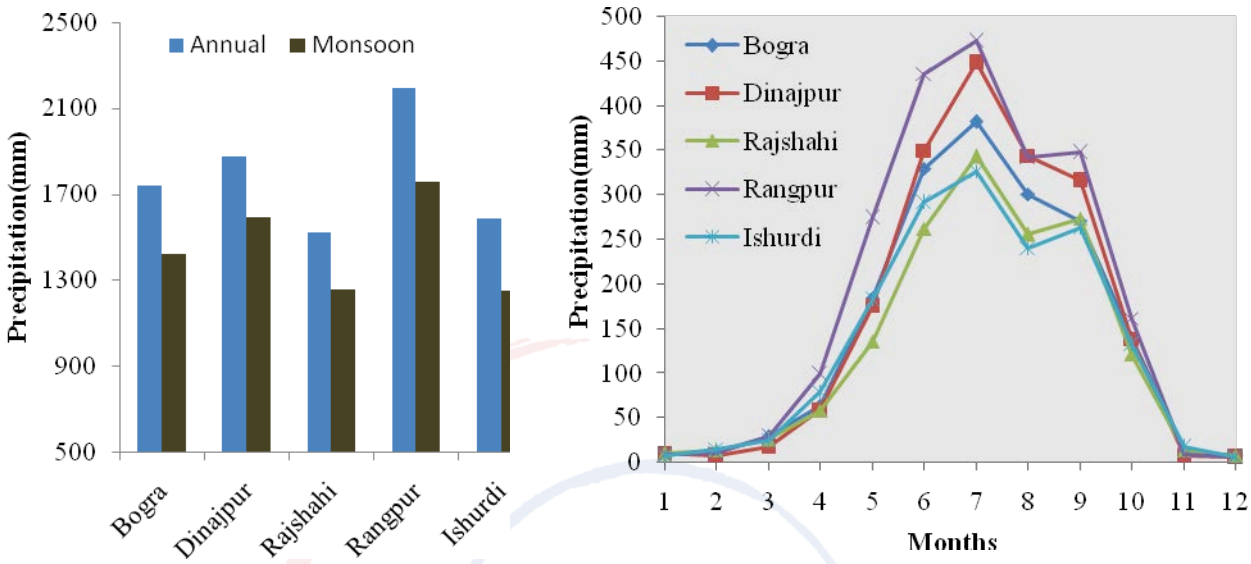

Figure2: Precipitation Pattern in the Districts of North-western region of Bangladesh.

Figure 3 shows 12-month SPI time series at Bogra and Rangpur stations. Similar time series have been derived for other stations. In most stations in the region, several severe droughts such those in 1961-62, 1966-67, 1972-73,1982-83,1994-95,1999-2000 and 2005-06 are observed. Note that the observation of such severe drought on the basis of SPI time series is at point scale and may not hold for the whole region. This point will be further elaborated in the spatial analysis of droughts. The GIS method was applied to generate April 12-month SPI maps.

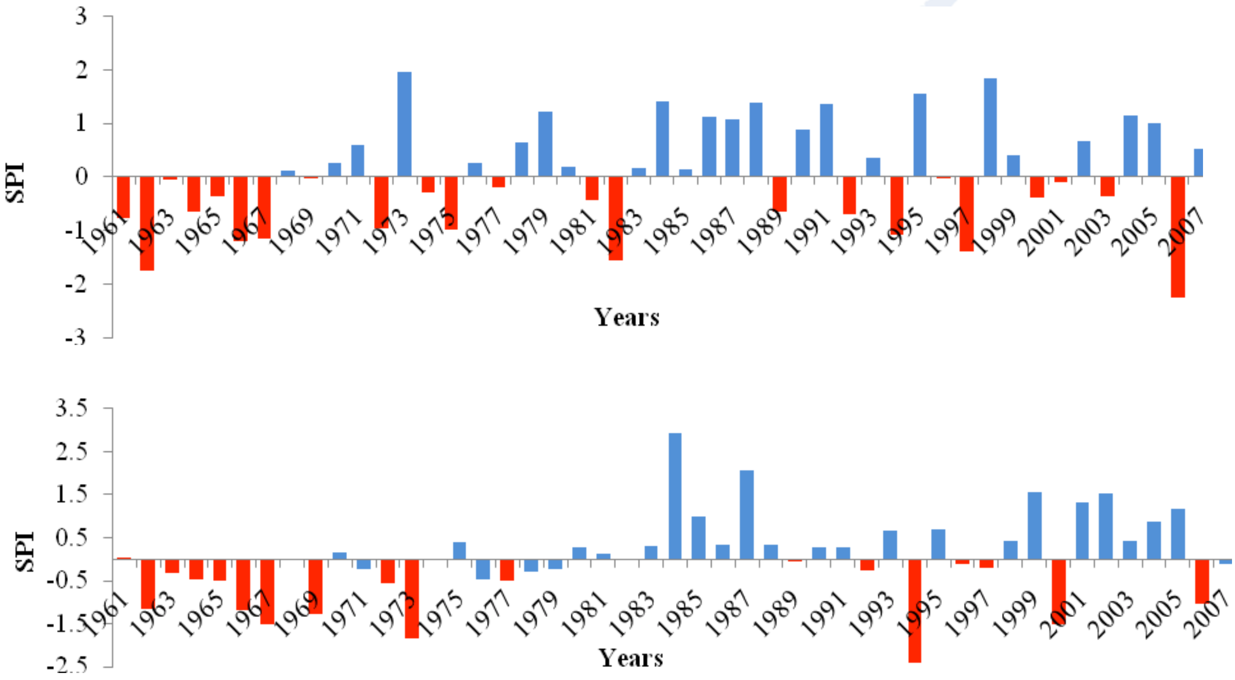

Figure 3: 12-month April SPI 1960-2008 time series for Bogra and Rangpur stations

Two of the most severe droughts during the concerned period at average values: a) SPI=-1.72 (1994-95) and b) SPI=-1.27 (2005-06), are better illustrations of the drought extent and intensity in the north-western region of Bangladesh. Calculated SPI index for 1994-95 proves that the drought assumed an extreme characteristics in wide area of Rangpur, Dinajpur, Panchagar, Nilphamary and Thakurgaon (SPI=-2.1 to -2.41) while in the remaining wider area it was severe (SPI=-1.5 to -1.99) and moderate (SPI=-1.0 to -1.49). In 2005-06, Bogra and Gaibandha were under the strike of extreme drought (SPI=-2.00-2.24), while the drought in kurigram Jaipurhat and Rangpur were severe.

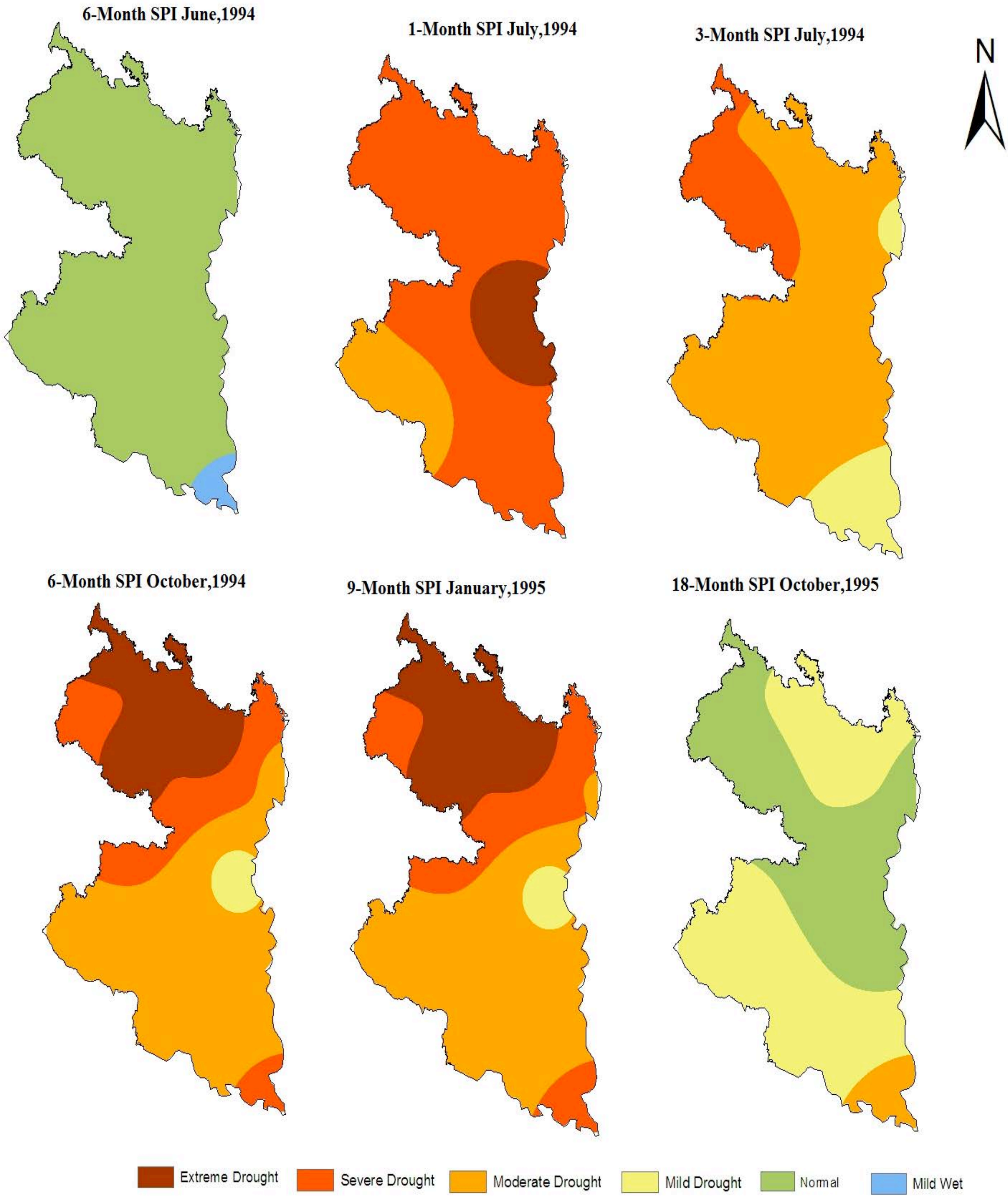

Figure 4: 1994-1995 Drought in different time scale of SPI

Basically, the 1994-95 droughts began in July 1994. Before then, conditions in the most of the part were normal and Pabna and Shirajgonj were relatively moist. The 6-month SPI map (Figure 4) through the end of June, comparing the January to June precipitation totals in 1994, showed SPI values +0.56 to -0.34 from Panchagar to Shirajgonj. The period from July 1994 through May 1995 was the driest for this region according to 48 years of recorded data. The drought peaked in intensity and spatial extent during July.1-month SPI maps for July shows severe dry conditions all around the region. Since the dry 1-month SPI does not necessarily resemble a real occurrence of drought, therefore, in this case the dry values during July were rather reflecting the beginning of a drought. From late 1994 into January 1995, very little precipitation fell in the north and northwest part of the study area concomitantly having relatively better precipitation at Bogra and Gaibandha. However, calculate SPI values reveal that the drought started to diminish from October, 1995.

Figure 5 shows the time series of percentage area in different drought category within the whole study area of observed 1994-95 drought. The most severe drought in terms of both magnitude and area covered corresponds to 1994-95 where about 30% of area experienced droughts of SPI less than -2.00. In the same year, some 30% of area faced SPI in the (-2 to -1.5) range.

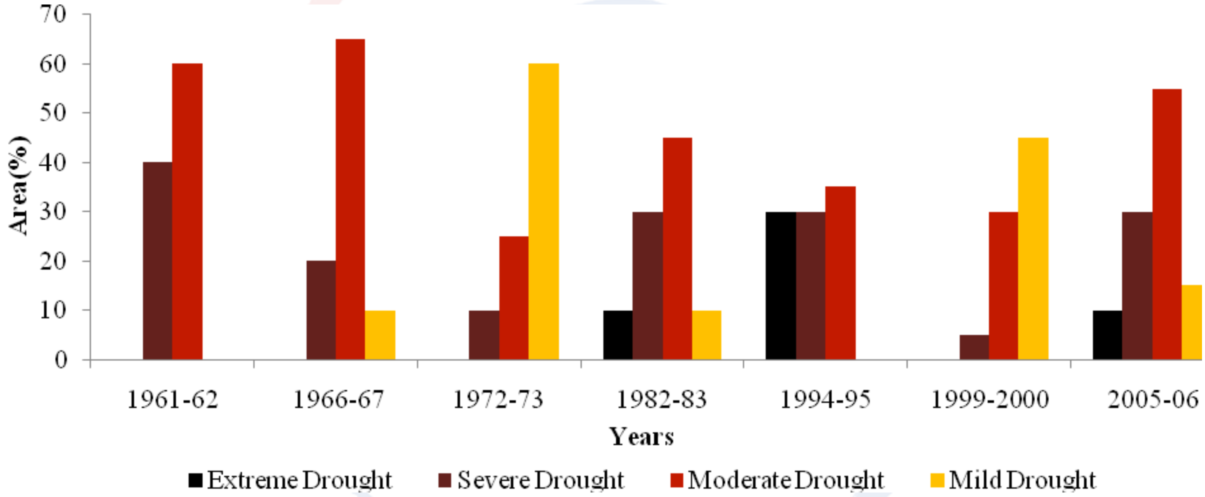

Figure 6: Percentage area covered by droughts of different severity (1994-95)

CONCLUSION

In this paper, spatial characteristics of droughts were studied in the north-western part of Bangladesh based on the commonly used standard precipitation index (SPI). This was carried out by plotting the 12-month April SPI and found 1961-62, 1966-67, 1972-73,1982-83,1994-95,1999-2000 and 2005-06 to be the drought years. GIS maps were generated to study the spatial extent of the droughts. Accordingly, the areas under various drought severity categories were identified and found that the most severe drought in terms of both magnitude and area covered corresponds to that of 1994-95 where about 30% of the northwestern part of Bangladesh experienced droughts of SPI less than -2.00 and some 30% of area faced SPI in the (-2 to -1.5) range. It is also found that most of the draughts were moderate (37%) and mild (36%) in nature but there was an increase in extreme droughts in the last two decades.

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Redefining economic efficiency in a post-fossil fuel world:
Relation between food and energy scarcity

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1. Introduction

The history of humankind, or even life in general, could simply be summed up as a continuous struggle for ever greater energy appropriation. For the great majority of human existence, the only source of energy that really mattered was the caloric intake gained directly from eating food, and the biomass energy used for making fire. Only much later, along with the arrival of the Neolithic Revolution some 8,000 years BC, did the newly discovered capacity of utilizing solar energy through deliberate land cultivation came to play an increasingly important role in the expansion of agrarian societies.

1.1. Industrial Revolution

It wasn't until the late 18th century in Great Britain, when the realization of the vast energy potential hidden in fossil fuels ushered in a historic breakthrough. This so-called Industrial Revolution is indeed the only paradigm shift comparable to the Neolithic Revolution both in the scale of its consequences for global population as well as the global environment. Whereas the Neolithic Revolution represented a transition from nomadic hunter-gatherer way of life to a more settled, agrarian-based one, the Industrial Revolution could best be described as an escape from the constraints of an organic economy (Wrigley, 2010) to the industrial future of newly-found prosperity and limitless economic growth.

Even though the discoveries of the seemingly inexhaustible world deposits of coal, oil, and natural gas allowed for some two-hundred years of fast economic expansion and population boom, the evolution of modern energy systems has also been inextricably linked with the quest for higher conversion efficiencies (Smil, 2010). On one hand, the enormous energy density of fossil fuels led to a rising share of energy surplus enabling substitution of human power with machines, thus driving the process of industrialization and urbanization with all the lavish wastefulness associated with modern consumer lifestyles. On the other hand, rising efficiency of energy conversions, as demonstrated by the transition from the early steam-engines to modern electric motors, has been reflected in the improving performance of entire economies, so that the resulting per capita energy use in modern societies is even more pronounced when compared to the energy use in pre-industrial societies in useful terms rather than as the rates of gross energy consumption (Smil, 2010).

1.2. Industrial agriculture

The abundance of cheap energy obtained from fossil fuels did not only lead to the rise of factories and urbanization, but at the same time, and perhaps even more importantly, it brought about a radical transformation of production methods in agriculture. By far the most important innovation was the discovery of industrial production of ammonia, the so-called Haber-Bosch process, in early 20th century. This single invention, which subsequently led to the widespread use of artificial fertilizers in farming, is estimated to be responsible for sustaining one-third of the Earth's population (Wolfe, 2002). However, this procedure is energy intensive and currently consumes about 5% of world natural gas production (IEA, 2007).

Vast amounts of energy are also needed for the production of pesticides and herbicides, as well as for running of agriculture machinery, processing, refrigeration and transport. Today's food production and distribution is thus almost entirely fossil fuel dependent. It has been suggested that 1 food calorie derived from industrial agriculture requires as much as 10 calories of fossil fuel inputs (Pimentel et al., 1994). In other words, fossil fuel and technology have transformed agriculture from a net energy producer to a net energy consumer. Consequently, modern industrial agriculture is a high-energy input business with correspondingly high levels of yields. But despite the large increases in yields achieved during the last century, industrial farming is by no means energy efficient – it merely manages to purchase more energy inputs in order to obtain higher outputs (Ponting, 2007).

Through industrialization and large scale energy investment, global food supply has become ever more centralized, globalized and expedient in producing large quantities of monoculture crops. About half of the world's food intake currently comes from just four plant species – rice, maize wheat and potatoes (FAO, 2010). But what is perceived as economical cost-efficiency today, might become an inefficient liability for the future, when high energy prices expose the inherent vulnerabilities of industrial food production and distribution, which so much depends on fossil fuels. Therefore we need to reevaluate our notion of long-term efficiency, with a particular consideration to modern agriculture.

2. Neoclassical efficiency

In neoclassical economics, the Cobb-Douglas production function is widely used to represent the relationship of an output (total production Y) to inputs (labor L, capital K).

$$Y = AL^{\alpha}K^{\beta}$$

Available technology determines the output elasticities of labor (α) and capital (β), but it is the total factor productivity (A), that is considered to be the residual responsible for effects in total output not caused by inputs. In other words, neoclassical efficiency is a sum of intangible qualities, ranging from technical progress to worker skills, that tries to explain the empirical trend of productivity growth (the so-called Solow residual).

Both technological progress and accumulation of knowledge have undoubtedly improved *cost* efficiencies of industrial production processes, but it would be a mistake to equate economic productivity with resource efficiency. On the surface, economic cost efficiency might seem like an objective concept, unless we realize that not all costs of production are accounted for (externalities), resource and energy scarcity is not addressed, and therefore the intertemporal issue of macroeconomic optimum is likewise ignored.

In practical terms, what neoclassical efficiency often comes to mean is nothing more than efficiency in either producing somebody a monetary profit, or efficiency of replacing renewable energy and labor with the incredibly cheap, concentrated energy found in fossil fuels. If we recognize, that productivity gains raise resource depletion (rebound effect) and that limits to growth are determined by limits to substitution (Smulders, 2005), then the logical conclusion is to search for a new definition of efficiency that would represent a more useful principle of long-term policy planning and resource management.

3. Redefining efficiency

In order to reflect more realistically the new paradigm of global resource scarcity, revised definition of efficiency based on physical indicators needs to include the following points:

- Tangible values, such as energy consumption per unit of production, would take precedence over the intangible total factor productivity of neoclassical economics
- The concept of marginal utility in neoclassical economics would be replaced by entropy theory of value established on a measurable mathematical function with clear physical meaning (Chen, 2005)
- Energy Return on Investment (EROI) could be used as an efficiency indicator of economic investments, complementing the conventional cost-benefit analysis
- Policy plans with wider social and environmental repercussions should not only consider the issue net energy (EROI), but also the long-term impact on local communities as well as environmental resiliency

Additionally, the difference between the quantity of energy and the concentration of energy, i.e. exergy, needs to be understood. Strictly speaking, the world will not face an energy crisis as fossil fuels run short; what we will face is an *exergy crisis* – a serious shortage of energy in highly concentrated forms (Greer, 2009). It is crucial to keep this distinction in mind especially in connection with renewable energy, such as solar or wind, because though abundant in quantity, low density of renewable energy cannot substitute for the highly concentrated energy found in fossil fuels.

3.1. EROI and exergy efficiency

As the global production of crude oil reached its peak in 2006 (IEA, 2010), and with rapidly rising energy demands of developing countries, it is easy to foresee a world of skyrocketing energy prices. Not only will the physical quantity of global petroleum supply keep falling, but also the amount of net energy per oil barrel will continue to decline, reflecting the rising costs of new exploration and extraction.

Energy return on investment (EROI) is the ratio of the amount of usable energy acquired from a particular energy resource to the amount of energy expended to obtain that energy resource. It is thought by many to be a critical factor for determining the past, present, and future status of human society (Hall, 2008).

EROI =Energy ReturnEnergy Invested

When the EROI of a resource is equal or lower than 1, that energy resource becomes an energy sink. If, for example, EROI of a specific biofuel drops below 1, then it no longer can be used as a primary source of energy, no matter what other economic indicators might say. It has been suggested that a minimum EROI of 10:1 is required to support our global industrial civilization as shown in Figure 1. Contrast it with the net energy of pre-industrial agriculture, which has been estimated as EROI on the order of 1.1-1.6 depending on place and time (Staniford, 2010). The sobering implication of such comparison is that without fossil fuels it would hardly be possible to support our current world economy even with the best alternative options available, such as nuclear or renewable energy.

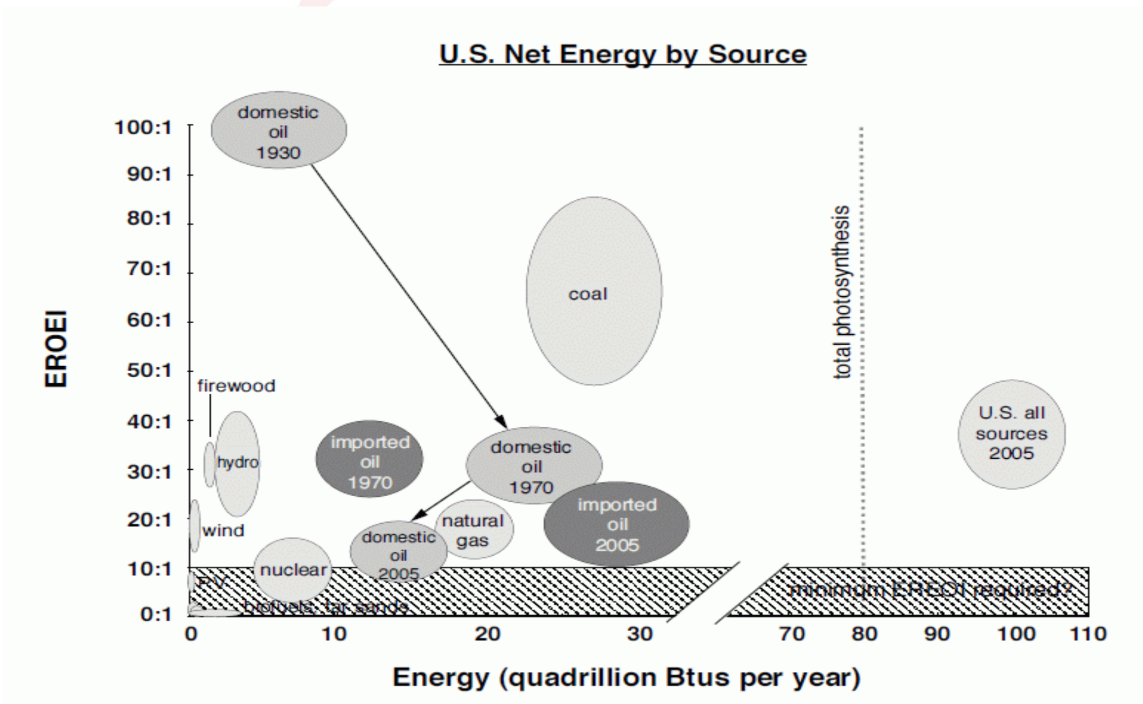

Figure 1: "Balloon graph" representing quality (y axis) and quantity (x axis) of the United States economy for various fuels at various times. The historical trend of decreasing net energy of oil is evident.
Source: US EIA, Cutler Cleveland and C. Hall

That brings us to the concept of *exergy* efficiency, which is closely related to the first and second law of thermodynamics (Hoang, 2010). Exergy efficiency (f) is expressed as the ratio of useful work outputs (U) to exergy inputs (E), depicted in the following formula:

f (exergy efficiency) =U (useful work outputs)E (exergy inputs)

The inclusion of useful work as a factor of production eliminates much of the unexplained Solow residual by effectively accounting for technological progress in terms of the decreasing exergy intensity of output and increasing efficiency of conversion of fuel inputs (exergy) to "useful work" (Warr, B., et al., 2010).

Both concepts of EROI and exergy efficiency are closely related, but whereas EROI indicates the qualitative side of energy investment, exergy analysis provides a more qualitative insight. Such concept of technical efficiency, as opposed to the economic efficiency, can be regarded not only as a reliable proxy measure of technical progress, but it can be applied whenever efficiency of energy policy is concerned, be it a production of bioethanol, tar-sands or a construction of nuclear power-plant.

As for the role of technological progress in dematerialization of the economy, there is no agreement. While skeptics point to the empirical fact that economic systems are necessarily material in nature (Daly, 1996), some researchers admit a theoretical possibility of highly dematerialized economy in the distant future (Ayres, 1998). And although it is impossible to define a finite absolute minimum material input for a unit of economic welfare in general, there is one notable exception – food. Dietary requirements cannot be dematerialized below the caloric intake required to keep our bodies healthy. Hence the issues of food and energy scarcity, as well as the size of global population are all closely interrelated (Figure 2).

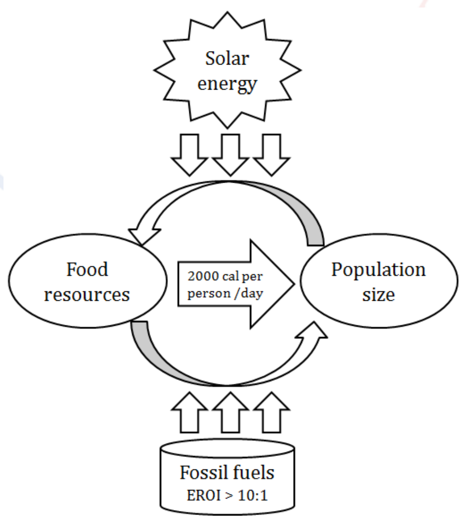

Figure 2. The relationship between energy, food and population

3.2. <u>*Complex efficiency* – the case of sustainable agriculture</u>

Energy efficiency as represented by EROI, though a necessary condition for the long-term viability of any ecosystem, is not sufficient as a sole guiding principle of efficient management of human affairs for the following reasons:

- it does not address the issue of equity, i.e. efficiency for whose sake?
- it does not address the issue of environmental resiliency, i.e. efficiency to what end?

As an example of multi-criteria evaluation of what I decided to label *complex efficiency*, let us consider the issue of sustainable agriculture and contrast it with the current model of industrial agriculture.

The economic efficiency of industrial agriculture is usually justified on the grounds of economies of scale, theory of comparative advantage, and low labor costs. As a result, political preference is given to monocultures, mechanization, subsidies to large farm operators and centralization of food distribution, all with the rationale of reducing monetary-costs (mainly labor costs) and increasing food surplus. This logic, however, is build on the assumption of perpetual economic growth fueled by an ever abundant supply of cheap energy, mainly oil and natural gas. Once we take fossil fuels out of the equation, suddenly the whole concept of efficiency collapses: human labor and animal power becomes more economical than fuel intensive machinery, biodiversity on small farms becomes more productive than monocultures on large-scale fields, and decentralized local production becomes more empowering than the centralized global distribution.

Also, when talking about efficiency of human economy, we need to ask the question of whom does efficiency benefit – in other words, we must address the issue of equity. Can we talk about efficient food supply, if it is in the hand of few oligopolistic firms? Shouldn't the issues of food sovereignty (Martinez-Alier, 2011), local empowerment, and employment all be included in the definition of socially effective agricultural policy?

Likewise, agricultural methods resulting in soil erosion and environmental degradation can hardly be called efficient. Hence, when talking about sustainable agriculture what we also need to consider are the long-term impacts on environmental resiliency, (Pretty, 2008).

What I propose here is to replace the neoclassical notion of short-term cost efficiency with a more comprehensive framework of complex efficiency, which would not only address the objective condition of energy efficiency (EROI), but would also include the normative spheres of social equity and environmental resiliency (Huppes, G., 2009). As a result, the issue of effectiveness of specific agricultural policy would no more rest solely in the hands of economists and government specialists, but a variety of stakeholders would also have their say in deciding what is efficient for them, their communities and their environment.

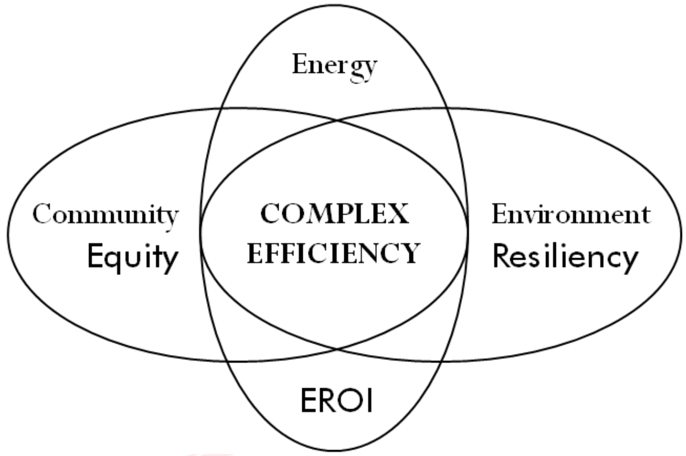

Figure 3. Complex efficiency for sustainable future

4. Implications for the post-fossil fuel world

Industrial agriculture, although energy inefficient and largely dependent on diminishing stock of fossil fuels, is what supports the ever growing global population. Energy prices are thus linked ever more closely with global food security, as was revealed by the global food crises of 2008 and even the recent uprisings in Middle East. High energy-intensity of centralized food supply thus represent its main vulnerability.

As a first step in tackling the dangers of rising energy scarcity, it is essential to adopt EROI analysis as a standard tool of energy policy planning. Though not without drawbacks, such as the problematic definition of system boundaries, its strength comes from its objectivity, as EROI directly reflects the reality of physical energy flows. Second, in order to extend the concept of economic efficiency into social and environmental systems, the concept of complex efficiency can be employed as a theoretical framework for a more comprehensive sustainability analysis. Despite the practical difficulty of evaluating normative issues such as equity or resiliency, it is nonetheless important to include these in the analysis, since all economic decisions are implicitly driven by normative goals anyway.

The question of the future roles agriculture should play within industrial countries is a topic of much heated debate. Much of the discussion stems from the confused definitions of efficiency – whereas some support free trade policies on the grounds of cost-efficiency, others point to the multiple functions that agriculture fulfills. What I wanted to demonstrate in this paper is that the concept of efficiency can have various meanings, depending on the scope of definition. Consequently, even if we can agree on the goals our economy should strive to fulfill, the means of achieving them invariably differ according to what definition we apply and also according to historic circumstances.

Whether it is environmental resource scarcity or nonrenewable resource markets that may pose a bigger challenge for the future, it is clear that the question of means (inputs), goals (outputs) and their interdependency (i.e. efficiency), needs to be reexamined. In the face of looming global energy and food crises, the close relation between food and energy scarcity needs to be recognized and tackled simultaneously, so as to soften the landing into a new paradigm of post-fossil fuel world.

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Effect of soil solarization in greenhouse agro-ecosystem of organic vegetable production

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Abstract: - Soil solarization as safe method can play an important role in plant pest and disease management in greenhouse agro-ecosystem. In this research we used soil solarization for the control weeds and pests and the same time for the increase of cucumber crop. The results were very significant in comparison to check plot. In addition, the soil solarizations have increased the stem length of cucumber plant almost twice as much as check plot and the same time crop production gone up to more twice in treatment plots with regards to check plots.

Key-Words: - soil solarization- greenhouse- organic- vegetable

1 Introduction

The problem of disease in greenhouse crop is severe, and their control by conventional methods is becoming very expensive and almost impossible. With the ban of Methyl bromide it is becoming very difficult to disinfect the soil and use of their chemicals are also uneconomical and at the same it is a threat to human safety [3]. Then we should look for alternative methods to replace the synthetic chemicals such as soil solarization which is very cheap in comparison to other methods, and very safe with no harms.

2 Material and methods

The greenhouse was divided to eight equal plots (each plots was 4.5×3 m) in two rows and one plot in each row were left untreated for check plots. (Fig.1)

1	2	3	4
8	7	6	5

Fig.1. Organic greenhouse divided to eight equal plots.

The trials were carried out in randomized complete design with two treatments and four replications. As you see in fig.1, three replications were done with no removed of weeds and no till. The last three replications were one as described in solarization manual with removal weeds tilling the soil. As numbered in the fig.1, the plots number 4, 8 were marked as check and plots number 1, 3, 6 were marked as till treatment and the plots number 2, 5, 7 were marked as no till treatment plots. All plots were irrigated by flood method and after the treated plots were covered by transplant polyethylene plastic [2]. The soil temperature under the plastic were measured daily by thermometer in different depth

We also measured the check plots temperature by thermometer as done in treatment plots. After two month during in summer (July to August) the cover plastic were removed from treatment plots and were irrigated again to see which weeds will emerge or otherwise to solarization had no effect on them. 17 days after irrigation the grown weeds were counted and were weighted by digital scale with accuracy 0.01 gr. The numbers of weeds grown in different plots were recorded.

After that all plots expect plot number 4, were shown by Saukrates cucumber variety with 40 cm spacing. The cucumber fruit were collected each two days on random basis then weighted and stem length were measured at the end of growing season.

3 Result and discussion

3.1 Comparison of temperature developed by solarization

Comparison of temperature developed by solarization at different depth of soil level as shown in fig.2

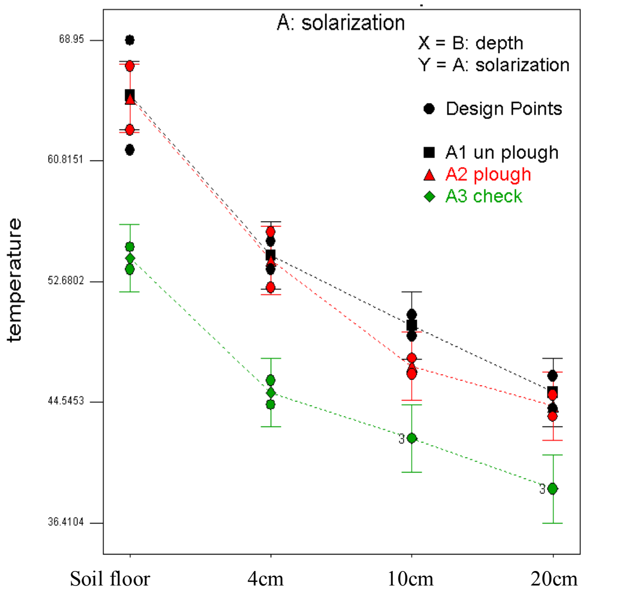

Fig.2. Comparison of temperature developed by solarization in 2 treatments and check plot

Fig.2 shows that ploughed and unploughed plots didn't show any significant difference. Comparison between check plots and treated plots showed very significant difference. As described in solarization manuals that the soil should be ploughed before solarization [1], but in our test we can conclude that there is no difference between ploughed and unploughed plots. The mean highest temperature were at soil floor in unploughed treatment plots ($68.95^{\circ C}$) and the mean least temperature at the same depth were in check plot ($54.25^{\circ C}$). The mean highest temperature of 20 cm depth greenhouse soil was in unploughed plots ($46.3^{\circ C}$) and the mean least temperature at the in same depth was in check plot.

3.2 The effect of soil solarization on destruction weeds seed

According to our results the mean weight of Common purslane and Bermuda grass were almost similar in treated plots and showed no significant difference but for treated and untreated (check) plots showed significant difference. (Fig 3 and 4)

The highest and lowest weights of Common purslane were in check plot (73.38 gram) and unploughed plots (0.63 gram), respectively.

The highest and lowest weights of Bermuda grass were in check plot (400gram) and unploughed plots (0.12 gram), respectively.

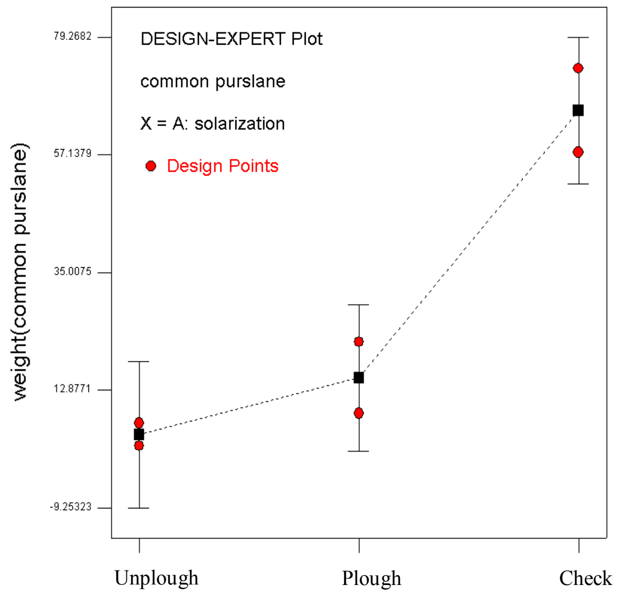

Fig.3. the mean weight of common purslane in 2 treatment and check plot

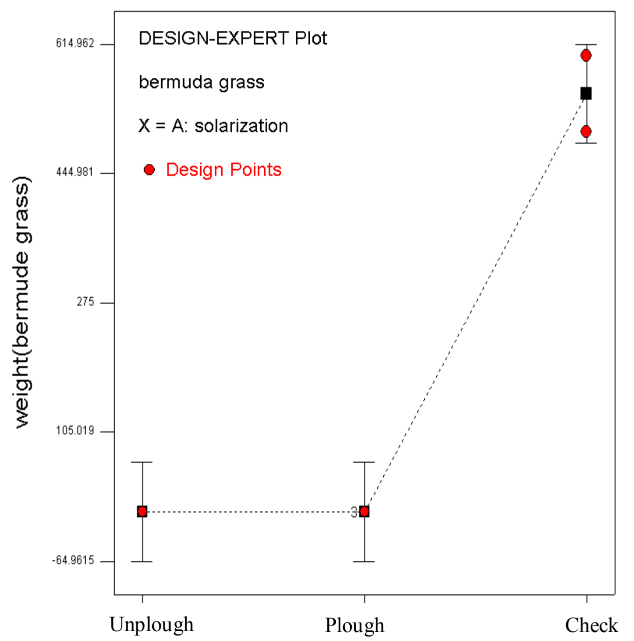

Fig.4. the mean weight of Bermuda grass in 2 treatment and check plot

According to our results the mean number of Field bindweed and Johnson grass were almost similar in treated plots and showed no significant difference but for treated and untreated (check) plots showed significant difference. (Fig 5 and 6)

The highest number of Johnson grass was in check plots (28 tillers), also The highest number of The Field bindweed was in check plots (3 weeds). The Field bindweed and Johnson grass didn't grow at all in both treated plots.

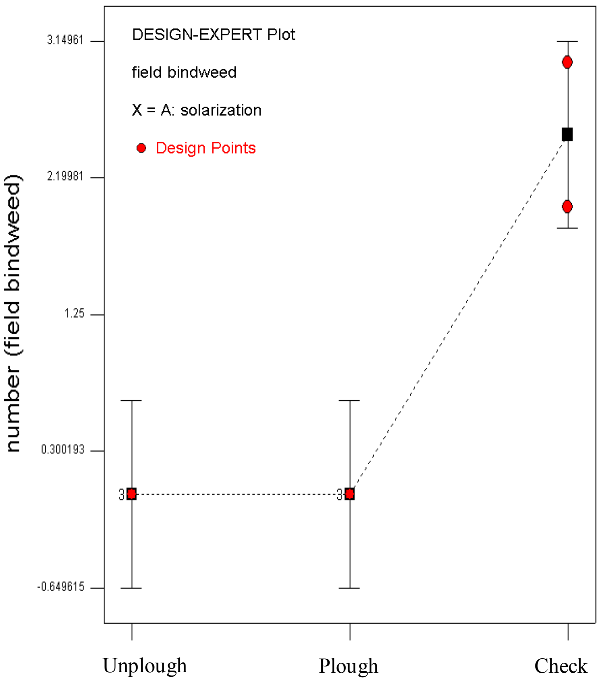

Fig.5. the mean number of Field bindweed in 2 treatment and check plot

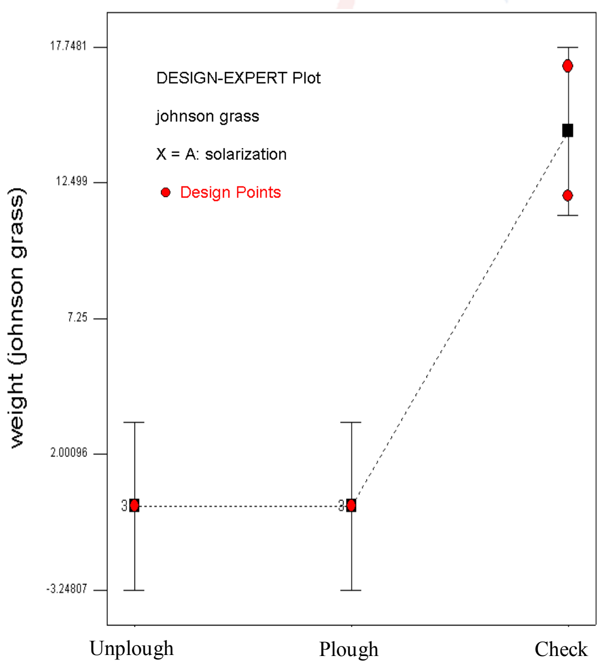

Fig.6. the mean number of Johnson grass in 2 treatment and check plot

3.3 The effect of soil solarization on crop production and stem length.

The soil solarization had dramatic effect on total output of crop and production.

E.g. the mean fruit production from one plant reach to 4100 gram in unplough treated plots in comparison in check plots the highest crop production per plant reach to 1700 gram.(Fig.7)

Also the stem length of plant reached to 10.20 meter in unploughed treatment plots but in check plot the highest stem length was 3.9 meter at end of cultivation season. (Fig.8)

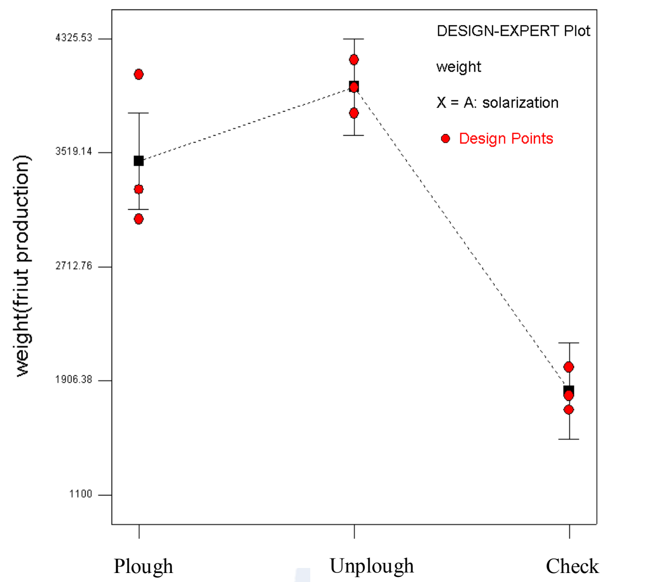

Fig.7. Effect of solarization on the mean weight of fruit from each plant cucumber in 2 treatment and check plot

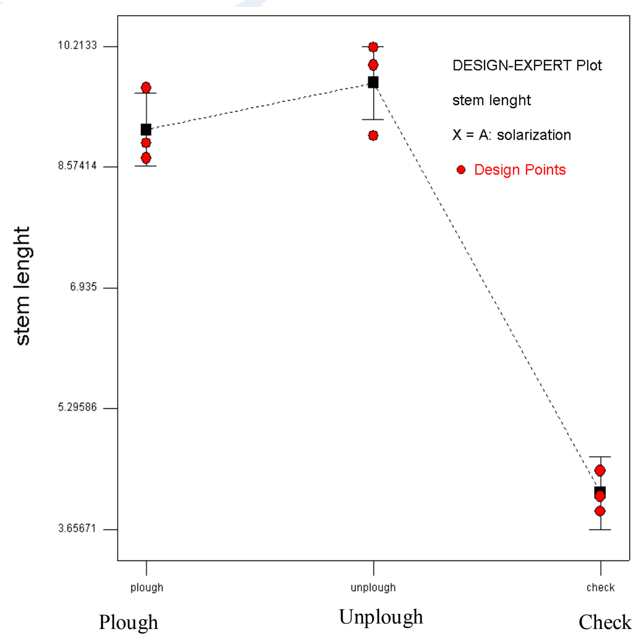

Fig.8.Effect of solarization on the mean stem length of plant in 2 treatment and check plot

In total, in treated plots the soil had more pores in soil texture and there the roots could penetration in soil more easily than untreated (check) plots.

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PUBLIC PARTICIPATION TOWARDS ENVIRONMENTAL ISSUES IN KOTA BHARU, KELANTAN, MALAYSIA

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ABSTRACT

Public participation has been recognized as key objectives for local, national and global environmental programmes and has been propagated through the various policies and declarations. Public participation means a process that participate the public in the decision making procedures of an organization. The objective of this paper is to highlight participation of Malaysian public in the environmental issues in order to achieve sustainable development. The study was to identify the public participation in environmental issues in Kota Bharu, Kelantan, Malaysia. The research was based on a set of questionnaire. A total of 200 respondents were interviewed and filled in questionnaire. From the study, Malaysian public are concerned about environment, but their concerns do not naturally translate into action. For Malaysian public participation to be successful, general public should be provided with effective notice of opportunities to participate in environmental issues, and provided with sufficient information to enable them to do so effectively.

Keywords: public participation, environmental issues, sustainable development, public awareness

INTRODUCTION

The principle of sustainable development encompasses social, environmental and economic issues, entailing concern with present and future generations. In order to move towards more sustainable development, there is the need to identify and increase the effectiveness of public participation in environmental issues. Promoting public participation in environmental issues has been deemed crucial in recent years. There was a clear need for action to be taken, to increase public awareness on the importance of the environment.

Public participation has been recognized as key objectives for local, national and global environmental programmes and has been propagated through the various policies and declarations such as the Rio Declaration, Earth Charter and UNEP Agenda 21. Principle 10 of the Rio Declaration for example encourages each country to have informed citizens who can participate in environmental management. The role of the Government, the media, schools and other institutions is important in raising awareness on environmental issues if the public is to understand environmental issues and participate at all levels.

Generally, participation can be defined as developing processes of collective learning that change the way that people think and act. In detail, public participation means a process that participate the public in the decision making procedures of an organization. These range from passive participation, where people are told what is to happen and act out predetermined roles, to self-mobilization, where people take initiatives largely independent of external institutions (Pretty 1995). Public participation in environmental matters can go by many names, among them community-based initiatives, community-based environmental management, collaborative, grass-roots ecosystem management, partnerships, community-based environmental protection and civic environmentalism.

Public participation in environmental matters includes the availability of opportunities for members of the public to provide input in the making of decisions which have, or are likely to have, an impact on the environment, including in the enactment of laws and enforcement of national laws, policies, and guidelines. The participation and involvement of public or local people in the sustainable management of environment matters will benefit them in terms of their livelihoods, recreation, socio-culture or spiritual resources and peaceful existence in the community. The public should be given authority and facilitation in identifying problems, deciding solutions, planning and implementing, monitoring and evaluation. It should also be involved in decisions regarding measures to address problems and opportunities. Only then will it be possible to enhance sustainability of management activities.

In Malaysia, in order to mitigate the adverse impacts of development on the environment, the Environmental Quality Act 1974 was amended to include EIA (Environment Impact Assessment) in 1985 and the order came into force in 1987. Malaysia has made it mandatory with respect to nineteen activities that are considered to leave deleterious effects on the ambience. The law provides for adhering to the widely accepted procedure, including people's participation, especially of those who might be affected by the proposed development project or any other activity to which an EIA is a necessary requirement. Public participation in decision-making in an EIA process brings together developers, government authorities and the public that helps to clear up misunderstanding and hatches a better understanding of relevant issues, meets public needs, enhances access to environmental information, leads to better development decisions, results in fewer court cases because areas of controversy are identified and most of them are hammered out at the early stage of the development or planning process, minimizes public frustration and anger, potentially enhances public trust of government decision-making, and strengthens credibility of the EIA regime (Glasson et al. 1999).

Furthermore, the Town and Country Planning Act 1976 introduced the concept of the Structure Plan and Local Plan. The idea of the Act was to ensure much more co-ordinated planning of development projects in each State with participation of local population. Referring Section 12A of this Act (which was amended in 2001), before commencing the preparation of a local plan, the local planning authority shall make publicity that the plan will be prepared with its objectives and the purposes, and the publicity should include the matters that the local planning authority proposes to be included in the plan. It shows Malaysian government has put an effort to increase the role of public in preparing development plans (Dasimah & Oliver 2008).

OBJECTIVE

The objective of this paper is to highlight participation of Malaysian public in the environmental issues in order to improve their involvement on sustainable development process.

METHODOLOGY

The study was to identify the public participation in environmental issues in Kota Bharu, Kelantan, one of the states in Malaysia. Kota Bharu is the capital of Kelantan state. The study was carried from January till April 2010. This research involved with primary and secondary data. The SPSS was applied for data analysis. The research was based on a set of questionnaire. A total of 200 respondents were interviewed and filled in questionnaire. Secondary data collected from the related agencies, journal, proceedings and books.

ANALYSIS AND FINDINGS

The analysis involved analyzing of feedback from the respondents who were involved in filled in the questionnaire. Feedbacks of respondents have been studied to identify the existing of public participation in environmental issues in order to improve the public involvement on sustainable matters of the development process. From the survey, it was found that, 50.5% respondents concern environment must be preserved and conserved because of their importance and contribution to human life. As evidence, 47% of respondents acknowledged the importance of environment in maintaining human health status and another 14.5% give an economic reason which environment destruction could effecting their income especially farmers. For that reason, 99.5% of the respondents strongly agreed that public participation and involvement are an essential part to achieve environmental sustainability. However, only 9.5% stated that public was the main stakeholders in protecting the environment. This is because only 5% respondents were have opportunity and invited by related agencies to involve in development process especially to discuss further about the effect of the project to the environment and local community.

The study was shown that, 90.5% respondents worried about environment deterioration phenomenon. Indeed, for 66.5% of respondents, industries and developers are the main actors in destructing the environment. For the question whether natural environment should be changed to other land use or development project which is unsustainable, 78% respondents disagreed. The study also found that, 63% of the respondents get the current information and related environmental issues from mass media especially television and radio. For them (85.5%), television is the most important tools in educating and increasing awareness among public regarding the importance of environment. According to 28% respondents, to minimize current environmental problems and increasing environmental quality, government should educating public the importance of public participation in environmental issues. Public should be educate regarding the purpose, importance and scope of their participation as well as the right, obligation and the proper ways for them to participate. Another 12.5% of the respondents suggest that the government should seriously consider in strengthening the roles of their related agencies regarding enforcement and making laws more compliance-friendly in order to enhance the quality of environment.

From the observation, it's still far beyond for Malaysian public to be main actors to protect the environment from deterioration. The main constraints which contribute to this situation are (Haliza 2008):

1. Poor public awareness and civil consciousness – many Malaysians are not aware of environmental problems although they may feel vaguely uneasy. Most don't care unless they are directly affected. This is also shortage of volunteers willing to spend their time and effort on environmental matters.
2. Limited response from the Government Agency – very often there is no reaction to complaints and memoranda or where is occurs, the response is inadequate or too slow. The bureaucrats and politicians do not take kindly to any criticisms.
3. Private sector hostility or fear – many of our capitalists, both local and foreign, regard the citizen movement as a threat to their profits and the luxurious life based on such profits. The economics costs of damage are very conveniently ignored.
4. Dearth of information on environmental problem exists despite claims to the country by some officials. Very little work is undertaken to make easily available to any interested Malaysian the full facts about our environmental problems.
5. Ignoring public participation – most of people in power both in the public and private sectors only paid lip-service to the right of public participation in environmental matters. Sometimes there is no initiative to include public representative as part of stakeholders in the development plan.

RECOMMENDATIONS AND CONCLUSIONS

Much of the environmental problems facing humanity are human-created but human society has chosen mostly to tackle them via the structural approach, employing science and technical solutions while ignoring the root causes (Chan 2010). This approach is ineffective. Thus, environmental issues are much more difficult to resolve, therefore, public awareness and participation is an essential part to achieve environmental sustainability. In Malaysia, it is still a challenge to ensure adequate and useful participation of public in the environmental issues. According to the feedback from respondents, the government should consider the following actions to increase the public participation (adaptation from Dasimah & Oliver 2008):

1. Establishing trust and credibility in the community through honesty and openness
2. Educating public on the importance of public participation in development process. This include educating the public regarding the purposes, importance and scope of the development plan, as well as the right, obligation and the proper ways for public to participate
3. Using simple and suitable language and also appropriate format of presentation (report, banner and multimedia presentation)
4. Involving the public early in the process, receiving feedback and addressing public concerns before making decisions
5. Understanding and respecting the values and limitations of participants
6. Providing sufficient in information on the development objectives, issues, challenges and potentials, existing environmental quality, positive and negative impacts of the proposed plan and the limitations of the development plan for public/participants
7. Inviting everyone to participate and giving equal opportunity to all participants
8. Providing on-line public participation

9. Providing longer period (more than one month) for public exhibition and it should include public holidays.
10. Showing high appreciation to the participants using appropriate approach, such as letter of appreciation informing them the actions taken by the planning authority on their opinions, comments or views.

Generally, Malaysian public are concerned about environment, but their concerns do not naturally translate into action. Therefore, challenges have to be overcome to allow creativity and synthesis in public participation process. For public participation to be successful, it is essential to maintain their involvement over time. To achieve that, general public should be provided with effective notice of opportunities to participate in environmental issues, and provided with sufficient information to enable them to do so effectively (Haliza 2010).

Luckily, over the years, the situation has changed. The deterioration of the environment, especially over the last twenty years, has created a great deal of concern among the public in order to manage and conserve the environment. The current situation showed that environmental awareness is increasing by public with increase number of citizen groups such as consumer organizations, NGO's and residential groups in providing dissenting views on development which degrades their surrounding environment. Opposition by local residents to the "Broga Incineration Project', public concerns about transboundary haze episodes and increased reports of illegal dumping of toxic are a few cases of many examples.

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Topic: Working towards enhancing the quality of urban life through a greener city: Aspects of policy and law in Malaysia relevant to urban green spaces development and environmental quality protection

Working towards enhancing the quality of urban life through a greener city: Aspects of policy and law in Malaysia relevant to urban green spaces development and environmental quality protection

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Abstract

Over the past decade, Malaysia has experienced a trend of rapid urbanization, with urban populations already represent over 60 percent of the total population. While urbanization is a natural consequence of economic development and industrialization, it does however lead to many challenges. One of which is the increasingly serious environmental pollution affecting the cities' sustainable development goals including that of pursuing a higher quality of life for the people. Considering the importance of upholding this sustainability goal, Malaysia is identifying various issues for consideration and measures for implementation. To that end, it is recognizing the importance of urban forests in improving environmental quality, and in providing livable places for its urban residents. At the same time, it is also recognizing urban development as a major threat to forest and other green spaces within the cities. For these reasons, Malaysia's policies on urban forest must take into account the need to promote tree-based resources catering to multiple urban demands, while balancing these demands against economic and other needs. For Malaysia, the implementation such policies has to be done through various means, including that of its integration within the legal framework. At present, there already exist a number of legislations that are directly or indirectly applicable to urban forests. In this paper, both these policies and laws are examined. The objective of this examination is to identify Malaysia's direction towards developing and protecting forests and other green spaces within the urban areas for the benefit of urban population and sustainable development.

Introduction

Being a developing country that strives to achieve the status of a developed nation by the year 2020, Malaysia considers economic development as a key player to achieve this target. Like other developing countries in the Southeast Asia, Malaysia experienced extremely high rates of urbanization especially for the past 20 years when the economy undergone major changes. These changes have led to a significant influx of rural people and migrants to urban centers. The present trend in Malaysia is that the rural population is on the decline. The projection of the percentage of urban population in Malaysia by 2030 is 77 per cent[1].

Malaysia's rapid urbanization in many of its cities and bigger towns has been accompanied by increasingly serious environmental pollution that may affect the country's sustainable living objectives. For this reason, Malaysia started to put more serious efforts in ensuring a better living condition of the urban population, including

[1] See the Department of Statistics Malaysia, http://www.statistics.gov.my/, date of accessed 10 April 2010.

enhancing the quality of the urban environment. One of such efforts taken by the government is through the development and protection of green spaces within the urban areas.

In any urban area, green spaces are considered to be important resources as they are part of the urban infrastructure, and are integral to the quality of life of its residents. For a developing country like Malaysia which is facing continuous environmental threats due to its rigorous economic development, urban green spaces would definitely provide various benefits to the community. Among their social benefits are those relating to health, employment, education, recreation, aesthetic and landscape benefits. In the context of environmental quality protection, green spaces can provide various services to urban areas. They include climate change and air quality improvement; energy savings, reduction of global warming and carbon dioxide; noise abatement; water use, reuse and conservation; soil conservation; solid wastes and land reclamation; and nature conservation, wildlife habitat and biodiversity.

Malaysia's seriousness towards developing and protecting urban green spaces has to be translated into policy directives and action plans. For this reason, it is necessary to identify and examine existing policy relevant to the matter, and to find out how Malaysia seeks to promote the objectives of these policies while balancing them against other priorities.

Policies

Up until now, there already exist a number of policy directives in Malaysia that stresses the importance of green spaces in enhancing the quality of life of the urban population. One of which is that of environmental policy. Generally, environmental policy is a manifestation of how the country's environment and natural resources are to be managed, and it has a direct impact on the way in which urban green spaces are to be developed and protected.

Policy directives pertaining to environmental protection can be found within the Malaysia's five year development plans or the Malaysia Plans. Until today, there are ten consecutive Malaysia Plans endorsed by the government, the latest being the Tenth Malaysia Plan (2011-2015) [2]. Within the Plans, sustainable development has been the guiding principle in formulating the environmental policy directive[3] through the integration of environmental consideration within economic development[4].

With sustainable development continues to be the key idea around environmental policy directives, the current Tenth Malaysia Plan looks at environmental protection in a holistic

[2] Jabatan Perdana Menteri, *Tenth Malaysia Plan 2011-2015,* Kuala Lumpur, Jabatan Percetakan Negara, 2011.
[3] Jabatan Perdana Menteri, *Ninth Malaysia Plan 2006-2010,* Kuala Lumpur, Jabatan Percetakan Negara, 2006.
[4] Malaysia's first ever environmental policy statements were made during the Third Malaysia Plan (1976-1980). See Jabatan Perdana Menteri, *Third Malaysia Plan 1976-1980,* Kuala Lumpur, Jabatan Percetakan Negara, 1976, p.219.

manner. For this reason, the Plan seeks to enhance the quality of life of the people, and ensures a high quality of life in urban and rural areas as parts of government's environmental commitments.[5]. In this regard, The Plan focuses, among other things, in building vibrant and attractive living spaces; and in prudent management and conservation of environmental resources. In addition, the Plan also focuses on the importance of open spaces and green corridors[6] as measures towards growing of cities in a sustainable manner. Among strategies included by the Plan are the introduction of guidelines for green townships, the requirement on the states to gazette forests as protected areas, and the planting of more trees to green the country[7].

Apart from the Malaysia Plans, policy on green spaces can also be found within the National Urbanization Policy (NUP). This policy which was introduced in 2006[8] aimed at creating a livable city with a peaceful community and living environment through sustainable urban development. The NUP was also introduced to manage the increasing number of urban population through an emphasis on socially, economically and physically balanced development of the Malaysian towns. For this reason, the NUP serves as the main thrust for all planning and urban development activities in the country[9]. Consequently, the NUP must be taken up by all implementation agencies for purposes of the followings[10]:

- To apply the NUP as the basic urban development framework for Peninsular Malaysia;
- To implement the NUP at federal, state and local government levels; and
- To interpret suggestions within the NUP into programmes and projects.

Within the NUP, various thrusts have been introduced to coordinate and guide the planning and development of urban areas. Several of these thrusts can be linked to urban green spaces development. For example, Thrust 1 of the NUP strives for the achievement of a sustainable urban development and contains a proposal for the conservation of environmentally sensitive area[11].

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[5] Jabatan Perdana Menteri, *Tenth Malaysia Plan 2011-2015,* Kuala Lumpur, Jabatan Percetakan Negara, 2011, p.245.

[6] Jabatan Perdana Menteri, *Tenth Malaysia Plan 2011-2015,* Kuala Lumpur, Jabatan Percetakan Negara, 2011, p.257.

[7] Jabatan Perdana Menteri, *Tenth Malaysia Plan 2011-2015,* Kuala Lumpur, Jabatan Percetakan Negara, 2011, p.305.

[8] This Policy was introduced by virtue of section 6B of the Town and Country Planning Act 1976, Amendment 2001, Act A1129.

[9] See the Department of Town and Country Planning Malaysia, http://www.townplan.gov.my/dpn/, date accessed 10 April 2009.

[10] See the *Pekeliling Majlis Perancangan Fizikal Negara Bilangan 5 (1/2007) Perlaksanaan Dasar Perbandaran Negara,* at the Department of Town and Country Planning Malaysia's official website at http://www.townplan.gov.my/, date of accessed 5 May 2009.

[11] See NUP 8 of Thrust 1 of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.43.

The term "environmentally sensitive area" under Thrust 1 is defined by the NUP as[12]:

> "an area rich in miscellaneous biology such as forest, swampland, environmentally risk area, erosion area and life supporting areas such as water catchment areas".

Within the NUP, areas considered as "environmentally sensitive" have been identified to include the following[13]:

- highland and steep;
- water catchment;
- wildlife and reserve;
- river;
- swampland;
- coastal;
- permanent forest reserve; and
- geological heritage and landscape.

Among the proposed conservation of the environmentally sensitive area includes the protection and maintenance of prime agriculture areas, as well as the establishment of green areas as buffer zones to limit urban development. In addition, the same thrust also targeting at providing adequate open space and recreational areas to meet the requirements of the population[14]. The term "open space" is defined by the NUP as "a space specifically meant for public use or benefit". This includes land or space allocated as an area for relaxation or picnic and recreation such as the followings[15]:

- gardens;
- children playground;
- playfield;
- sports ground;
- floral garden; and
- landscaped and planned area.

[12] See glossary of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.105.
[13] See glossary of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.105.
[14] See NUP 9 of Thrust 1 of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.43.
[15] See glossary of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.104.

Additionally, proposals relevant to open spaces and green areas could also be found within Thrust 5 of the NUP on the creation of conducive and livable urban environment. Under the NUP, the term "green areas" is defined as[16]:

> "forest reserve, prime agriculture area; environmentally sensitive area, open space and playground".

The Thrust 5's proposal, which echo the holistic approach of environmental policy directives of the Malaysia Plans, seeks for sustainable and environmentally friendly development that shall form the basis of environmental conservation and improve the urban quality of life[17]. For this purpose, the NUP requires that urban development to give emphasis to reduce air, noise and water pollution. It also requires the enforcement of legislations, guidelines and standards relating to environmental conservation, and to encourage activities that can help reduce the impact of urban heat islands.

Examination so far of existing policies has shown the value of green spaces within urban planning development and environmental protection in Malaysia. This is an indication of Malaysia's seriousness towards enhancing the quality of life of the urban population through the incorporation of green spaces within its urban development. While Malaysia's commitment has been indicated within the policy, it is also necessary to ensure that such policy is implemented through various means, including that of the law. Examination below seeks to identify provisions within the existing laws in Malaysia that are relevant on the matter.

Legislations

For Malaysia, local authority law is one of the most relevant laws for the purpose of urban green spaces development and environmental quality protection. Generally, the local authority in Malaysia has the jurisdiction on matters relating to urban planning and environmental protection within their area[18]. Existing local authority laws, namely the Local Government Act 1976, the Town and Country Planning Act 1976 and the Street Drainage and Building Act 1974, allow the local authority to carry out various functions relating to urban green spaces. Among such functions includes:

- maintenance and improvement of the environment within its locality;
- maintenance of parks and gardens;
- conservation of physical features such as rivers, streams, and trees; and
- prevention of air, water and land pollution.

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[16] See glossary of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.105.

[17] See NUP 26 of Thrust 1 of the National Urbanization Policy at Federal Department Town and Country Planning Peninsular Malaysia, *National Urbanisation Policy,* Kuala Lumpur, Ministry of Housing and Local Government, 2006, p.63.

[18] Refer to the Town and Country Planning Act 1976.

The local authority's function towards the protection of urban green spaces is further strengthened through the amendment of the Town and Country Planning Act 1976[19]. The amendment was done in 2001 to incorporate provisions that put a greater emphasis on open spaces and green areas within any planning development. Under this Act, the term "open space" is defined as[20]:

> "any land whether enclosed or not which is laid out or reserved for laying out wholly or partly as a public garden, park, sports and recreation ground, pleasure ground, walk or as a public space".

It is a requirement under the Act for the local authority to identify or propose the location of open spaces within any urban planning development, and to use their by-laws to gazette the identified open spaces in the local area[21].

Section 20 of the Act makes it a prohibition on any person to commence any development otherwise than in conformity with the planning permission granted to him. Under section 21A, it is a requirement for the applicant to submit a development proposal report which shall contain matters relating to the a description of the land including its physical environment, topography, landscape, geology, contours, drainage, water bodies and catchments and natural features thereon; and a survey of the trees and all forms of vegetation. For this purpose, section 21B which provides for the requirement of the layout plans requires that the plans in respect of any land should contain the following:

- measures for the protection and improvement of its physical environment;
- measures for the preservation of its natural topography;
- measures for the improvement of its landscape;
- measures for the preservation and planting of trees thereon;
- the location and species of trees with a girth exceeding 0.8 metre and other vegetation thereon;
- the making up of open spaces;
- the proposed earthworks, if any; and
- a description of the works to be carried out.

Any unauthorized development, including those affecting any green area or open spaces is an offence as provided in section 26. This section imposes penalties in a form of fine or imprisonment upon conviction.

Another provision under the Town and Country Planning Act 1976 pertinent to urban green spaces protection is that on the planting of trees as provided by the Tree Preservation Order. This Order was introduced during the amendment of the Act in

[19] Act 172.
[20] Section 2 of the Town and Country Planning Act 1976.
[21] See Parts IIB and III of the Town and Country Planning Act 1976.

1995[22] which is meant to address the issue of rapid development that neglects the importance of environmental conservation particularly with respect to tree preservation.

Specifically, section 35A authorizes the local planning authority, in the interest of amenity, to preserve any tree, trees or group of trees in its area through a tree preservation order with respect to such tree, trees, or group of trees. This preservation order may contain provisions relating to the prohibiting the felling of; and for securing the planting of trees or the replacement of trees by replanting in such manner as may be determined by the local planning authority. Clause (4) of section 35A provides for penalty for offences committed under section 35A which include the imposition of fine and imprisonment.

Additionally, under section 35E, the person who is found guilty under section 35A (4) for felling any tree in respect of Tree Preservation Order is also required to replace such tree by planting another tree. In the event of a failure to replace the tree, section 35F authorizes the local planning authority to proceed replacing such tree notwithstanding payment of a fine imposed[23]. Consequently, all costs and expenses reasonably incurred by it shall be reimbursed by the person in default of such replacement. Under section 35H, there is also a prohibition on the felling of trees with girth exceeding 0.8 metre. Any person who contravenes this provision commits an offence and may be liable to either a fine or imprisonment.

Another relevant local authority law, the Local Government Act 1976[24] provides that all open spaces and green areas come within the administration of the local authority if they are considered as a "public place". The Act defines "public place" as "any open space, parking place, garden, recreation and pleasure ground or square, whether enclosed or not, set apart or appropriated for the use of the public or to which the public shall at any time have access".

Matters relating to public place are set out in Part VII of the Act. Under section 63 the local government is authorized to deal with matter relating to the general control and care of all places within the local authority area for the use of the public[25]. For this purpose, the local government is empowered to deal with matters arising from the act of public nuisance within its area. While the provision on public nuisance under this Act is general, it can nevertheless be applied to include various aspects of urban green spaces, including the protection of natural resources within such forest such as cathment area and wildlife. One provision on public nuisance under this Act that is relevant to protect watercourses and river banks within urban forest are section 69 on the banks of a watercourse, and section 70 on the pollution of river. Similarly, another local authority law, the Street, Drainage and Building Act 1974[26] also provides provisions on nuisance which promotes environmental protection and cleanliness within urban green areas. They include section

[22] Act A933.
[23] Section 35E(5) of the Town and Country Planning Act 1976.
[24] Act 171.
[25] Section 64 of the Local Government Act 1976.
[26] Act 133.

68 on offences that constitute public nuisance, and section 70A on earthwork where any person must submit relevant plants and specifications to the local authority before carrying out any earthwork. Generally, provisions on public nuisance under both legislations are pertinent in providing direct and indirect protection of urban green spaces. Through these provisions, local authority can take actions against any person who commit nuisance affecting public interest, including that affecting environmental quality within the urban green areas.

Apart from the local authority laws, environmental law is another area of law that is relevant for the purpose of urban green spaces protection. The most relevant legislation is the Environmental Quality Act 1974. Generally, this Act deals mainly with environmental protection and pollution control, and has various strategies that are directly or indirectly relevant in the context of urban green spaces.

Under the Act, "environment" is defined as:

> "the physical factors of the surroundings of the human beings including water, atmosphere, climate, sound, odour, taste, the biological factors of animals and plants and the social factor of aesthetics". The term "element" in relation to the environment means "any of the principal constituent parts of the environment including water, atmosphere, soil, vegetation, climate, sound, odour, aesthetics, fish and wildlife". Whereas the term "segment" in relation to the environment means "any portion or portions of the environment expressed in terms of volume, space, area, quantity, quality, or time or any combination thereof".

The Act further defined the word "pollution" as:

> "any direct or indirect alteration of the physical, thermal, chemical, or biological properties of any part of the environment by discharging, emitting, or depositing environmentally hazardous substances, pollutants or wastes so as to affect any beneficial use adversely, to cause a condition which is hazardous or potentially hazardous to public health, safety, or welfare, or to animals, birds, wildlife, fish or aquatic life, or to plants or to cause a contravention of any condition, limitation, o restriction to which a licence under this Act is subject".

From the definitions above, it can be argued that while the Act may not specifically deal with urban green spaces protection, its scope is nevertheless wide enough to include environmental protection within such spaces for purposes of health, safety and welfare of the public. These definitions are also significant as they reiterate the objectives of Malaysia's environmental policy on the holistic approach towards environmental protection and quality of life enhancement.

One of the relevant sections under this Act is section 24 on soil pollution. "Soil" is defined here to include "earth, and, rock, shales, minerals and vegetation in the soil[27]". Section 24 restricts any person from polluting, or causing or permitting to be polluted any soil or surface of any land. According to clause (2) of section 24, a person is deemed to pollute any soil or surface of any land if he does any of the followings:

- he places in or on any soil or in any place where it may gain access to any soil any matter whether liquid, solid or gaseous; or
- he establishes on any land a refuse damp, garbage tip, soil and rock disposal site, sludge deposit site, waste-injection well or otherwise used land for the disposal of or a repository for solid or liquid wastes so as to be obnoxious or offensive to human beings or interfere with underground water or be detrimental to any beneficial use of the soil or the surface of the land.

Thus, this section can be applied in protecting urban green spaces against pollution through non-point discharges, such as the discharge of a liquid wastes on any such spaces. The same provision may also be applied to landfill owners, or any person who discharge wastes on such forest, or of such wastes produce leachate that leaks into any river within any urban green spaces and cause pollution to it. Under section 24, any person who is found guilty under this section is liable to a fine or imprisonment, or both.

For the purpose of the protection of water resources or catchment area within any urban green spaces, the most relevant provision is section 25. This section restricts any person from emitting, discharging or depositing any environmentally hazardous substances, pollutants or wastes into any inland waters. "Inland waters" are defined by the Act as "any reservoir, pond, lake, river, stream, canal, drain, spring or well, or any part of the sea above the low water line along the coast, or any other body of natural or artificial surface or subsurface water[28]". Under this section, various acts and omissions that constitutes inland water pollution offences are provided, including their penalty in a form of fine or imprisonment, or both.

Similar protection can also be given to green spaces in relation to air pollution under section 22 of the Act. This section restricts any person from discharging any environmentally hazardous substances, pollutants or wastes into the atmosphere. Among actions that constitute such discharge include:

- placing any matter in a place where it may be released into the atmosphere;
- causing or permiting the discharge of odours which by virtue of their nature, concentration, volume or extent are obnoxious or offensive;
- burning of any wastes of the trade, process or industry; or
- using any fuel burning equipment not equipped with any device or control equipment required to be fitted to such equipment.

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[27] See Section 2 of the Environmental Quality Act 1974.
[28] See Section 2 of the Environmental Quality Act 1974.

Under this section, any person who is found guilty of the offence under section 22 shall be liable to either a fine or imprisonment.

Apart from provisions on pollution control, another relevant provision under the Environmental Quality Act 1974 is that on environmental impact assessment (EIA) under section 34A. In the Malaysian context, EIA is introduced as a measure to achieve the objective of sustainable development. Thus, EIA is applied not only for the purpose of preventing potential environmental degradation but also for ensuring the balance between economic development and environmental protection. For these reasons, EIA requirement is made compulsory on activities deemed to have adverse effects on the environment.

At present, there are 19 activities classified as “prescribed activities” that require the submission of the EIA report. The list of these activities is provided in the Environmental Quality (Prescribed Activities)(Environmental Impact Assessment) Order 1987. Some of these activities relate, directly or otherwise, to the protection of urban green spaces. They include:

- specified agricultural developments proposal;
- airports;
- drainage and irrigation;
- land reclamation;
- forestry;
- housing;
- industry;
- infrastructure;
- mining;
- quarries;
- railways;
- transportation;
- resort and recreational development; and
- water supply

Prescribed activities that may be relevant to urban green spaces as stated above can involve some degree of adverse environmental impact which occur during preconstruction, construction and operational stages. These impacts include water logging, salt water intrusion, alteration of river features, soil erosion and sedimentation, changes of environmental quality, public health and communicable diseases and impairment of beneficial uses of environmental resources[29].

[29]For further elaboration on the impact of the water-related activities on water resource, see Department of Environment, *Environmental Impact Assessment Guidelines for Drainage and/or Irrigation Projects*, Kuala Lumpur, Department of Environment, 1995.

During the implementation of the project, green areas and other environmental resources may be affected due to several reasons such as the project being situated in a water catchment area or very steep slopes; it involves land clearing; it causes land erosion and siltation; it has poor drainage facility and improper sewage treatment; or poor water management. The primary objective of EIA on this type of project is to ensure, among other things, that during construction and operational stages, the project takes mitigating measures to avoid soil erosion and sedimentation of water resources. EIA is important to ensure that not only the development of this particular project is properly located and planned, its environmental degradation is also avoided or minimised.

Under section 34A, any person intending to carry out any of the listed activities is required to submit to the Department of Environment for his approval a report containing an assessment of the impact the activity is likely to have on the environment. Any person who fails to comply with the provisions of section 34A may be liable to a fine or imprisonment, or to both.

Apart from environmental law, another area law relevant for the purpose of urban green spaces protection is the one of forestry, specifically the National Forestry Act 1974[30]. While this Act is meant to provide for conservation and protection of forest in general, it is nevertheless significant towards forests that are situated within the urban areas. One of the main conservation strategy introduced under this Act is through the power given to the state authority under section 7 to constitute any land as a permanent reserved forest. Forest land can be gazette as a permanent reserved forest for various classifications as provided in section 10. They include:

- timber production forest under sustained yield;
- soil protection forest;
- soil reclamation forest;
- flood control forest;
- water catchment forest;
- forest sanctuary for wild life;
- virgin jungle reserved forest;
- amenity forest;
- education forest;
- research forest; and
- forest for federal purposes.

Further protection is given to the permanent reserved forest through the imposition of penalties. Under section 15 (1), any person is prohibited from taking any forest produce from a permanent reserved forest except under the authority of a licence. This section imposed a penalty of up to RM500000 and to imprisonment for a term which shall not be less than one year but shall not exceed twenty years or to both such fine and imprisonment[31]. Under section 32, no person shall occupy or carry out any activity upon any land within a permanent reserved forest, unless he is the holder of a use permit. Any

[30] Act 313.
[31] Section 15(2) of the National Forestry Act 1984.

person who contravenes this provision shall be guilty of an offence and shall on conviction be liable to a fine not exceeding RM50000 ringgit or to imprisonment for a term not exceeding five years or to both such fine and imprisonment.

In addition, offensive littering in a permanent reserved forest is also an offence under section 83 of the Act. Those who found guilty under this Act may be liable to a fine not exceeding RM10000 or to imprisonment for a term not exceeding three years or to both such fine and imprisonment. Under section 83 (3), offensive littering in a permanent reserved forest includes creating an objectionable stench or degrades the beauty or the appearance of property or detracts from the natural cleanliness or safety of property by intentionally through the following acts:

- discarding or depositing any rubbish, trash, garbage, debris or other refuse;
- draining, or causing or permitting to be drained, mining sludge, industrial effluent, sewage or the drainage from a cesspool, septic tank, recreational or camping vehicle waste holding tank or other contaminated source; or
- permitting any rubbish, trash, garbage, debris or other refuse to be thrown from a vehicle which he is operating or which is under his control.

Arguably, provisions on permanent reserved forest under this Act can be applied upon forests that are situated within the urban areas. For example, within the city of Kuala Lumpur, there exist three forest reserves namely the Bukit Nanas Forest Reserves, Bukit Sungai Puteh Forest Reserve and Sungai Besi Forest Reserve. These residual forests are Kuala Lumpur's very important areas of natural environment but at the same time are facing threat of development. Thus, such provisions are pertinent particularly towards their protection.

Conclusion

In essence, Malaysia's holistic environmental policy directives are significant in the context of both environmental protection, and quality of life enhancement. What is equally significant is the recognition given to the importance of green spaces towards enhancing the quality of life of the urban population. Such recognition is an indication of the shift in the understanding of the roles of green spaces at raising the city profile. This is also an indication of Malaysia's changing priorities while seeking new approaches to achieve the broader goal of sustainable development. In relation to the law, up until now, Malaysia already has a range of laws on urban green spaces to implement the policy objectives. These laws, mainly in forms of local authority law, environmental law and forestry law, provide various strategies towards the development and protection of green spaces within the urban areas.

For Malaysia, having policy and law on urban green spaces is definitely the right step towards achieving the objectives of sustainable and quality living of the urban population. However, Malaysia still has a long way to go in order to successfully attain the said objectives. Arguably, matters relating to urban green spaces are in fact complex issues causing a great challenge for Malaysia. Green spaces, particularly forest areas are still a contested resource because of different values, functions and interests affecting their different uses and legal jurisdiction. Thus, next steps for Malaysia are to identify possible challenges, and to work towards overcoming them. With continuous commitments, it is possible that the policy targets of providing sustainable and quality living environment to the urban population through the betterment of urban green spaces can be achieved.

Thermal modeling of parabolic solar water heaters by adapting the fully mixed model of the storage tank

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Abstract

Predicting storage tank temperature in parabolic solar water heaters through a simple, capable model has always been a challenge for such systems designers. Furthermore, low computational load during the model usage in simulation and low error is of great importance. Due to unreliability of the available non-stratified (fully mixed) storage tank models, either the storage tank should be stratified or the available models should be adapted to become reliable. Since the storage tank stratified model leads to high computational load, here the available non-stratified model for the storage tank is adapted in order to present a reliable model. By modeling the parabolic collector and the piping in the simplest way possible and considering these models in the adapted model of the storage tank a simple, accurate thermal model for parabolic solar water heaters is presented.

Due to the gray box modeling, the unknown parameters of the presented model are either determined from constructional data such as water specifications, or by applying genetic algorithm (G.A.) technique based on the experimental data. The responses of the corresponding model are then compared with the experimental data in order to validate the accuracy and the performance of the presented model. The results obtained demonstrate the viability of the proposed model.

Keywords: Parabolic solar water heaters, Storage tank modeling, Non-stratified thermal model, Grey-box modeling, Genetic algorithm method.

1. Introduction

In this paper developed models for a solar collector [1] and a storage tank [2] are adapted to model a parabolic solar water heater. Like other thermal systems the adapted model is a grey-box model which is involved with unknown parameters. The grey-box approach to model construction stems from the fact that it is best to take advantage of the fundamental knowledge of a system. This knowledge is usually expressed in terms of a set of ordinary or partial differential equations obtained from basic principles [3]. For identifying the unknown parameters an optimization tool is needed. Genetic algorithm method has been used to adjust the parameters of the model to the observed experimental data. Genetic algorithms have many advantages over the conventional optimization methods. It does not require a complete system model and can be employed to globally search for the optimal solution [4].When the identified model is nonlinear in the parameters, using conventional methods like standard least squares technique will not provide superior results. In these cases, genetic algorithm methodologies are investigated as potential solutions to obtain good estimation of the model parameters [5-7].

The paper is organized as follows: Section 2 describes the parabolic solar water heater prototype in detail. The grey-box model is introduced in Section 3 along with the G.A. method used to adjust its unknown parameters. Afterwards the responses of the adapted model are compared with real data in a variety of situations in Section 4 to validate the proposed model and the results are discussed. The paper ends with some conclusions.

2. Parabolic solar water heater description

The K.N.Toosi University of Technology parabolic solar collector and a thermal storage tank together form a prototype of a parabolic solar water heater (See fig. 1) [8]. This facility has been used for two years as test bed of various control strategies. In the various types of solar water heaters [9], this solar water heater is a split, open type with parabolic collector.

Fig 1. The K.N.Toosi University of technology parabolic solar water heater [8]

From the point of view of control, the manipulated variable is the fluid flow rate which can be adjusted by a control valve (See fig. 2). The water heater specifications are demonstrated in table 1. By changing this flow rate it is possible to control the collector outlet and storage unit temperature to some extent.

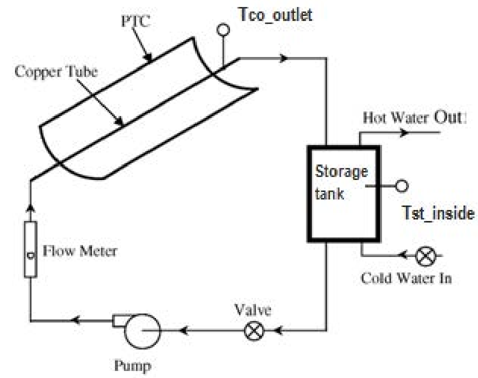

Fig 2. Piping diagram of the solar water heater

Table 1. Parabolic solar water heater specifications [8]

Collector specifications			
Aperture width (meter)	1	Mirror thickness (mm)	4
Collector length (meter)	2	Concentration ratio	90
Parabola focal point distance (cm)	25	Acceptable angle (degree)	2.5
Receiver outer diameter (mm)	22	edge angle (degree)	90
Receiver inner diameter (mm)	20		
Storage tank specifications			
Maximum capacity (lit)	60	Storage scale (cm)	50×50×50
Insulation type	2		
Equipments specifications			
Pump power (Watt)	80	Pump head (meter)	10
Pump flow (lit per min)	1-15	Stepper motor torque (Kg × cm)	40

3. Component modeling and identification

3.1. Piping model

Due to the short length of piping between the storage tank and the collector (1) and (2) are assumable. If the piping is not short in length, (1) and (2) should be adapted considering the energy losses of the piping.

$$T_1 = T_{st_{inlet}} = T_{co_{outlet}} \tag{1}$$

$$T_2 = T_{co_{inlet}} = T_{st_{outlet}} \tag{2}$$

Parameters and symbols used in (1), (2) and other following equations of this paper are all introduced in the symbols section at the end of the paper.

3.2. Storage tank model

The storage tank consists of a steel box equipped with insulation (figure 3). Basic thermodynamic laws are considered in modeling the storage tank. Some simplifying assumptions are considering the fluid in the storage tank to be homogeneous and modeling the storage tank as fully mixed (due to the storage tank small size). This introduces a source of error in the model. This is unavoidable since there are no other measurement than the one provided by the storage temperature sensor. Considering these assumptions, (3) is assumable.

$$T_{st_{inside}} = T_2 \tag{3}$$

Based on storage tank structure following phenomena are introduced for thermal analyses of the storage tank.

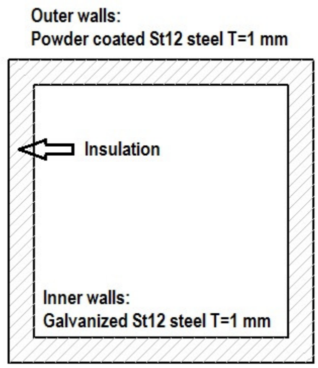

Fig 3. Storage tank structure

Transport. During the operation, fluid cycles from the collector to the storage unit and vice versa. This causes changes in their energy content. This procedure has two effects. The temperature of water that enters the collector rises quickly and by entering to the tank it rises the storage tank temperature. Considering the storage unit to be ideal (i.e. fluid is only heated in the storage unit and there is no energy loss happening in this process) the storage tank is analytically modeled by (4), [1].

$$\dot{T}_2 = \frac{q(T_1 - T_2)}{V} \tag{4}$$

Conduction. By modeling the storage tank as fully mixed, this is sensible to neglect the fluid conduction in the storage tank. To compensate this, here the thermal effect of the storage inner steel box is added to the fully mixed model of storage tanks. To consider this effect the inner steel box is assumed to be at the same temperature of the fluid. Based on this assumption the above analytic formula of the thermal storage tanks is adapted by (5).

$$\dot{T}_2 = \frac{q(T_1 - T_2)}{V + V_{eq}} \tag{5}$$

The parameter V_{eq}, is the same parameter used to compensate the stratification neglect in storage tank modeling to some extent. If the storage tank capacity of the solar water heater is too high, (5) could be changed and replaced by a stratified storage tank thermal model. The maximum storage tank capacity which this model is reliable for has not been discussed in this paper.

Losses to ambient. Another conduction heat transfer happens through the insulation. In (6) and (7) the effect of this phenomenon is added to (5).

$$T_3 = T_{st_{outside}} \tag{6}$$

$$\dot{T}_2 = \frac{q(T_1 - T_2)}{V + V_{eq}} - \frac{KA_{st_{in}}(T_2 - T_3)}{\rho_f c_{Pf} L_{st}(V + V_{eq})} \tag{7}$$

Energy losing from outer walls happens due to the gradual increment in the tank outside surfaces temperature. As the temperature of the tank outside surfaces rises, the convection current becomes stronger and causes energy losing. The outer walls of the storage tank are very thin so it is assumed that the two sides of the walls are in a same temperature. Considering this energy balance equation of the storage tank outside walls leads to (8).

$$\dot{T}_3 = \frac{KA_{st_{in}}(T_2 - T_3)}{m_{st} c_{st} L_{st}} - \frac{h_{st} A_{st_{out}}(T_3 - T_{amb})}{m_{st} c_{st}} \tag{8}$$

3.3. Collector model

The collector model [1] is adapted using energy balance equation for the receiver tube. This model is presented by (9) and (10).

$$T_{ave} = \frac{T_1 + T_2}{2} \tag{9}$$

$$\dot{T}_1 = \frac{\eta_{opt} I_{dir} G}{\rho_f c_{pf} L_R A_R} - \frac{q(T_1 - T_2)}{L_R A_R} - \frac{\pi D_{out} L_R h_R (T_{ave} - T_{amb}) + e}{\rho_f c_{pf} L_R A_R} \tag{10}$$

In (10), the solar irradiation (I_{dir}) is calculated according to the Daneshyar formula [10]. After modeling all components of the parabolic solar water heater the related thermal model can be presented by (7), (8) and (10). In the presented model of parabolic solar water heaters, magnitudes of seven parameters (η_{opt}, h_R, e, V_{eq}, K, h_{st} and m_{st}) are not exactly determined, thus, these unknown parameters must be identified. Other coefficients can either be determined from spatial specification of the parabolic solar water heater or the physical properties of the materials.

3.4. Unknown parameters identification

To identify the seven mentioned unknown parameters an experiment was conducted on 6th August 2010. Using G.A. optimization method the six parameters were identified as shown in table 2 according to the conducted test.

Table 2. Identified parameters

Parameters	η_{opt}	h_R	e	V_{eq}	K	h_{st}	m_{st}
Value	0.6875	77.20	4.23	0.0027	0.666	58.66	2.41

G.A. settings are presented in table 3 and the fitness function to be used in G.A. method is shown in (11).

Table 3. G.A. settings

Item	**Value**	**Item**	**Value**
Population size	20	Migration	Forward, fraction: 0.2, int.: 20
Crossover rate	0.8		
Mutation rate	0.2	Selecting	Stochastic uniform
Generations	20-30	Reproduction	Elite count: 2

$$Fitness\ Function = \frac{\sqrt{\left(T_{1_{plant}} - T_{1_{model}}\right)^2} + \sqrt{\left(T_{2_{plant}} - T_{2_{model}}\right)^2}}{2} \qquad (11)$$

4. Experimental results and discussion

After identifying the unknown parameters two other experiments were conducted on 7th and 12th August 2010 in various conditions (See table 4) to validate the model and the identification process. Figure 4 and figure 5 compare model output with real data of the two conducted experiments.

Table 4. Various conditions of each experiment

Date	**Water volume** (lit)	**Flow rate** (lit/min)	**Weather condition**	**Location**
6th AUG 2010 (Training test)	25.3	2.34	Sunny	Iran - Tehran
7th AUG 2010 (Validating test)	40	2	Sunny	Iran - Tehran
12th AUG 2010 (Validating test)	30	5	Sunny	Iran - Tehran

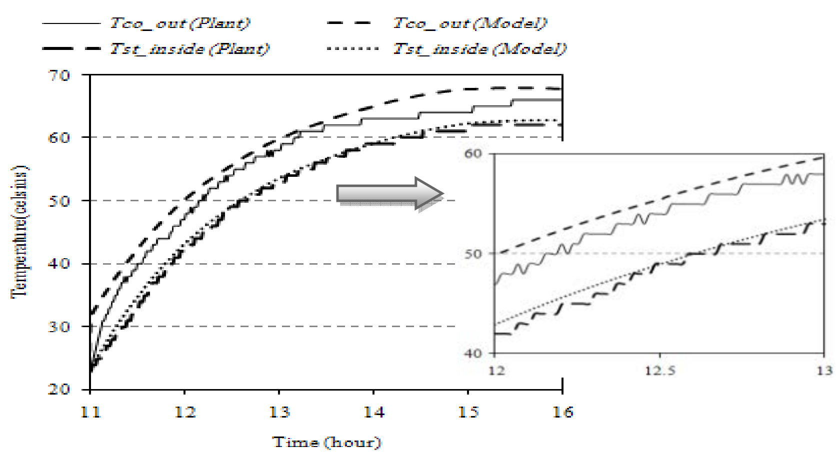

Fig 4. Model output and real data of the 7th August 2010 test

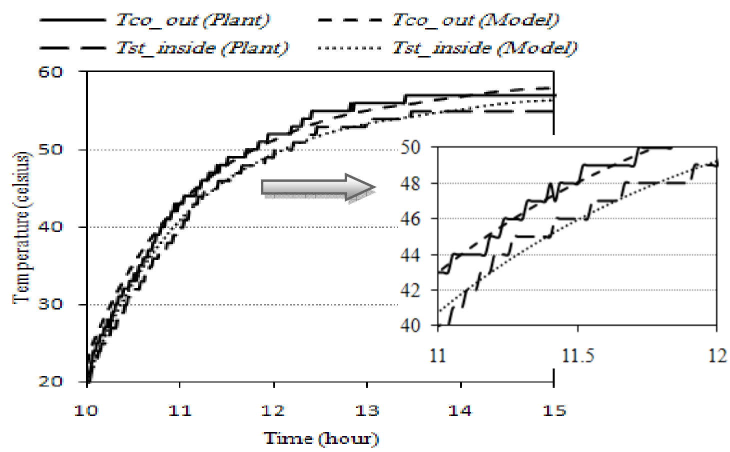

Fig 5. Model output and real data of the 12th August 2010 test

As it is shown in figures 4 and 5 the model is predicting the real data in an acceptable manner. The average error of the model is indicated in table 5.

Table 5. The model average error

Date of experiment	Place of measuring	Average error
7th AUG 2010	Collector outlet	4.45 %
	Inside storage unit	1.65 %
12th AUG 2010	Collector outlet	1.73 %
	Inside storage unit	1.45 %

5. Conclusion

In this paper simple models of a parabolic collector and a storage tank were adapted to model a parabolic solar water heater. The model can predict the real data in an acceptable manner as it was shown in section 4. Since this adapted model contains physical parameters and low computational load during its use in simulation, it can be used in the parabolic solar water heaters designing. This includes designing of both dimensional specifications of the components such as the collector aperture, and technical specifications such as the water flow rate. Such designing could improve the abilities of software which are currently used in solar systems designing such as Polysun [11]. By modeling other solar equipments and apparatus and identifying the related parameters for each manufacturer a great database could be produced to be used for dimensional and technical designing of solar systems.

List of Symbols

A_R	Receiver tube section area
$A_{st_{in}}$	Surface of storage tank inner steel box
$A_{st_{out}}$	Surface of storage tank outer box
c_{pf}	Water specific heat capacity
c_{st}	Specific heat capacity of storage tank outer box
D_{out}	Receiver tube outer diameter
e	Constant error of collector modeling
G	Collector aperture
h_R	Receiver tube convection coefficient
h_{st}	Convection coefficient of storage tank outer box
I_{dir}	Solar irradiation
K	Insulation conductivity
L_{st}	Length of storage tank insulation
L_R	Receiver tube length
m_{st}	Mass of storage outer box
q	Pump flow rate
T_{amb}	Ambient temperature
T_{ave}	Average receiver tube temperature
$T_{co_{inlet}}$	Collector inlet temperature
$T_{co_{outlet}}$	Collector outlet temperature
$T_{st_{inlet}}$	Storage tank inlet temperature

$T_{st_{inside}}$	Storage tank inside temperature (Storage tank temperature)
$T_{st_{outlet}}$	Storage tank outlet temperature
$T_{st_{outside}}$	Temperature of storage tank outer box
t	Time
V	Water volume in the storage tank
V_{eq}	Equivalent of the storage tank inner steel box to consider its thermal effect (The same parameter which is considered to adapt the thermal model of fully mixed storage tanks)

Greek symbols

ρ_f	Water density
η_{opt}	Collector efficiency

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