Virtual Water Trade as a Tool of Managing Water Resources in Egypt

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Abstract

In regions suffering from water shortage, water policies are formulated. Egypt is one of those states that endure water shortage. In the past, when water resources were sufficient in Egypt, relying on water supply management tools was considered appropriate. However, over time, with the continuous rise in population, the increasing demand for food and drinking water together with the fixed supply of water resources, the need for water demand management (WDM) policies emerged vigorously. This persuades some economists to apply the concepts of "virtual water" and "water footprint" in managing water resources in Egypt.

In this study, we start by reviewing the virtual water comparative advantages and related concepts such as water footprints. Issues related to the assessment of virtual water content of commodities and water savings are also examined. The paper focuses on how to make use of the virtual water concept in the agricultural sector with emphasis on the major agricultural products in Egypt and assess its effect in terms of water saving.

The main purpose of this study is to determine the optimal pattern of domestic production and / or imports and exports of the most water demanding crops. This is influenced by the productivity of water used (cash value per unit of water used in such products). Therefore, calculating the water productivity for the selected group of crops will assist in making the decision to import or to locally produce based on the comparative advantages of these products in terms of water productivity.

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Introduction

Water is the source of life on Earth for all living organisms. Water is the second most important of all natural resources on earthnext to air. The concept of water as an economic good came up during the preparatory meetings for the "Earth Summit in Rio de Janeiro" of 1992. It was brought forward and discussed extensively during the "Dublin conference on Water and the Environment", and became one of the four "Dublin Principles" that emphasize the fact that water as a finite essential non-substitutableresource has an economic value and should be recognized as an economic good (Zaag&Savenije, 2006).

"Water Scarcity" is the point at which the aggregate impact of all users impinges on the supply and /or quality of water- under prevailing institutional arrangements- to the extent that the demand by all sectors, including the environment, cannotbe satisfied fully.Water scarcity can be measured by the amount of water that is withdrawn compared to the available amount of internal renewable and inflowing water from other countries. According to the United Nations, countries with water scarcity problems are classified as follows:

- A country having water resources less than 1700 m^3 per capita is a "Water Stressed Country".
- A country having less than 1000 m^3 per capita is suffering from a "Chronic Water Scarcity".
- Finally a country having less than 500 m^3 per capitais facing a "Severe Water Scarcity".

According to suchclassification, Egypt became one ofthe**"Chronic Water Scarcity Countries"**since 2007-2008**,** where water resources per capita dropped to about 858 (available water resources 70.36 Bm^3 ÷ population size 82 million people) at that time.

Table (1): Egypt's Water Surplus/ Deficit (Bm^3) During 2003-2008

Year	**Water Resources**	**Water Uses**	**Difference**
	Bm^3	**Bm^3**	**Bm^3**
2003/2004	68.76	67.1	+1.66
2004/2005	69.16	67.8	+1.36
2005/2006	69.56	68.6	+0.96
2006/2007	69.96	69.3	+0.66
2007/2008	70.36	72	-1.64

Source: Prepared by the researcher based on the data from www.mwri.gov.eg

The deficit in Egypt's water budget is **partly** explained by:

- The inability of the agricultural sector (that consumes over 80% of Egypt's water), governments and institutions toadapt to the fact of the existence of water scarcity.
- The inefficient use of the water resources in the agriculture sector triggered by vast production and exports of agricultural crops with high virtual water content.

The main objective of this paper is to determine how Egypt can change its agricultural crop pattern to conserve water consumption in that sector and transfer the saved water to other significant sectors in the economy and/or other crops characterized with low virtual water.More specifically, our core aim would be to review:

1. The current water use pattern in producing the main agriculture crops in Egypt.
2. The virtual water content of Egypt's exports and imports of those major crops.

3. Investigate to what extent Egypt can save water if it changed its agricultural crop pattern by altering the scheme of its agricultural exports and imports.

So, in the second section of this study we will examine the significance of the agriculture sector in the Egyptian economy. The third section will discuss the "virtual water" and "virtual water trade" concepts. In section four, we concentrate on "water footprint and its calculation" and apply that for a bundle of exported and imported goods in Egypt during the period (1997-2007).In section five, we proceed to calculate water savings due to external trade in selected commodities. Then in sections six and seven, water productivity of traditional and potential export and import crops of the Egyptian economyis calculated. Sections eight and nine analyze how may Egypt change its Agricultural trade pattern to save water and we examine a number of suggested scenarios for water use in Egypt.

1. **The Agriculture Sector in The Egyptian Economy:**

In 2008, Egypt 's population approached 81.5 million people with an annual growth rate of 1.8%. In 2007, the labor force working in the agriculture sector did not exceed 27%, whereas this percentage has climbed to almost 50% in the service sector (www.worldbank.org).

Figure (1) illustrates Egypt's gross domestic product (GDP) growth rate during the period (1980-2009) whichhas experience a lot of fluctuations during this period.

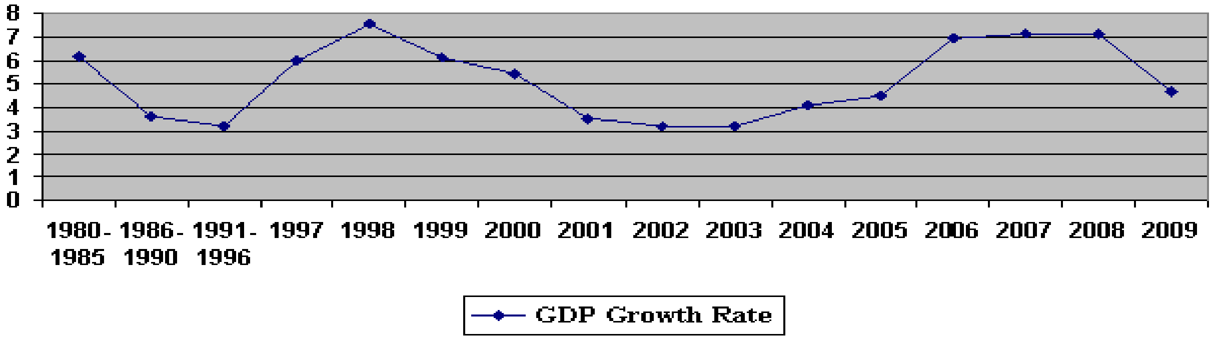

Figure (1): Egypt's GDP Percentage Growth Rate (1980-2009)

Source:IMF, 2009.

The agricultural sector is not the largest sector. As shown in table (2), its contributionin GDP was –on average- less than 20 percent. However, it is considered the most active one in the Egyptian economy due to the important and effective role it plays in its international trade.

The details of the Egyptian agricultural net exports ($1000) are presented in table (3) and figure (2).

Figure (2) shows that Egypt always reported a large agricultural trade deficit. During the period of (1997-2006) this deficit grew by about 16% (FAOSTAT, 2009).

1. **Virtual Water and Virtual Water Trade Concepts:**

The concept of "**virtual water**" emerged in the early 1990's and was first defined by Professor J.A. Allan as the water embedded in commodities. In other words; producing goods and services requires water; the water used to produce agricultural and industrial products

Table (2): Gross Domestic Product (GDP) Structure

Year / Sector	1990	2000	2001	2002	2003	2004	2005	2006	2007*	2008*
	%	%	%	%	%	%	%	%	%	%
Agricultural Sector	19	17	14	16	17	15	14	15	14	14
Industrial [1]Sector	29	33	30	32	33	31	33	36	36	36
Services	52	50	56	52	50	54	53	49	50	50

Source: http://en.wikipedia.org/wiki/Economy_of_Egypt
*http://www.worldbank.org

Table (3): Agricultural Net Exports ($1000) for the Period (1997-2006)

	Agricultural Exports	**Agricultural Imports**	**Agricultural Net Exports**
1997	486,273	3,369,919	-2,883,646
1998	447,345	3,752,614	-3,305,269
1999	558,732	3,601,762	-3,043,030
2000	476,157	3,334,615	-2,858,458
2001	395,970	3,171,980	-2,776,010
2002	518,547	3,174,382	-2,655,835
2003	504,399	3,146,760	-2,642,361
2004	553,615	3,852,995	-3,299,380
2005	431,102	3,425,589	-2,994,487
2006	438,875	3,760,572	-3,321,697

Source: FAOSTAT, 2009.

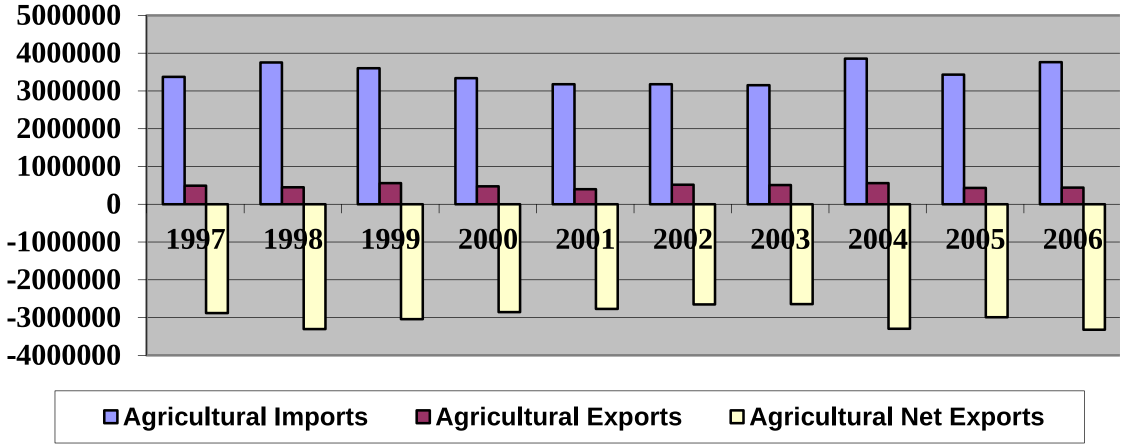

Figure (2): Agricultural Net Exports ($ 1000)

[1]The industrial sector include automobiles manufacturing, chemicals, consumer electronics and home appliances, steel industry, textiles and clothing, and finally the construction and contracting sector. While the services sector include banking and insurance, communications, transport and tourism.

Source:Prepared by the researcher based on data from table (3).

is called the virtual water of the product (Allan, 1998). Virtual water is also called **"embedded** or **exogenous water".** "**Virtual Water Trade"** is one of the techniques that are used to alleviate the severity of the of water scarcity in many countries.

The concept of 'virtual water' leads to focus on the "opportunity cost of water" when evaluating crop production and international trade alternatives. The virtual water concept is closely related to the notion of **"comparative advantage"** from international trade theory (Allan, 1999; Earle, 2001; Wichelns, 2001). In essence, countries can enhance the total value of goods and services available to residents by exporting products for which the country has a relative or comparative advantage in production, while importing products for which the country has a comparative disadvantage. Accordingly, countries in water-short regions may gain from trade by importing water-intensive crops, while using their limited water supply for other activities that generate greater incremental values.

The main advantage of "virtual water trade" is that it is a way to close deficits in the water budgets of water short countries. Another advantage is that virtual water trade presents itself as an alternative source of water to countries suffering from water scarcity. It is also considered as an environment friendly technique.
On the other handthe reliance on trade can encompass some risks such as deteriorating terms of exchange, uncertainty of supplies, and price instability.

2. Water Footprint and its Calculation:

The water footprint concept was introduced by Hoekstra in in 2003.It is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of the country.

The major factors determining the per capita water footprint of a country are:

- The average consumption volume per capita, generally related to gross national income of the country.
- The consumption habits of the inhabitants of the country.
- Climate conditions, in particular evaporative demand.
- Agricultural practice.

A nation's water footprint has two components:

- **internal water footprint**which is the volume of water used from domestic water resources;
- **external water footprint**which is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the country.

At the individual level, the water footprint is equal to the total virtual water content of all products consumed.

The total water use within a country itself is not the right measure of a nation's actual appropriation of the global water resources. The sum of domestic water use(m^3/yr) per year (**WU)** and net virtual water import (m^3/yr)**(NVWI**)can be seen as a kind of 'water footprint' of a country, on the analogy of the 'ecological footprint' of a nation:

Water Footprint = WU + NVWI…… (1)

The net virtual water import(m^3/yr) of a country **(NVWI)** is:

NVWI= GVWI – GVWE ……… (2)

Where:
GVWI: gross virtual water import to a country is the sum of all imports.
GVWE: gross virtual water export from a country is the sum of all exports.

In the case of a positive (NVWI) into a country, this net virtual water volume should be added to the total domestic water use. In the case of negative (NVWI) ;i.e, net export of virtual water from a country, this value should be subtracted from the volume of domestic water use.
Calculating the water footprint is important for calculating how much the country is water scare; where water scarcity (WS) of a nation is defined as the ratio of total water use to the nation's water availability (WA).

WS = (WU / WA) × 100 ……… (3)

Water scarcity generally range between 0% and 100%, but can -in exceptional cases- be above hundred per cent, this is the case if there is more water needed for producing the foods and services consumed by the people of a nation than is available in the country.

The water dependency(**WD**)of a nation is calculated as the ratio of the net virtual water imports into a country to the total national water appropriation:

WD = {NVWI / (WU + NVWI)} ×100 …….. (4)

The water dependency index vary between 0% and 100%. A value of zero means that gross virtual water import and export are in balance or that there is net virtual water export. If the water dependency of a nation approaches 100%, the nation relies completely on virtual water import.

The counterpart of the water dependency index, the **'water self-sufficiency index'** is defined as follows:

WSS = {WU / (WU + NVWI)} ×100 ……..… (5)

The water self-sufficiency of a nation relates to the water dependency of a nation in the following simple way:

WSS = 1−WD………… (6)

The measure of (WSS)denotes the national capability of supplying the water needed for the production of the domestic demand for goods and services. Self-sufficiency is 100% if all the water needed is available and taken from within the own territory. Water self-sufficiently approaches zero if a country heavily relies on virtual water imports.

Table (4)below shows water footprint , water self-sufficiency and water dependency of Egypt as of year 2008.

Virtual water content is usually measured as:

Virtual water content (m^3/ton) = crop water requirement (mm/crop period) ÷ crop yield (ton/ha),

The "**crop water requirement**" is the total water needed for evapotranspiration,[2] from planting to harvest for a given crop in a specific climate region.The **"crop yield"**-also known as **"agricultural output"**- is the amount of plant harvested per unit area for a given time. It is usually expressed in kilograms per hectare (or metric ton per hectare).

Table (4): Water Footprints, Water Scarcity, Water Self-Sufficiency and Water Dependency of Egypt in 2008.

	Unit of Measurement	**2008**
Population	Million people	81,527,000
Water Withdrawal	$10^6 m^3$/year	72,000
Water Availability	$10^6 m^3$/year	70,360
Gross Virtual Water Export	$10^6 m^3$/year	901.6
Gross Virtual Water Import	$10^6 m^3$/year	16,937.1
Net Virtual Water Import	$10^6 m^3$/year	16,035.5
Water Footprint	$10^6 m^3$/year	88,035.5
Water footprint per capita	m^3/year/capita	1079
Water Scarcity	%	102
Water Dependency	%	18.3
Water self sufficiency	%	81.7

Prepared by the researcher.

Therefore virtual water content (**VWC**)will be calculated as follows:

$$\mathbf{VWC = ET_a \div Y} \quad \text{………(7)}$$

Where:

Eta: is the actual evapotranspiration that is assumed to be equal to the reference evapotranspiration (Et_o), calculated with the Penman-Monteith method (FAO, 1998)

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. The evapotranspiration rate is normally expressed in millimetres (mm) per unit time. As one hectare has a surface of 10,000 m^2 and 1 mm is equal to 0.001 m, a loss of 1 mm of water corresponds to a loss of 10 m^3 of water per hectare. In other words, 1 mm day^{-1} is equivalent to 10 m^3 ha^{-1} day^{-1}.

Y: is the crop yield, which is equal to production (tonnes) divided by area harvested (hectare).

Quantifying (VWC) of products is not an easy task as Hoekstra (2003) argued because of the many factors that influence the amount of water consumed in a production process, such as:

- The place and period of production
- The production method.
- The method of attributing water inputs into intermediate products to the virtual water content of the final product.

Tables (5) and (6) below show those measures in case of Egypt for a selected basket of major crops. Examining the figures in these 2 tables reveals some interesting results:

- Sugar cane crop is the bigger consumer of irrigation water in this basket of crops. However compared to the rest of crops in the selected basket, VEC ofsugar cane is very low.
- Water use in grapes' cultivation is relatively high, fourth after cotton. Nonetheless, VWC in grapes is relatively low compared to cotton, rice and dry beans.
- Tomatoes and dry beans are very close in terms of water consumption per, however, VWC of tomatoes is almost 0.08 that of VWC of dry beans.
- Aside from lentils, VWC of all Egypt's crop imports is lower than VWC in its exports of cotton.

Table (5): Average Crop Water Requirement, Average Crop Yield and Virtual Water Content for Selected Export Crops in Egypt During the Period (1997-2007)

Crop	ET_a (m^3/ton/crop period) (1) [(1)]	Y(ton /Ha) (2) [(2)]	VWC(m^3/ton) (3)[(3)] = (1) ÷ (2)
Rice	13,870	6.5	2,134
Sugar Cane	16,340	118.4	138
Potatoes	7,070	23.9	296
Dry Onions	6,700	28.3	237
Oranges	10,970	17.8	616
Cotton	7,250	2.4	3,020
Dry beans	5,750	2.8	2,053
Grapes	9,430	17.5	539
Tomatoes	5,500	34.2	161
Strawberries	8,620	22.6	381

Sources: (1) Calculated from Chapagain and Hoekstra, 2004.
(2) Calculated by the researcher.
(3) Calculated by the researcher.

3. Calculating National Water Savings Due to Trade:

The most direct positive effect of virtual water trade is the water savings it generates in the countries that import water intensive products. A nation can save its domestic water resources by importing a water-intensive product rather than produce it domestically; this is what is called **water saving through trade.**

The water savings are directly the result of the quantity of imports multiplied by the local virtual water contents (VWC) of the imported goods,while water loss isthe quantity of exports multiplied by the local virtual water contents (VWC) of the exported goods (Hoekstra and Chapagain, 2004):

Water savings (m^3) = Imports of selected crop (ton) × VWC (m^3/ton)……..(8)
Water losses (m^3) = Exports of selected crop(ton) × VWC (m^3/ton) ……..(9)

Table (6): Average Crop Water Requirement, Average Crop Yield and Virtual Water Content for Selected Import Crops in Egypt During the Period (1997-2007)

Crop	ET_a (m^3/ton/crop period) (1) [(A)]	Y(ton /Ha) (2) [(B)]	VWC(m^3/ton) (3) = (1) ÷ (2)
Wheat	5,700	6.3	905
Maize	7,710	7.7	1,001
Soybeans	7,540	3	2,513
Broad beans, horse beans, dry	5,430	3.2	1,697
Lentils	8,670	1.7	5,100

Sources: (1) Calculated from Chapagain and Hoekstra, (2004).
(2) Calculated by the researcher .
(3) Calculated by the researcher.

Table (7) below demonstrates that Egypt has saved more than 10.5 Gm^3 of water during the period of 1997-2007 by importing 5 types of major agricultural products. On the other hand, table (8) calculates the amount of lost water due to exports of the selected crops during the same period which sums up to 2.07 Gm^3.This means the**"net water savings"**due to crop trade in Egypt during that period was about (10.59 Gm^3 – 2.07 Gm^3) or 8.52 Gm^3.

Table (7): Water Savings (Gm^3) for the Main Imported Crops in Egypt During the Period (1997-2007)

Crop	Import (ton)[(1)] (1)	VWC (m^3/ton) [(2)] (2)	Water savings (Gm^3) [(3)] (3) = (1) × (2)
Wheat	5,208,860	905	4.71
Maize	4,071,614	1,001	4.08
Soybeans	371,279	2,513	0.93
Broad beans, horse beans, dry	252,459	1,697	0.43
Lentils	85,900	5,100	0.44
Total Imported Water Savings for the selected crops = 10.59Gm^3			

Source: (1) FAOSTAT,2009.
(2) Calculated by the researcher.
(3) Calculated by the researcher.

4. **Water Productivity of exported and imported crops:**
   Productivity is a ratio between a unit of output and a unit of input.Increasing water productivity means growing more food or gaining more benefits with the same or less water.
   The water productivity of each crop could be calculated using the following formula:

Water Productivity = WUE (Kg/ m^3) × Price (L.E. /Kg)…… (10)

Where:
Water productivity: is expressed in L.E. per m^3.
Price: is the farm gate selling price in L.E. per Kg.
WUE: is the water use efficiency expressed in Kg per m^3. It is calculated as

WUE = Yield (Kg/Ha) ÷ Et_a (m^3/Ha)………….(11)

Table (8): Water Losses (m^3) for the Selected Exported Crops In Egypt for the Period (1997-2007)

	Exports (ton)[(1)] (1)	**VWC (m^3/ton) [(2)] (2)**	**Water Losses (Gm^3) [(3)]** (3) = (1) × (2)
Rice	653,924	2,134	1.39
Sugar cane	287,403	138	0.04
Potatoes	256,348	296	0.07
Dry onions	213,201	237	0.05
Oranges	179,986	616	0.12
Cotton	107,850	3,020	0.33
Dry beans	19,704	2,053	0.04
Grapes	13,318	539	0.01
Tomatoes	9,336	161	0.01
Strawberries	4,512	381	0.01
Total Exported Water (Losses) for the selected crops 2.07 Gm^3			

Source: (1) FAOSTAT,2009.
(2) Calculated by the researcher.
(3) Calculated by the researcher.

The calculations of those ratios of (WUE) and water productivity are presented in table (9) for the selected basket of exported crops and in table (10) for the selected basket of imported crops in Egypt during the period (1997-2007). Figure (3) and (4) plot those figures for the same period. Examining those figure reveal the following:

- For all export crops –except strawberries, cotton and dry beans- water productivity is very small compared to water use efficiency.
- In case of rice and cotton crops - 2 major exports in Egypt- both of WUE and water productivity are relatively very low.
- For all imported crops in the selected basket, water productivity is either higher then WUE or almost equivalent.

Table (9): Water productivity (L.E/ m^3) for the Selected Export Crops In Egypt for the Period (1997-2007)

	Average Price (L.E/Kg) (1)	Water Use Efficiency (Kg/ m³) (2)	Water productivity (L.E/ m³) (3) = (1) × (2)
Rice	0.87	0.47	0.41
Sugar Cane	0.12	7.24	0.87
Potatoes	0.73	3.39	2.48
Onions	0.30	4.22	1.27
Oranges	0.71	1.62	1.15
Cotton	3.40	0.33	1.12
Dry beans	2.99	0.48	1.43
Grapes	0.83	1.85	1.53
Tomatoes	0.47	6.21	2.92
Strawberries	5.69	2.62	15

Source: (1) Calculated by the researcher.
(2) Calculated by the researcher.
(3) Calculated by the researcher.

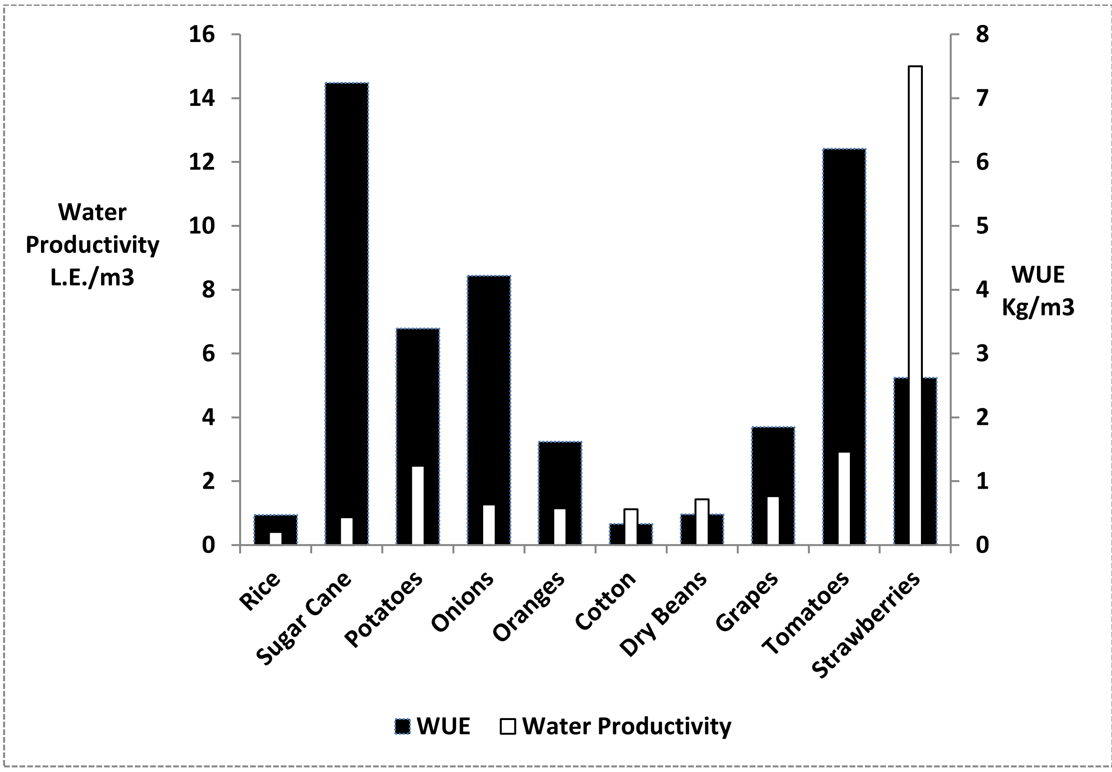

Figure (3): WUE and Water Productivity for the Selected Export Crops in Egypt for the Period (1997-2007).

Source: Prepared by the researcher based on data from table (9).

Table (10): Water Productivity (L.E/ m³) for the Selected Import Crops In Egypt for the Period (1997-2007)

	Average Price (L.E/Kg)	Water Use Efficiency (Kg/ m³) (2)	Water productivity (L.E/ m³)

	(1)		(3) = (1) × (2)
Wheat	0.84	1.11	0.93
Maize	0.82	0.99	0.81
Soybeans	1.36	0.39	0.53
Broad beans, horse beans, dry	1.61	0.58	0.93
Lentils	2.30	0.21	0.48

Source: (1) Calculated by the researcher.
(2) Calculated by the researcher.
(3) Calculated by the researcher.

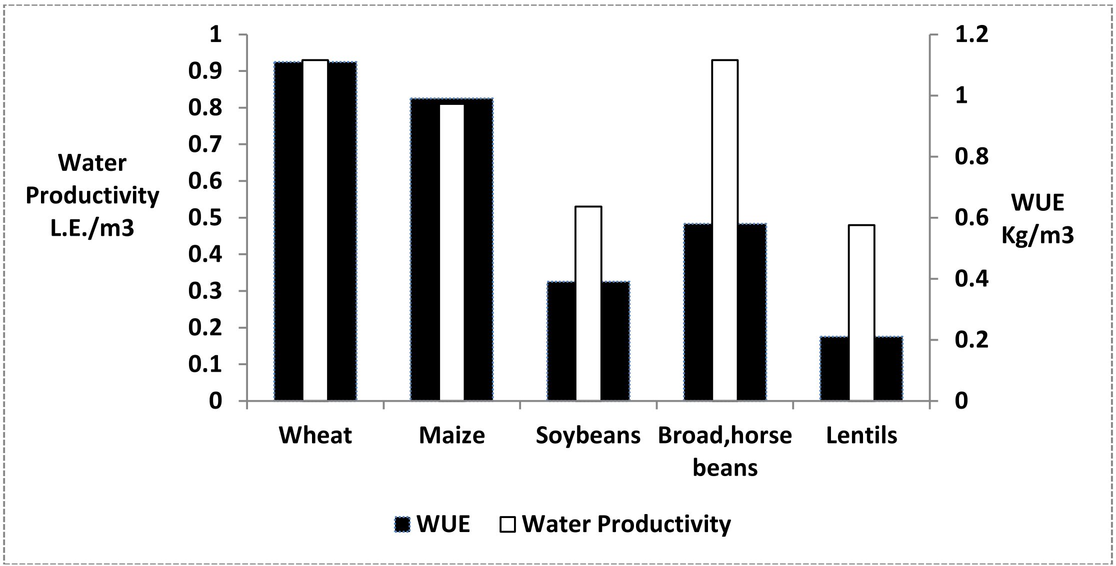

Figure (4): WUE and Water Productivity for the Selected Imports Crops in Egypt for the Period (1997-2007).

Source: Prepared by the researcher based on data from table (10).

7. Water Productivity of Other Important Agricultural Products in Egypt:

We present in table (11) the production of the 20 most important food and agricultural Egyptian commodities ranked by quantity for the year 2007. Seven of those crops (sugar cane, tomatoes, rice, potatoes, orange, dry onion and grapes) on that list are among the major exported crops in Egypt. Wheat and maize – 2 of Egypt's main imported crops- are also considered major agricultural production on the list.

Table (11): Production of Top Agricultural Commodities (tons) in 2007

Commodity	Production (tons)
Sugar cane	17,014,272
Tomatoes	8,639,024
Wheat	7,379,000
Rice paddy	6,876,830
Maize	6,243,220
Sugar beets	5,458,210
Cow milk, whole, fresh	3,187,317
Potatoes	2,760,460
Buffalo milk, whole, fresh	2,609,821
Oranges	2,054,626
Watermelons	1,912,991
Dry onions	1,485,933
Grapes	1,485,010
Dates	1,313,696
Eggplants (aubergines)	1,160,621
Bananas	645,429
Sorghum	843,840
Other melons incl. cantaloupe	829,779
Tangerines, mandarins, clem.	748,395
Pumpkins, squash & gourds	724,579

Source: FAOSTAT, 2009.

We proceed to calculate water productivity for other important commodities in table (11) to decide whether it is beneficial for Egypt to continue with the existing trade pattern, or it is worthwhile to make adjustments in its production as well as exports and import prototype!! The results of the calculations are presented in table (12) and figure (5) below. Surprisingly enough, some of those products –such as cantaloupe and squash for instance- turned out to have higher water productivity than some of the major traditional exported crops such as rice and cotton, for instance.

8. How Can Egypt Change its Agricultural Trade Pattern To Save Water?

Our previous calculations and analysis help us to deduct the following results:

1. It is clear thatall the selected crops on the **imports side** enjoy relatively low water productivity varying from 0.93 L.E./m^3**(wheat)** to 0.48 L.E./m^3**(lentils).** So we suggest that it would be advisable to continue importing these water intensive commodities as a way to rationalize the use of our national water resources. For instance, if we stop importing wheat or maize (their water savings is 4.71 & 4.08 Gm^3, respectively) the total water use in the agricultural sector would rise by about 40%. Still, we may not be able to enlarge our domestic production enough to meet the growing needs for these two products.
2. It is recommended to increase the production – and exports – of **"strawberries"** as the most profitable commodity in the traditional export basket. As for tomatoes, potatoes, grapes, oranges and dry onions, it is also recommended to expand their production to increase their exports. These products are characterized – as shown in the previous figure- by their relatively high water productivity.

Table (12): Average Price Level, WUE and Water Productivity for Selected Egyptian Products during the Period (1997-2007):

	Average Price (L.E/Kg) (1)	**Water Use Efficiency (Kg/ m^3) (2)**	**Water Productivity (L.E/ m^3) (3) = (1) × (2)**
Watermelons	0.39	4.72	1.84
Dates	0.84	2.07	1.73
Eggplants (aubergine)	0.39	3.07	1.19
Other melons incl. cantaloupe	0.53	4.71	2.90
Pumpkins, squash & gourds	0.51	4.92	2.50
Sorghum	0.86	1.11	0.95
Tangerines, mandarins, clem.	0.60	1.38	0.83
Bananas	0.60	2.04	1.22

Source: (1) Calculated by the researcher.
(2) Calculated by the researcher.
(3) Calculated by the researcher.

3. When it comes to **"cotton"** and **"dry beans"** things are different. Both enjoy relatively reasonable water productivity because of the relatively high price for both commodities. So, it is not an easy task to make a clear cut decision concerning these two commodities. Yet, the WUE of those two crops is not strong enough. So:
    - **If water saving is our priority,** we should exclude these two products from our exports' list.
    - But **if the main objective is foreign exchange revenues,** then these two products should stay on the exports' list, but with lower rank.
4. Exporting **"sugar cane"** in the form of "**molasses"** reflects another type of dilemma. The fact that its WUE is relatively high is explained by its relatively large yield (due to its nature as a bulky product). However, the problem is in its very low water productivity due to the very low price of molasses. It would be more beneficial if we can divert the water used in that product (even partially) to irrigate more productive crops.

5. Exporting **"rice"** is a big problem in Egypt due to its very high water consumption per ton and the very low water productivity which is mitigated by its relatively low price. Therefore, it is recommended not to continue producing and exporting this amount, because rice is harvested on a vast area which represented about 65% -on average- of the total harvested area in Egypt during the period 1997-2007.

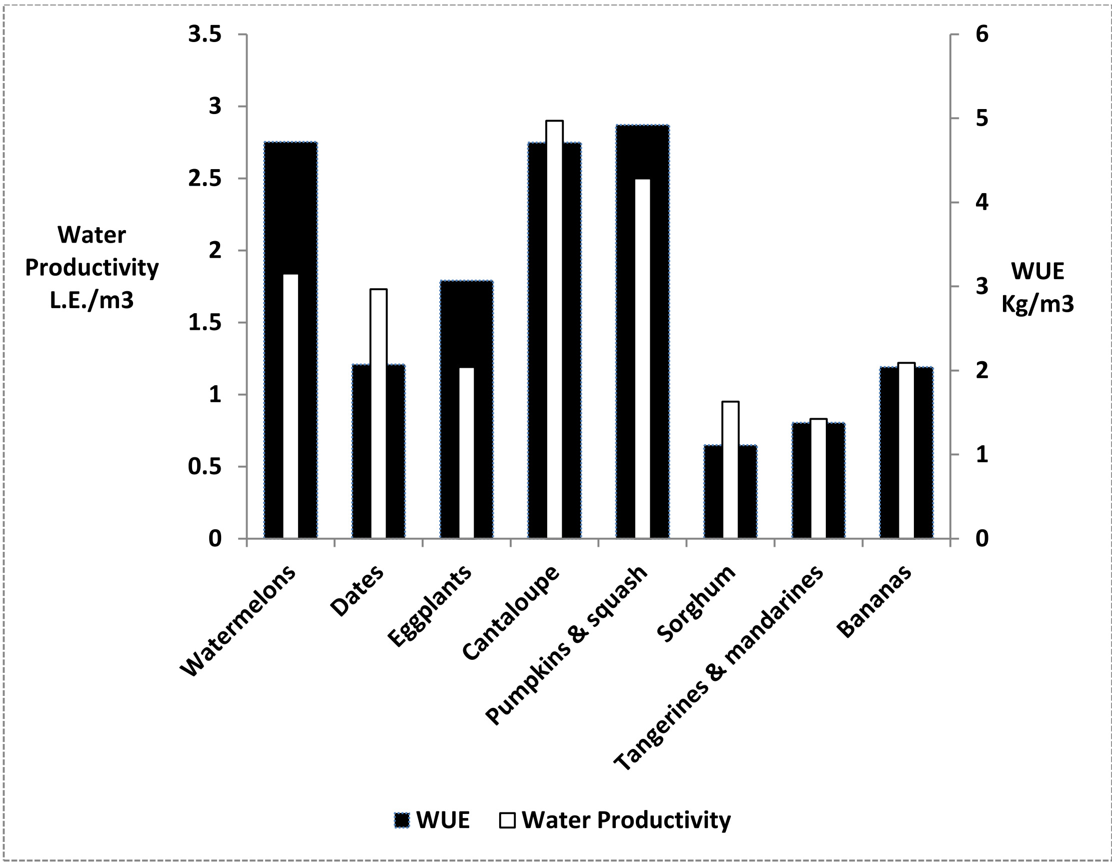

Figure (5): WUE and Water Productivity for Some Suggested Crops in Egypt for the Period (1997-2007).

Source: Prepared by the researcher based on data from table (12).

We can summarize the previous results regarding water savings and water productivity of export products and major import products in the following table (13). Note that the mark (√) indicates that the product satisfies the specified measure, whereas the mark (X) means that the product does not satisfy it and the mark (≈) indicates that the product is marginal in terms of satisfying the measure.

Figure (6) displays the water losses generated from the traditional exports arranged in descending order and figure (7) shows the water productivity for the same selected export crops arranged in descending order as well. By examining these two figures we find that rice comes at the tail of agricultural products that satisfies neither production measures nor water efficiency.

Figure (8) displays the water savings generated from the selected imports arranged in descending order, while figure (9) shows the water productivity for the same selected import crops arranged in descending order. It is obvious that the crop which satisfies both measures best is the wheat followed by the maize. This supports the decision we took earlier to continue on importing these crops. Based on water productivity presented in figure (9) we find that wheat and broad horse beans are equal, but what gives the wheat higher weight is its very high significance in the Egyptian diet.

Table (13): Water Saving and Water Productivity of Various Products

Crop	Water Saving	Water Productive	Water Saving & Water Productive
Rice	**X**	**X**	**X**
Sugar Cane	√	**X**	**X**
Potatoes	√	√	√
Onions	√	≈	≈
Oranges	≈	≈	≈
Cotton	**X**	≈	≈
Dry beans	√	√	√
Grapes	√	√	√
Tomatoes	√	√	√
Strawberries	√	√	√
Wheat	√	√	√
Maize	√	√	√
Soybeans	√	≈	≈
Broad beans, horse beans, dry	≈	√	≈
Lentils	≈	≈	≈

Source: Prepared by the researcher.

9. Suggested Scenarios for Water Use in Egypt:

Let us imagine **three scenarios:**

First Scenario:stopping or cutting the rice exports. This -of course- will affect both the amount of water being lost (1.39 Gm^3) and the revenues generated from exporting 653,924 ton at 876 L.E./ton which is 572,837,424 L.E. If we were able to cut the rice exports; then we can use the saved water (1.39 Gm^3) to increase the quantities of more productive crops.

Table (14) displays the scenario of cutting the rice exports and substituting it with the highest water productive crops . This table shows the effect of tripling the exports of "strawberries", "tomatoes", "potatoes", "grapes", "dry onions" and doubling the exports of "dry beans" on the revenues and the amount of water lost.

Table (15) compares the total revenues and water lost generated from changing the current trade pattern –by increasing the exported quantity– with the current rice exports. Under the constraint of having insufficient land and water to increase the production, we conclude that:

1. **If the foreign exchange revenues is our priority,** then it is wise to change the current trade pattern according to the scenario shown in table (14), because the revenues generated from the current rice exports (572,837,424 L.E) is about 40% of the total revenues generated from changing the current trade pattern (994,847,144 L.E) as shown in table (15).
2. **If the water savings is our priority;** then our decision will coincide with the decision we took earlier taking into consideration the revenues priority, since the total water lost –from increasing the exports quantity of the highest productive crops- is 0.48 Gm^3 which is smaller than half the amount of water that is lost from the current rice exports (1.39 Gm^3). Hence, we can either increase the exports by more than three folds till the amount of water lost due to this increase is equal to that consumed by rice exports

or introduce one or more of the suggested potential export crops this moves us to the second scenario.

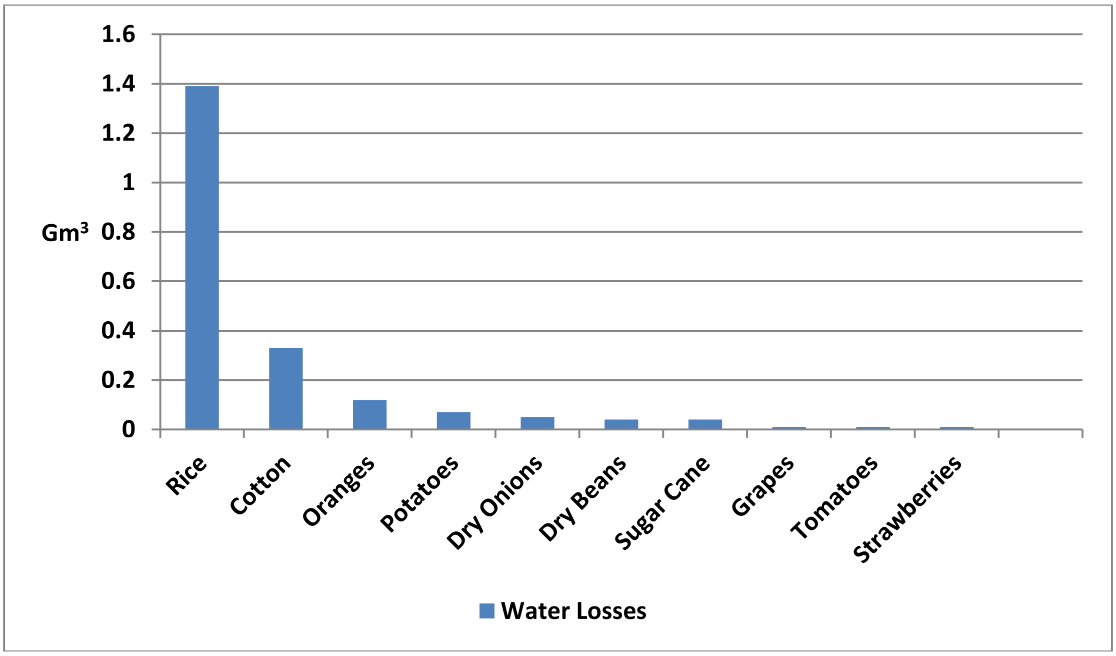

Figure (6): Water Losses Generated from Selected Exports Arranged in Descending Order

Source: Prepared by the researcher based on data from table (4.6).

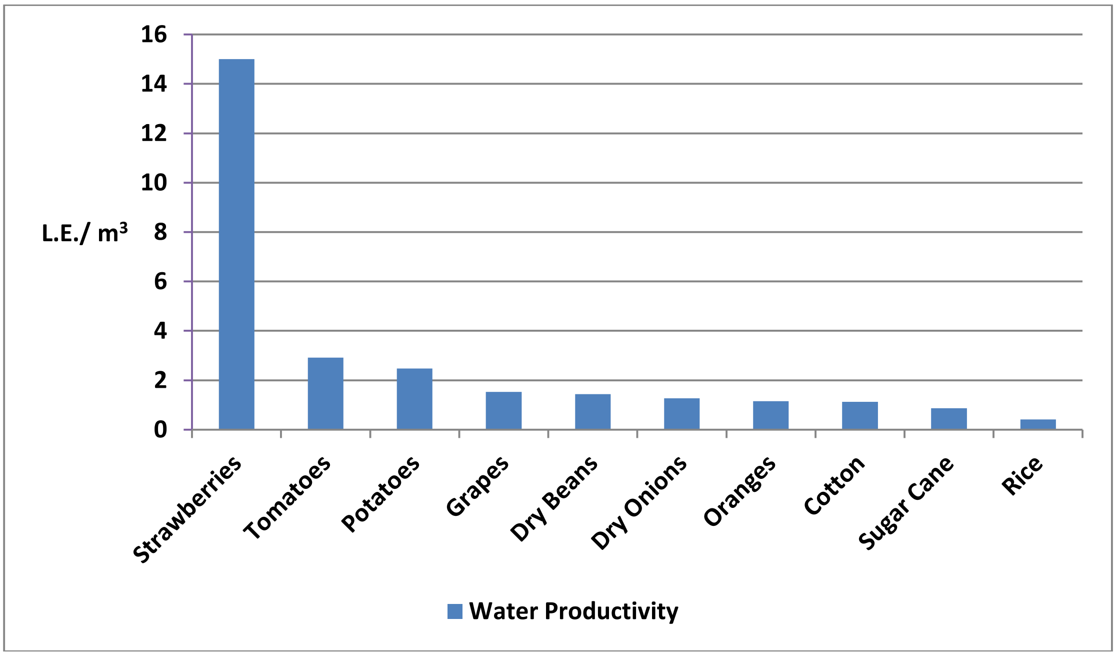

Figure (7): Water Productivity Generated from Selected Exports Arranged in Descending Order.

Source: Prepared by the researcher based on data from table (4.8).

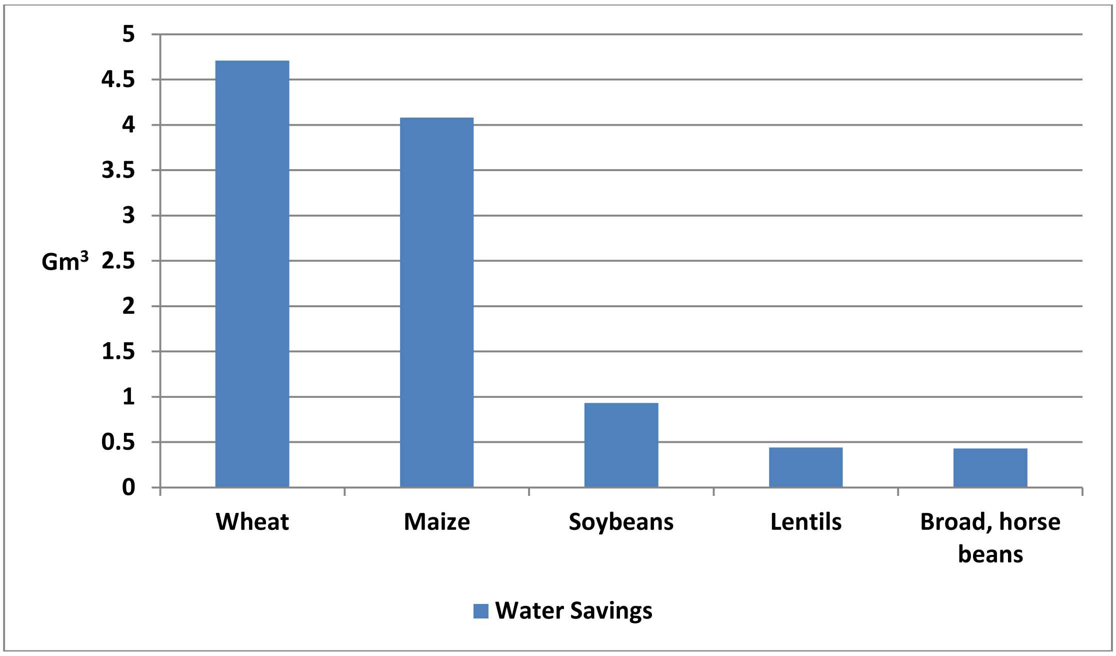

Figure (8): Water Savings Generated from Selected Imports Arranged in Descending Order

Source: Prepared by the researcher based on data from table (4.5).

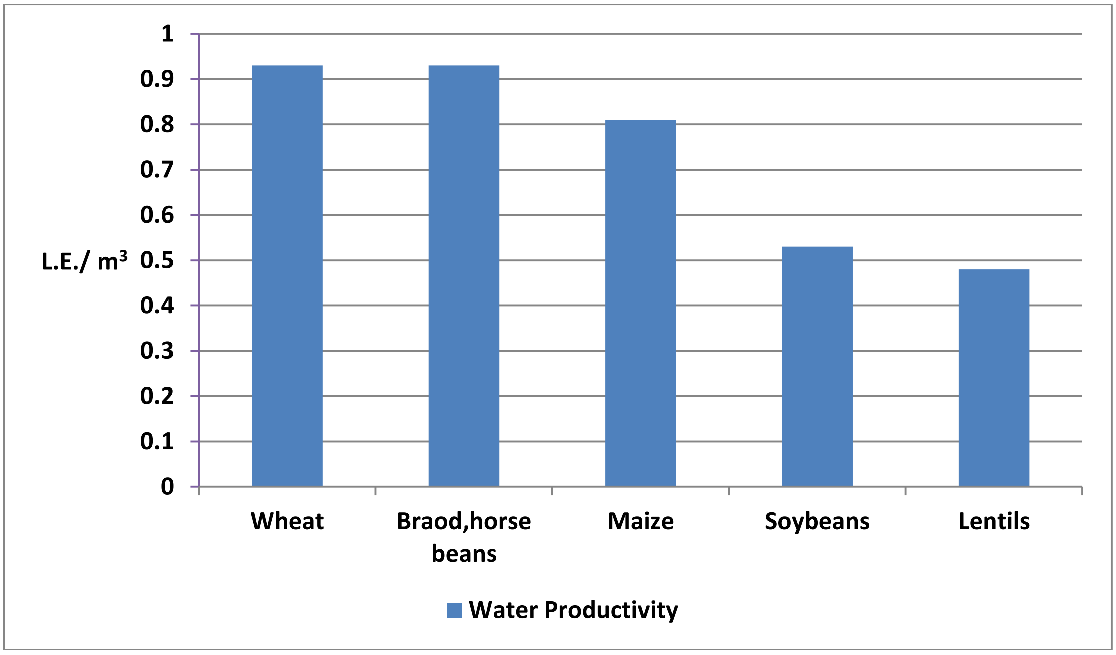

Figure (9): Water Productivity Generated from Selected Imports Arranged in Descending Order

Source: Prepared by the researcher based on data from table (4.10).

Table (14): The Effects of the First Scenario.

	Exports Quantity (ton) (1)	Price (L.E./ton) (2)	**Revenues (L.E.) (1) × (2)**	Exports Quantity (ton) (3)	VWC (m^3/ton) (4)	**Water Losses Gm^3 (3) × (4)**
STRAWBERRIES						
Current Situation	4,512	5,686	**25,655,232**	4,512	381	**0.001**
Doubling Exports	9,024	5,686	**51,310,464**	9,024	381	**0.003**
Tripling Exports	13,536	5,686	**76,965,695**	13,536	381	**0.005**
TOMATOES						
CurrentSituation	9,336	468	**4,369,248**	9,336	161	**0.001**
Doubling Exports	18,672	468	**8,738,496**	18,672	161	**0.003**
Tripling Exports	28,008	468	**13,107,744**	28,008	161	**0.004**
GRAPES						
CurrentSituation	13,318	830	**11,053,940**	13,318	539	**0.007**
Doubling Exports	26,636	830	**22,107,880**	26,636	539	**0.014**
Tripling Exports	39,954	830	**33,161,820**	39,954	539	**0.021**
DRY BEANS						
CurrentSituation	19,704	2,993	**58,974,072**	19,704	2,053	**0.04**
Doubling Exports	39,408	2,993	**117,948,144**	39,408	2,053	**0.08**
DRY ONIONS						
CurrentSituation	213,201	303	**64,599,903**	213,201	237	**0.05**
Doubling Exports	426,402	303	**129,199,806**	426,402	237	**0.10**
Tripling Exports	639,603	303	**193,799,709**	639,603	237	**0.15**
POTATOES						
CurrentSituation	256,348	728	**186,621,344**	256,348	296	**0.07**
Doubling Exports	512,696	728	**373,242,688**	512,696	296	**0.15**
Tripling Exports	769,044	728	**559,864,032**	769,044	296	**0.22**
Rice						
CurrentSituation	653,924	876	**572,837,424**	653,924	2,134	**1.39**

Source: Prepared by the researcher.

Table (15): Rice and Selected Crops Revenues and Water Losses

Crop Name	**Revenues (L.E)**	**Water Lost (Gm^3)**
Strawberries	76,965,695	0.005
Tomatoes	13,107,744	0.004
Grapes	33,161,820	0.021
Dry Beans	117,948,144	0.08
Dry Onions	193,799,709	0.15
Potatoes	559,864,032	0.22
Summation	**994,847,144**	**0.48**
Rice	**572,837,424**	**1.39**

Source: prepared by the researcher.

Second Scenario: cutting rice exports and use the conserved water to introduce some new crops that are not listed in the traditional exports list. Depending on the figures of water productivities along with the WUE presented in figure (7), we would suggest to start by adding first the "cantaloupe" then the "pumpkins, squash and gourds" then the "watermelons".

Third Scenario: cutting rice exports and **redirect** this amount of water –that have been conserved- to more productive sectors in the economy, such as **commercial**, **industrial and tourism sectors.**From a social and economic point of view this policy can be justified since the marginal value of water and the revenues generated from its use for the commercial, tourist and industrial sector is estimated to be greater than its value in agriculture. Advocates of this scenario justify their opinion based on the fact that the transfer of water from the agricultural sector to the commercial, industrial and tourism sectors will result in a cut back in irrigated agriculture with all its difficulties. Thus, as less water becomes available for irrigation in the agricultural sector there will be less employment in agriculture and hence there must be well planned, well financed programs of training and education of the farmers to prepare them for more productive occupations in the commercial, industrial and tourism sectors which is expected to increase the Egyptian GDP.
When considering this scenario of reallocating the water to commercial, tourist and industrial sector attention must be paid for the environmental impact beside the revenues effect. Environmentalists and ecologists believes that agriculture keeps the country green and by applying this scenario the farmers themselves will become promoters of the sales of their farmlands for more productive projects. This is profitable to the farmers but it may turn large areas into densely populated areas and the green areas will be disappearing.

10.Conclusions:

This study aimed at deciding on which crops to grow and export in Egypt and on which crops to import. Knowing the national virtual water trade balance is essential for developing a rational national policy with respect to virtual water trade, It will also help us find a way to let governments interfere in the current national virtual water trade balance in order to achieve higher global water use efficiency and thus saving the natural resource and make it last longer.

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