Greenhouse Gas Emissions of Robusta Coffee Plantation in Thailand

Tanomlap Rachawat, King Mongkut's University of Technology Thonburi, Thailand
Siriluk Chiarakorn, King Mongkut's University of Technology Thonburi, Thailand
Amnat Chidthaisong, King Mongkut's University of Technology Thonburi, Thailand

The Asian Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
Robusta coffee is one of main industrial crops in Thailand. Most of robusta coffee beans are used as raw materials for instant coffee products. The greenhouse gas (GHG) emissions of robusta coffee product from acquisition of coffee cherries are necessary data to assess the carbon footprint of robusta coffee products. This paper studied GHG emissions and identified the hotspots of robusta coffee plantation in Thailand. The 180 datasets were collected by questionnaires and field surveys in Chumphon province, the largest robusta coffee planting area in Thailand, in the year 2014. The functional unit of analysis was 1 kg of robusta fresh coffee cherry. The scope of the study included land preparation, cultivation and harvest. The amount of GHG emissions in a unit of kgCO_2e/kg of fresh coffee cherry was calculated by following the guidelines of carbon footprint of the product method provided from Thailand Greenhouse gas management organization (public organization) and emission factors were referred from national life cycle inventory and IPCC databases. The results showed that the GHG emissions from small (0.16-1.60 ha), medium (1.61-3.20 ha), and large planting area (more than 3.20 ha) were 1.19, 1.25 and 1.11 kgCO_2e/kg of fresh coffee cherry, respectively. The weighted average of GHG emissions was 1.20 kgCO_2e/kg of fresh coffee cherry. The largest GHG emissions was from fertilizers (96%), followed by herbicides (1%), organic fertilizer (2%) and fossil fuel consumed in agricultural machines (1%).

Keywords:Robusta coffee, coffee cherry, plantation, greenhouse gas emissions, Thailand

1.Introduction

In Thailand, the coffee industry has grown rapidly due to high demand markets. It was reported that the revenues from coffee products in Thailand was up to 2,500 million baht in 2008 with total productivity of 50,442 tonnes [1]. 95 % of coffee products are from robusta coffee, which is commonly grown in the south of Thailand, especially in Chumphon and Ranong Province. However, in the past few years, coffee products from Thailand lost their competitive export because coffee products from Vietnam and Indonesia have lower production cost and to be sold in lower price [2]. Accordingly, the Department of Agriculture has drafted a strategic plan focused on the development of the coffee industry during the year 2014-2017 [2]. The ultimate gold of this strategy is to increase the export values from coffee products by encouraging coffee farmers to improve coffee productivity and reducing production cost and environmental impacts through the whole production chains [2]. The first step to follow the strategic plans is identifying the hotspots of resource consumption and environmental impacts from coffee cultivation. This research aims to study the inventory of resources used and estimate greenhouse gas (GHGs) emissions from robusta coffee cultivation. The outcome of this study will be preliminary information supporting the development of coffee industry in Thailand.

2. Methods

2.1 Data collection

The primary data collection was conducted in Chumphon province, located in the south of Thailand which is the largest robusta coffee planting area in Thailand. The size of the sample of the population in the study was calculated by Taro Yamane's method as shown in Eq.1 [3]. The 180 datasets were obtained by questionnaires and field surveys. The questionnaires were designed for collecting all necessary data for assessment of GHG emissions. In this study, the area of robusta coffee cultivation was 518.08 ha, which can be divided into 3 sizes such as a small farm (0.16-1.60 ha), a medium farm (1.61-3.20 ha) and a large farm (more than 3.20 ha).

$$n = \frac{N}{1 + Ne^2} \qquad \text{(Eq.1)}$$

n = sample size required.
N = population size
e = sampling error can be accepted.

The numbers of datasets divided by plantation area are presented in table 1.

Table 1 Number of datasets divided by plantation area

Small plantation area (0.16-1.60 ha)	Medium plantation area (0.16-1.60 ha)	Large plantation area (0.16-1.60 ha)
42 datasets	92 datasets	46 datasets

2.2. Calculation of carbon footprints

In this study, Life Cycle Assessment of the product (LCA) is used as a tool to calculate GHG emission from robusta coffee cultivation. The scope of this study is shown in Fig. 1. The process starts from land preparation, cultivation, maintenance and harvest. The inventory of raw materials, resources, energy, wastes during cultivation process was constructed, based on a functional unit of 1 kg fresh robusta coffee cherry as presented in Table 2. The activity data were then converted to GHG emissions by following the guidelines of carbon footprint of the product method provided from Thailand Greenhouse gas management organization (public organization) and emission factors were referred from national life cycle inventory [4] and IPCC databases [5].

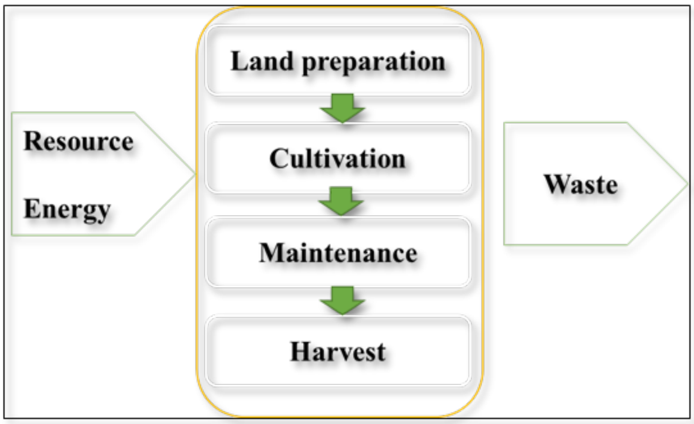

Figure 1 Scope of this study

Table 2 Inventory of data collection in this study

Process	Unit	Activity data	data collection
Land preparation	kg	No machinery, herbicides and fertilizers used.	questionnaires and field surveys
Cultivation	kg	▪ organic fertilizer	questionnaires and field surveys
Maintenance	kg L L kg	▪ chemical fertilizer ▪ gasoline ▪ diesel ▪ herbicide	questionnaires and field surveys
Harvest	kg	No machinery used.	questionnaires and field surveys

GHG emission was calculated by the guidelines of carbon footprint of the product method provided from Thailand Greenhouse gas management organization (Eq.2)

$$\text{GHG Emission (kg } CO_2) = \sum \left[\text{Activity data (unit)} \times \text{EF (kg } CO_2\text{/unit)}\right] \quad \text{(Eq.2)}$$

Emission factors used in this study was shown in Table 3.

Table 3 Emission factors used in this study

Activity data	Unit	Emission factors (kgCO_2eq/unit)	References
Organic fertilizer	kg	0.3320	[5]
Chemical fertilizers			
▪ 15-15-15	kg	1.5083	[6]
▪ 13-13-21	kg	3.6737	[6]
▪ 16-0-0	kg	1.3470	[6]
Gasoline	kg	0.7069	[6]
Diesel	kg	0.3282	[6]
Herbicide	L	10.2000	[5]

3. Results

3.1 GHG emissions from small plantation area (0.16-1.60 ha)

The average GHG emissions of robusta coffee cultivation in small coffee farms are shown in Fig 2. Total GHG emission was 1.19 kg of CO_2e per kg of coffee cherry. The largest GHG emission was mainly contributed by chemical fertilizers, 96 percent of all GHG emissions, followed by organic fertilizer, 3.13 percent of all GHG emissions.

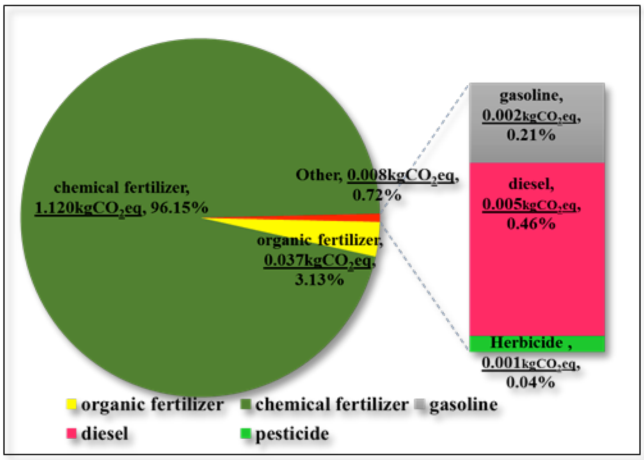

Figure 2. GHG emissions from small coffee farm

3.2 GHG emissions from medium plantation area (1.61-3.20 ha)

The average GHG emissions of robusta coffee cultivation in medium coffee farms are shown in Fig 3. Total GHG emission was 1.25 kg of CO_2e per kg of coffee cherry. Similar to GHG emission from small coffee farm, the largest share of GHG emission was from chemical fertilizers, 97 % of all GHG emissions, followed by organic fertilizer, 2.58 % of all GHG emissions.

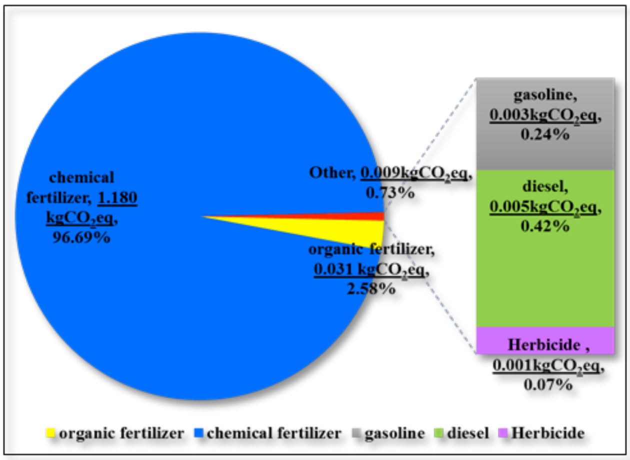

Figure 3. GHG emissions from medium coffee farm

3.3 GHG emissions from large plantation area (more than 3.20 ha)

The average GHG emissions of robusta coffee cultivation in large coffee farms are shown in Fig 4. Total GHG emission was 1.11 kg of CO_2e per kg of coffee cherry. Chemical fertilizer is also the main hotspots of GHG emission, accounted for 96%, followed by organic fertilizer, 3.16 percent of all GHG emissions.

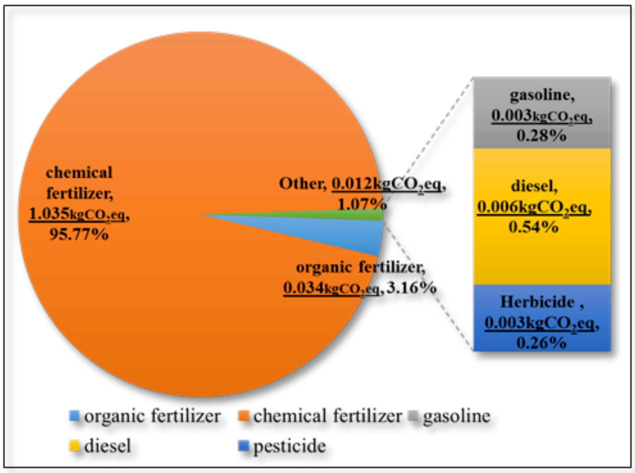

Figure 4. GHG emissions from large coffee farms

The average of GHG emission from robusta coffee cultivation based on number of samples is 1.20 kg of CO_2e per kg of coffee cherry. Among all sizes of coffee planting areas, the lowest GHG emission was from large coffee farms, followed by small and medium coffee farms, respectively. This might because the process of applying fertilizers in large farms has better economies of scale than small and medium farms. Similar to all planting area, chemical fertilizer is the major source of GHG emission from robusta coffee cultivation. This is because the chemical fertilizers that coffee farmers usually apply to soil are formula 15-15-15, 13-13-21 and 46-0-0, which has high content of nitrogen. Nitrogen in soil can be oxidized to nitrous oxide (N_2O), an important GHG with the Global warming potential (GWP) of 310 [7]. Accordingly, GHG reduction measure from robusta coffee cultivation should be paid attention on the optimal fertilizer application such as use low nitrogen chemical fertilizer and reduce chemical fertilizer uses by improving soil property.

4. Conclusion

The average of GHG emission from robusta coffee cultivation based on number of samples is 1.20 kg of CO_2e per kg of coffee cherry. The robusta coffee cultivation in medium farm emits the highest GHG emission while, that in large farm emits the lowest GHG emission. The hotspot of GHG emission is chemical fertilizer application. The optimal fertilizer application and soil management are recommended measures to reduce GHG emission from robusta coffee cultivation in Thailand.

5. Acknowledgement

The authors would like to thank the Division of Environmental Technology, School of Energy, Environment and Materials (SEEM), King Mongkut's University of Technology Thonburi, (KMUTT), National Research Council of Thailand (NRCT) for financial supports. The authors also would like to thank Chumphon Horticultural Research Centre for their kind collaboration.

References

[1] Office of Agricultural Economics, 2557, Coffee Online: http://www.oae.go.th/ewt_news.php?nid=16698&filename=index.

[2] Ministry of Agriculture, 2009, Strategy coffee year 2009-2013 Online: http://www.oae.go.th/ewtadmin/ewt/oae_baer/.../article_20100929152142.ppt .

[3] Yamane, T.,1967, Statistics: An introductory analysis. New York: Harper and Row.

[4] Thailand Greenhouse Gas Management Organization, 2015, Guidelines for assessing the carbon footprint of products. Under the program, promoting the carbon footprint of products, No.5, pages 9-35.

[5] IPCC, 2007, IPCC Fourth Assessment Report: Climate Change 2007 Online: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

[6] Thailand Greenhouse Gas Management Organization. Emission Factor CFP, 2014, Online : http://thaicarbonlabel.tgo.or.th/download/Emission_Factor_CFP.pdf .

[7] IPCC, 1995, IPCC Second Assessment Report : Climate Chang 1995 Online:https://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf .

Contact email: basnoi@hotmail.com
Contact email: siriluk.chi@kmutt.ac.th