CROP WATER PRODUCTIVITY TOWARDS FUTURE SUSTAINABLE AGRICULTURE IN EGYPT

Hussein El Atfy[1]
Alaa E. Abdin[2]
Shaban Salem[3]

ABSTRACT

Water is characterized such as no alternative source can substitute it and it is not a commercial resource or commodity. The great challenge for the coming decades will be the task of increasing food production with less water particularly in basins with limited water resources. Molden et al. (2003) estimated that, by year 2020, approximately 75% of the world's population will live in areas experiencing physical or economic water scarcity. Most of these areas happen to be where most of the poor and food insecure people live. Meeting their food needs with locally produced food presents enormous challenge. Hence, the need is to increase water productivity of agricultural production systems in water scarce areas where the poor population is dependent on local production.

Increasing the productivity in agriculture will play a vital role in easing competition for scarce resources, prevention of environmental degradation, and provision of food security. Crop water productivity depends on several factors including crop genetic material, water management practices, economic and policy incentives, and people's acceptance. In a broad sense, productivity of water refers to the benefits derived from the use of water and is most often given in terms of mass of product, or its monetary value, per unit of water.

Therefore, the main goal of the current practical study is to assess water productivity for different crops, assist decision makers in developing sustainable agricultural policies for Egypt and maximize national water resources' productivity in different agricultural activities considering the supply and demand aspects and based on the efficient utilization of the water resource.

STUDY SPECIFIC ACTIVITIES

To successfully achieve the main study's goal, several major activities will be carried out as follows:

- Describe the current cropping pattern.
- Evaluate the crop water requirement pattern.
- Evaluate the gross margin of main crops in both new and old lands.
- Evaluate the water productivity of agricultural crops under different irrigation methods.

[1] First Undersecretary - Chairman of Irrigation Department, Ministry of Water Resources and Irrigation
[2] Director, Strategic Research Unit, National Water Research Center, alaa_ea_abdin@yahoo.com
[3] Research Associate Professor, Agriculture Economic Research Institute, Agriculture Research Center

- Evaluate the net water return of agricultural crops under different irrigation methods.
- Evaluate the net water return of crop rotations under different irrigation methods.

STUDY PROBLEM

The last year witnessed sharply changes in agricultural prices of all crops, particularly as a result of utilizing some crops such as corn, sugarcane, and sugar beet in producing ethanol as an alternative source of energy. The competition between using crops for food and energy changed the cropping pattern and farmer's attitudes in the world. The world agricultural crop prices affected the Egyptian local prices. The increase in producing energy from agriculture commodities has also affected the price of agricultural inputs, particularly machinery and fertilizer. Therefore, crop water productivity is considered an important factor that needs to be evaluated accurately towards future sustainable water and agriculture policies.

COLLECTED DATA UTILIZED

Data and information were collected to meet the current research objectives. The collected data were classified according to the following two categories:

Secondary Data

- Total cropped areas at the national level in both new and old lands. (Data source: Agriculture Economic Affairs Sector)
- Water Requirements at field levels in old lands (CAPMAS, Central agency for Public Mobilization and Statistics, Bulletin of irrigation and water requirement).
- Water requirements at field levels in new lands under the applied irrigation system. (Agricultural Research Center, Soil, Water and Environment Research Institute)

Cross-Sectional Data (Field Survey Data)

This type of data was collected through a specific questionnaire that was designed to collect certain data regarding the crop income in both new and old lands. This questionnaire is mainly concerned with the cost items and returns of the main crops.

METHODOLOGY OF STUDY

To assess the crops' water productivity, the current research reviewed the previously applied methodologies for crop water productivity assessment and implements the model that could be adopted to achieve the study's objectives.

Approach 1: Production Function Utilization

Agricultural production involves the combination of all inputs that are essential to produce agricultural outputs. For each agricultural production system, a generic production function (input-output relationship) can be derived as follows

$$Y = f(x1, x2, x3, \ldots xn) \quad (1)$$

Where Y is the output and x1, x2, x3, and xn are the production factors (land, labor, water, capital, energy and other inputs used in the production).

As production resources become scarce, producers seek ways to enhance the productivity of the resources and of the entire production system. Understanding the production function is a pre-condition for identifying opportunities for improving the performance of a production system. Increases in productivity can be achieved by two approaches: (a) increasing technical efficiency through more efficient utilization of production inputs; and (b) increasing allocation efficiency by producing outputs with the highest returns. An analysis of a single factor production function enables us to assess opportunities for maximizing returns from the use of this factor. Towards achieving the current research's goal, it is assumed that the only way to increase crop yield is by increasing the productivity of the water input. To optimize the production system, you must understand how output increases with increase in water input. The contribution of water to the production process can be described on both average and marginal basis at different levels of water input as follows:

Average Product of Water = Output / Water Input
Marginal Product of Water = Change in Output / Change in Water Input

The water output per feddan, Feddan = 4200 m^2, is defined as a function of effective water used by the plant. This is equivalent to the term resulting from the multiplication of the water use efficiency parameter and applied water. Three models could be used for the production function approach as follows:

Model 1: Some of the early work on water productivity was performed by Hexem and Heady (1978), who used field experiments in the United States to estimate yield as a function of inputs including water and fertilizer. One commonly used production function in the economic literature is a Cobb-Douglas production function of the form:

$$Y = Ax^{\delta}, \text{ with a requirement that } \delta < 1. \quad (2)$$

Where:
Y = Yield output per feddan
A = Equation parameter
δ = Equation parameter < 1
x = Water use input

Model 2: While some researchers have shown that Model 1 representation is reasonably accurate at the aggregate level, econometric evidence has shown that it is a poor representation of the yield response to water at a more micro-level. On the other hand, the literature showed evidence that a quadratic function is a better representation of water productivity as follows:

$$Y = a + bx - cx^2 \qquad (3)$$

Where:
Y = Yield output per feddan
a = Equation parameter > 0
b = Equation parameter > 0
c = Equation parameter > 0
x = Water use input > 0

This functional form has the property that above some level of input use, yields begin to decline. With an extreme weather shock, such as a flood, one can easily see how a field of crops is washed away, and the benefits of that additional flood water are negative.

Model 3**:** Another commonly used function is the Von Liebig, which assumes water exhibits constant returns below some threshold level, and a zero return above that threshold. This takes a form such as:

$Y = Ax \text{ if } x \leq x^*$
and
$Y = Ax^* \text{ if } x > x^*$

Existing literature work finds it is unclear which of these three functional forms is the most accurate, and further work needs to be done on this subject.

Approach 2: Crop Budget Approach

Crop budget is considered one of the economic tools to estimate the net return or profit. The estimated profit can be compared against the estimated per feddan profit for other crops and used to select the more profitable crops and crop combinations to be grown each year. It is worth noting that the profit in this budget may not be the maximum profit possible from one feddan of a specific crop. Any crop budget represents only one point on a production function. Therefore, there is a crop budget for every point on a production function; so a budget does not automatically determine the profit maximizing input levels. However, the profit must be properly interpreted, as it is the return or profit above all costs including opportunity costs on owned inputs, (Kay, 1981).

The first approach (the three models described above) requires the observations of the actual experiments that represent the quantity of water consumed and the associated crop's yield, with all other production factors held constant. For this reason, the current study adopted the second approach to assess the crop water productivity in terms of physical unit of production and monetary units. As mentioned above, the crop budget represents only one point on the production function and the net return does not represent the profit maximization. Therefore, the current study considered this fact and collected data from different farmers, carried out their crop budgets for each crop and calculated the average of these budgets to represent the reality of the crop budget situation.

THE FIELD SURVEY DATA

As mentioned above, specific field survey data is collected within the current study through questionnaire interviews. These data were analyzed and utilized to measure five indicators; break even yield, break even price, crop water productivity unit, crop water net return and crop rotation water net return.

Questionnaire Design

The questionnaire was designed and prepared for the farmers to collect certain types of data and information to support achieving the current research goal and objectives. The collection of data and information was carried out through direct interviews with farmers. Specifically, the questionnaire includes the following data and information items:

- Land tenure and size.
- Current cropping rotations.
- Variable costs of farm inputs; quantities and their associated prices.
- Total production and their associated prices.
- Labor requirements and their associated wages for different operations.
- Machinery requirements and their associated wages for different operations.
- Interest on variable costs.
- Fixed costs; machinery depreciation, interest, taxes, insurance and land charge.

Description of the Study Sample

The current research selected a stratified two-stage sampling of the farmers of Menoufia and Nubaria's villages, i.e. Menoufia represent the case of old lands with traditional irrigation and Nubaria for the new lands, it means reclaimed areas, with modern irrigation. The village represented the primary sample unit and the farmer was the secondary sample unit. From each selected village, 25 farmers were selected according to their proportional land holding sizes in order to make sure that the target farmers are homogenous in the sample and to capture all characteristics from different perspectives.

Sample Size and Selection

The first target population consisted of all farmers who are planting field crops, vegetables and fruits. The research team visited 10 farmers in each governorate and tested the questionnaire with them. From the pre test of surveyed data to be collected, the research team computed the variations of certain indication variables. Based on these variations, the proper sample size was determined to be 50 from each governorate. The sampled farmers were distributed as shown in table (1). It is worth noting that Nubaria, as the case of new land, has small farmer beneficiaries, graduates and investors. The sample has only contained small farmers and graduates because of some difficulties of meeting investors and the variations of the cropping pattern and crop production between investors and the other two classes.

Table 1. Distribution of sampled farmers according to holding size and location in sample governorates, 2008.

Holding Size Category	Menoufia	Nubaria
Less than 1 Feddan	10	0
1 - 3	20	0
3 - 5	15	0
Greater than 5 Feddans	5	50
Total	50	50

Source: Collected and calculated from the field survey, 2008.

0's in Nubaria are due to the minimum farms' size that equal to 5 feddan.

CURRENT CROPPING PATTERN IN EGYPT

The cropping pattern refers to the total area cultivated by different crops and their relative importance in the winter, summer, and nili, nili is an agricultural season lied between winter and summer seasons. It begins from June to September, seasons. Some cropping patterns were prepared as specific groups of crops, i.e. cereals, legumes, fodder, oil crops …etc, based on the target objectives. However, in all cases, the cropping pattern reflects the relative importance of the specific crop or group of crops to the total cultivated areas. Table (2) and figure (1) represented the winter cropping pattern structure. It could be noted that clover and wheat occupied about 76% of the total cropped area in winter season; distributed as 80% in old lands and 60% in new land because of planting barely(barley is a cereal crop) in new land which represented about 18.6% from total area cultivated in new land winter season.

In the summer season, the main crops are maize, rice, cotton, sugarcane and sorghum. The relative importance of them is 24.7%, 25.7%, 8.8%, 5.1% and 5.3% of total summer area distributed by different values between old and new lands as shown in table 3 and figure 2 below. The structure of the main activity in new land is different from old land area in summer season. Tomato and other vegetables represented about 43% while maize (white and yellow) and peanut represented about 17.2% and 12.7% of total summer crops respectively.

Table 2. Winter Cropping Pattern in Egypt, 2007.

Crop	Old Lands		New Lands		Total	
	Area (Feddan)	%	Area (Feddan)	%	Area (Feddan)	%
Clover	2102137	38.8	219884	18.5	2322021	35.2
Wheat	2220710	41.0	494819	41.6	2715529	41.1
Barely	23243	0.4	221862	18.6	245105	3.7
Faba bean	166192	3.1	69210	5.8	235402	3.6
Lentil	1841	0.0	34	0.0	1875	0.0
Fenugreek	11628	0.2	2380	0.2	14008	0.2
Check Peas	10787	0.2	72	0.0	10859	0.2
Lupine	2050	0.0	1695	0.1	3745	0.1
Flax	20378	0.4	442	0.0	20820	0.3
Winter Onion	69869	1.3	16772	1.4	86641	1.3
Garlic	21296	0.4	3557	0.3	24853	0.4
Sugar beat	225773	4.2	22535	1.9	248308	3.8
Potato	89650	1.7	19538	1.6	109188	1.7
Tomato	162074	3.0	38219	3.2	200293	3.0
Other Vegetables	236381	4.4	73467	6.2	309848	4.7
Other Field Crop	48830	0.9	5669	0.5	54499	0.8
Total	5412839	100	1190155	100	6602994	100

Source: Ministry of Agriculture and Land Reclamation, Economic Affairs sector, Agricultural Economics Bulletin, 2007.

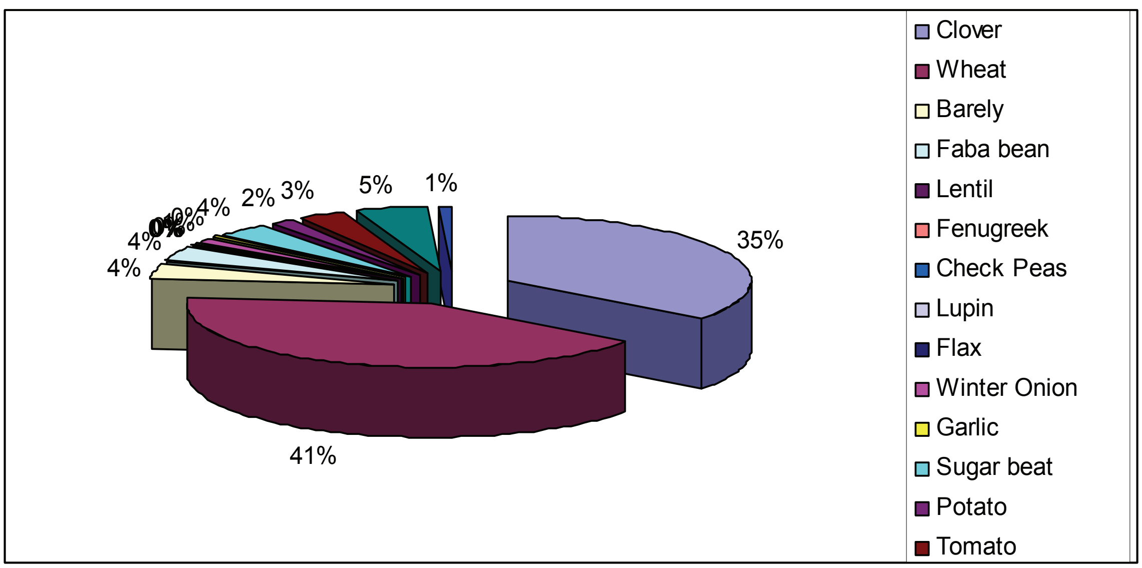

Figure 1. Winter Cropping Pattern Structure in Egypt, 2007.

Table 3. Summer Cropping Pattern in Egypt, 2007.

Crop	Old Lands		New Lands		Total	
	Area	%	Area	%	Area	%
Maize	1487697	26.4	120671	13.5	1608368	24.7
Sorghum	331984	5.9	15251	1.7	347235	5.3
Rice	1611804	28.7	60908	6.8	1672712	25.7
Yellow maize	143731	2.6	33455	3.7	177186	2.7
Pea nut	42240	0.8	113065	12.7	155305	2.4
Sesame	30412	0.5	44454	5.0	74866	1.1
Soya bean	18259	0.3	276	0.0	18535	0.3
Sun flower	22704	0.4	4472	0.5	27176	0.4
Summer Onion	12813	0.2	2505	0.3	15318	0.2
Potato	74926	1.3	10926	1.2	85852	1.3
Tomato	161090	2.9	105868	11.8	266958	4.1
Other Vegetables	549037	9.8	276096	30.9	825133	12.7
Other Field crops	275914	4.9	58375	6.5	334289	5.1
Sugarcane	295919	5.3	39144	4.4	335063	5.1
Cotton	566416	10.1	8150	0.9	574566	8.8
Total	5624946	100	893616	100	6518562	100

Source: Ministry of Agriculture and Land Reclamation, Economic Affairs sector, Agricultural Economics Bulletin, 2007.

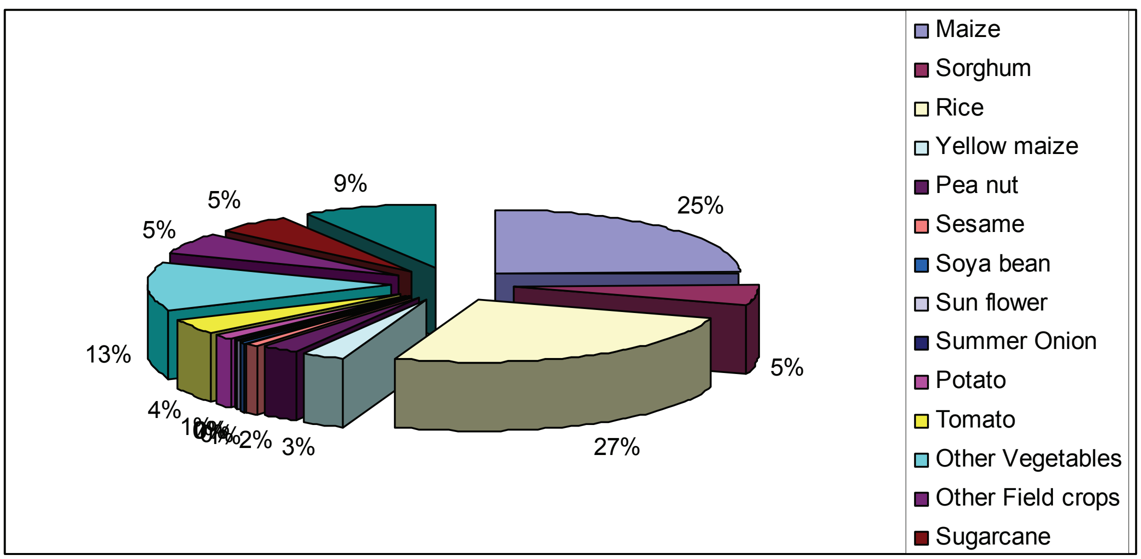

Figure 2. Summer Cropping Pattern Structure in Egypt, 2007.

In the nili season, the structure of cropping pattern also differed in the old and new lands and could be similar to the case of summer season. Tomato and other vegetables recorded about 37% versus 29% of total nili cropped area in both new and old lands respectively. The main constraint of this crop season is mainly the time of crops' planting and harvesting in addition to weather. For this reason, the crops cultivated in the nili season mainly appeared in Upper Egypt, (See table 4 and figure 3 bellow).

Table 4. Nili Cropping Pattern in Egypt, 2007.

Crop	Old Lands		New Lands		Total	
	Area (Feddan)	%	Area (Feddan)	%	Area (Feddan)	%
Maize	220761	38.9	22385	28.6	243146	37.6
Sorghum	6329	1.1	382	0.5	6711	1.0
Rice	403	0.1	2534	3.2	2937	0.5
Yellow maize	29130	5.1	15882	20.3	45012	7.0
Nili onion	14723	2.6	623	0.8	15346	2.4
Potato	61993	10.9	0	0.0	61993	9.6
Tomato	55183	9.7	14774	18.9	69957	10.8
Other Vegetables	111996	19.7	13858	17.7	125854	19.5
Other Field crops	67356	11.9	7752	9.9	75108	11.6
Total	567874	100.0	78190	100.0	646064	100.0

Source: Ministry of Agriculture and Land Reclamation, Economic Affairs sector, Agricultural Economics Bulletin, 2007.

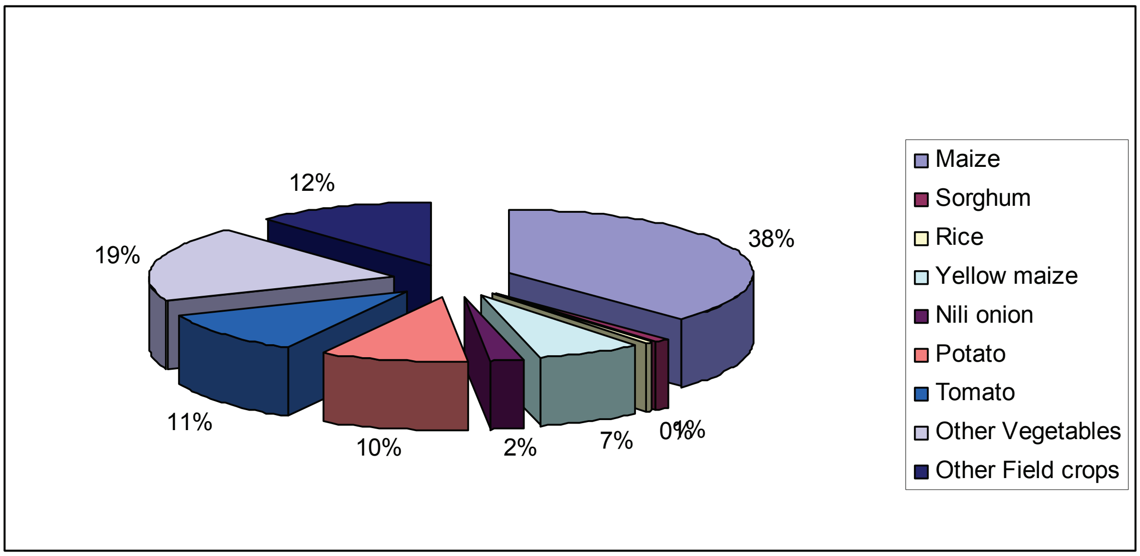

Figure 3. Nili Cropping Pattern Structure in Egypt, 2007.

WATER REQUIREMENT PATTERN

The water requirement pattern depends mainly on the cropping pattern. It is calculated from the cropping pattern based on multiplying the specific crop cultivated area by its per feddan water requirement and summed them up to estimate the total water requirement in winter, summer and nili seasons. Of course, the structure of water requirement pattern depends on per feddan crop water requirement as seen in tables 5, 6 and 7 and figures 4, 5 and 6 below. In the winter season, clover and wheat consumed about 81% of total water in the winter season. In the summer season, in spite of the relative importance of area cultivated by maize and rice that occupied 24.7% and 25.7% respectively, the rice crop consumed about 38% versus 24% by maize from total water consumption because of highly water requirement of rice. Therefore, more attention was introduced to decrease the area planted to rice and re-allocating it among other crops in the original areas or reclaimed additional areas. However, the decision here will depend on the objectives of agricultural strategy sector.

Table 5. Total Winter Water requirement Pattern in Egypt, 2007.

Crop	Old Lands			New Lands			Total million CM
	Area Feddan	Water Req. CM/Feddan	Total Water Req. million CM	Area Feddan	Water Req. CM/Feddan	Total Water Req. million CM	
Clover	2102137	2773.0	5829.2	219884	2608.0	573.5	6402.7
Wheat	2220710	1677.0	3724.1	494819	1751.0	866.4	4590.6
Barely	23243	1354.0	31.5	221862	1751.0	388.5	420.0
Faba bean	166192	1371.0	227.8	69210	1008.0	69.8	297.6
Lentil	1841	1837.0	3.4	34	1930.0	0.1	3.4
Fenu Greack	11628	1356.0	15.8	2380	n.a		15.8
Check Peas	10787	1704.0	18.4	72	n.a		18.4
Lupin	2050	1441.0	3.0	1695	n.a		3.0
Flax	20378	1234.0	25.1	442	1660.0	0.7	25.9
Winter Onion	69869	1862.0	130.1	16772	1610.0	27.0	157.1
Garlic	21296	1478.0	31.5	3557	1220.0	4.3	35.8
Sugar beat	225773	2007.0	453.1	22535	1415.0	31.9	485.0
Potato	89650	2003.0	179.6	19538	760.0	14.8	194.4
Tomato	162074	2003.0	324.6	38219	1066.0	40.7	365.4
Other Vegetables	236381	2003.0	473.5	73467	877.0	64.4	537.9
Other Field Crop	48830	2003.0	97.8	5669	n.a		97.8
Total	5412839			1190155			13650.7

Source: - Ministry of Agriculture and Land Reclamation, Economic Affairs sector, Agricultural Economics Bulletin, 2007.
- CAPMAS, Central agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.

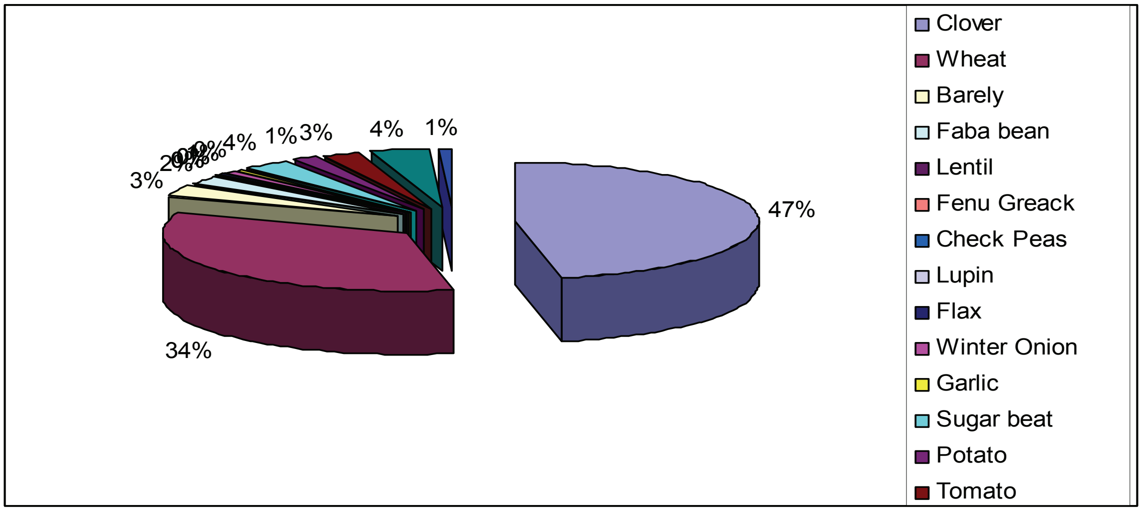

Figure 4. Total Winter Water requirements Pattern Structure in Egypt, 2007.

Table 6. Total Summer Water requirement Pattern in Egypt, 2007.

Crop	Old Lands			New Lands			Total million CM
	Area Feddan	Water Req. CM/Feddan	Water Req. Total million CM	Area Feddan	Water Req. CM/Feddan	Water Req. Total million CM	
Maize	1487697	3914.0	5822.8	120671	2171.0	262.0	6084.8
Sorghum	331984	2980.0	989.3	15251	1583.0	24.1	1013.5
Rice	1611804	5821.0	9382.3	60908	n.a		9382.3
Yellow maize	143731	3914.0	562.6	33455	n.a		562.6
Pea nut	42240	3895.0	164.5	113065	2686.0	303.7	468.2
Sesame	30412	2740.0	83.3	44454	n.a		83.3
Soya bean	18259	2955.0	54.0	276	2272.0	0.6	54.6
Sun flower	22704	2322.0	52.7	4472	2070.0	9.3	62.0
Summer Onion	12813	3658.0	46.9	2505	n.a		46.9
Potato	74926	2861.0	214.4	10926	1562.0	17.1	231.4
Tomato	161090	2861.0	460.9	105868	2146.0	227.2	688.1
Other Vegetables	549037	2861.0	1570.8	276096	n.a		1570.8
Other Field crops	275914	2861.0	789.4	58375	n.a		789.4
Sugarcane	295919	8854.0	2620.1	39144	n.a		2620.1
Cotton	566416	3102.0	1757.0	8150	n.a		1757.0
Total							25414.9

Source: - Ministry of Agriculture and Land Reclamation, Economic Affairs sector, Agricultural Economics Bulletin, 2007.
- CAPMAS, Central agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.

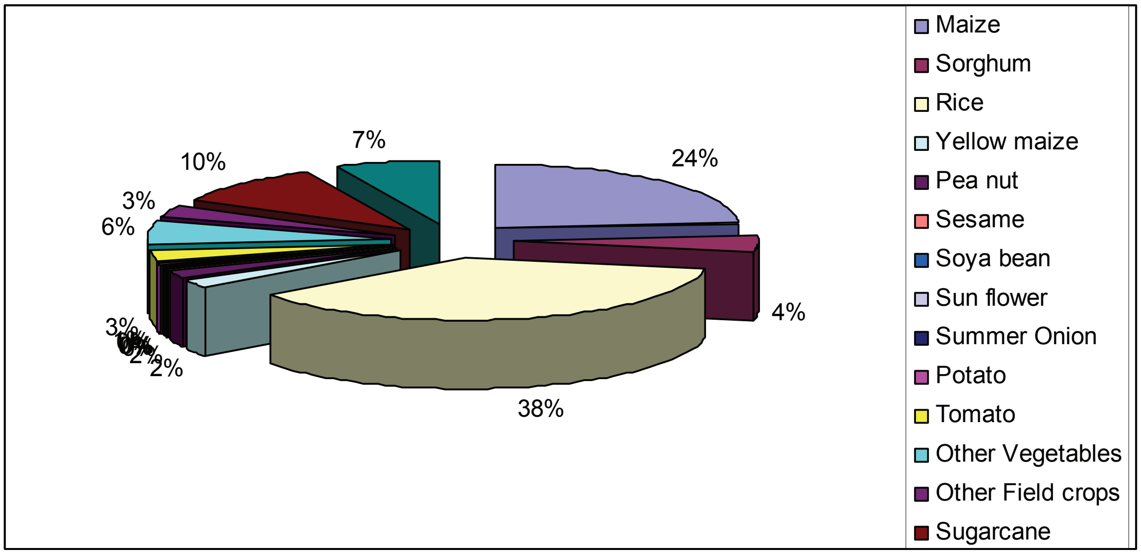

Figure 5. Total Summer Water requirement Pattern Structure in Egypt, 2007.

Table 7. Total Nili Water requirement Pattern in Egypt, 2007.

Crop	Old Lands			New Lands			Total Water Req. (CM)
	Area Feddan	Water Req. per Feddan	Water Req. Sub-total (CM)	Area Feddan	Water Req. per Feddan CM	Water Req. Sub-total (CM)	
Maize	220761	2436	537773796	22385	2436	54529860	592303656
Sorghum	6329	1947	12322563	382	1947	743754	13066317
Rice	403	6187	2493361	2534	6187	15677858	18171219
Yellow maize	29130	2436	70960680	15882	2436	38688552	109649232
Nili onion	14723	3161	46539403	623	3161	1969303	48508706
Potato	61993	2532	156966276	0	2532	0	156966276
Tomato	55183	2532	139723356	14774	2532	37407768	177131124
Other Vegetables	111996	2532	283573872	13858	2532	35088456	318662328
Other Field crops	67356	2532	170545392	7752	2532	19628064	190173456
Total	567874		1420898699	78190		203733615	1624632314

Source: - Ministry of Agriculture and Land Reclamation, Economic Affairs sector, Agricultural Economics Bulletin, 2007.
- CAPMAS, Central agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.

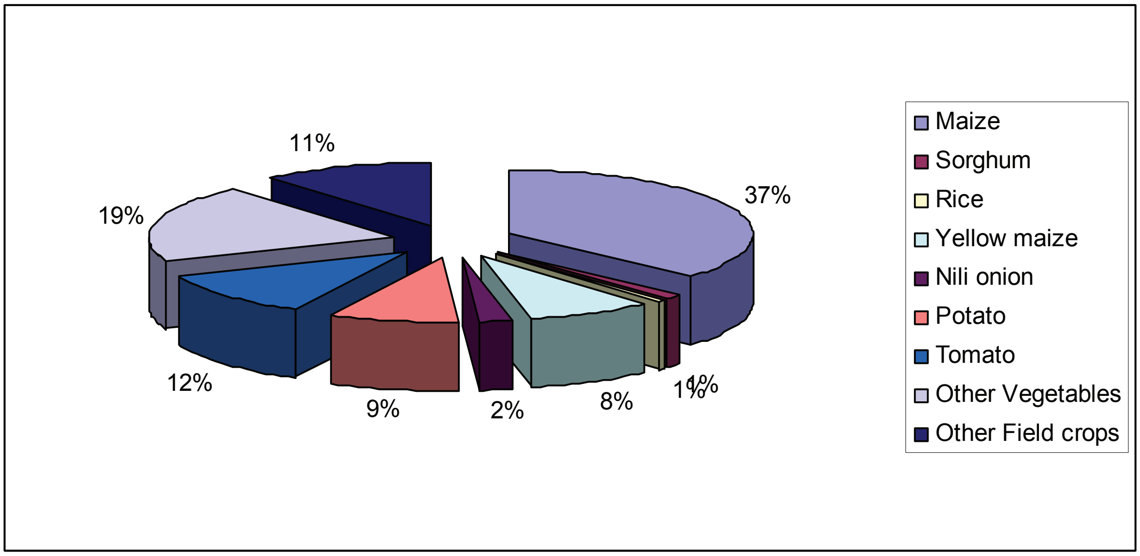

Figure 6. Total Nili Water requirement Pattern in Egypt, 2007.

CROP BUDGET

Crop budget can be organized and presented in several different formats, but they typically contain three different sections: income, variable costs and fixed costs. Following are the steps to estimate these sections in details:

Income

The first step to estimate income is to estimate the total production. Total production includes main and by product yield and the associated prices of these outputs for the studied crops. Of course, these variables are the average at the sampling level and could be considered a good estimate for the actual case in the previous agricultural year.

Variable Costs

The variable costs include seed, fertilizer, machinery, labor, machinery repairs, fuel and other items of variable cost. The variable costs are calculated by multiplying the quantities of each input by the associated price. The study also estimated the charge for the opportunity cost on capital invested in the variable costs. This charge covers the time period between expenditure of the capital and harvest when the income is received. Within the current research, an average time period of 6 months is assumed and a 10% opportunity cost is charged on the value of variable costs.

Fixed Costs

Fixed costs in the crop budget include machinery fixed costs and land charge. In the Egyptian circumstances, most of machinery work is hired and could be calculated as variable costs. Therefore, the fixed costs here are the charge of land. Land charge is the opportunity cost of land and represents the return for its use in crop production. Three methods could be adopted to determine the land charge: (1) an interest opportunity cost based on the current value of the land, (2) the owner's rental income from a typical crop share lease, or (3) a typical cash rent charge. The current research adopted the third method because of available knowledge for the cash rent of each crop in advance as can be obtained in the Egyptian rural societies.

Net Return

Net return calculated as the difference between the total return; total production multiplied by their farm gate prices, and the total costs calculated from the three items above. The net return here is not similar as its value published in agricultural economic bulletin because of the sharp increase in the price of fertilizer, energy, labor wages and land rent in addition to the high increase of the output prices. On the other hand, each crop budget estimated the shadow prices of all owned inputs and estimated all the other items of irrigation cost that included fuel and oil, custom application, equipment rent, depreciation, taxes and insurances. The price of water as a resource was considered as a cost recovery of water resource. Therefore, the net return here is expressing the economic profit.

Water Input

The water input can be specified as volume (m^3) or as the value of water expressed as the highest opportunity cost in alternative uses of the water. To estimate the water requirement of different crops, the current study utilized the data published by CAPMAS-Irrigation and Water Resource Bulletin at the field level and specifically the water requirement data for each crop at the field level.

Water Productivity Definition

Different indicators for water productivity could be used. In the current study, crop water productivity focuses on the field level. Water productivity at the field level refers to the amount of crop output in physical terms (crop yield in kilogram) or monetary terms (crop yield times its price in financial or economic terms) divided by the amount of water consumed (evaporated from the soil and transpired by the plant, the evapo - transpiration) - in other words, the crop per drop. However, productivity is a measure of performance expressed as the ratio of output to input. Productivity may be assessed for the whole system or parts of it. It could account for all or one of the inputs of the production system giving rise to two productivity indicators:

- **Total productivity :** the ratio of total tangible outputs divided by total tangible inputs; and
- **Partial or single factor productivity:** the ratio of total tangible output to input of one factor within a system. In farming systems the factors could be water, land, capital, labor and nutrients.

Water productivity (WP) is a partial-factor productivity that measures how the systems convert water into goods and services. Its generic definition can be recognized as:

Water Productivity (WP) = Output Derived from Water Use/ Water Input

<u>Indicators of Crop Water Productivity</u>

Water productivity is a very robust measure that can be applied at different scales to suit the needs of different stakeholders, (Shetty, 2006; Sharma, 2006). This is achieved by defining the inputs of water and outputs in units appropriate to the users' needs.
The numerator (output derived from water use) can be defined in the following ways:

- Physical output, which can be total biomass or harvestable product;
- Economic output (the cash value of output) either gross benefit or net benefit.

RESULTS OF WINTER FIELD CROPS

Following the previously mentioned methodology and equations, results of crop water productivity within winter season are presented in table (8) and figure (7). These results indicated that total productivity in old land is higher than in new land and consequently the net return because of higher production and lower costs in old land, except for the faba bean crop. However, the situation will be different if the water were not free. In new lands, the irrigation method is either sprinkler or dripper that consumed less water than the flood method. Water productivity in physical units can be used only to compare the productivity of water in old and new lands for the same crop. From this indicator, crop water productivity is higher in old land, i.e. flood irrigation method, than new one in both wheat and long clover while the opposite occurred in the case of faba bean and sugar beat which used the drip irrigation method because of the less water lost in drip irrigation compared with sprinkler and flood and less water is consequently consumed. The indicator of net return of water illustrated the same results of the physical one in addition to the variability of water return in old and new lands for long clover crop.

Table 8. Crop Water Productivity for Main Winter Field Crops in Old and New Lands under Different Irrigation Methods.

Crop	Wheat		Long Clover		Faba bean		Sugar beat	
	Old Land	New Land	Old Land	New Land	Old Land	New Land	Old Land	New Land
Irrigation Method	**Flood**	Sprinkler	**Flood**	Sprinkler	**Flood**	Drip	**Flood**	Drip
Water Requirement (m^3/Feddan)	1677	1751	2773	2608	1371	1008	2007	1415
Total Production (Ton Feddan)	3.41	2.48	30	26	1.4	1.55	25	19
Net Return (L.E/Feddan)	5,850	3,054	1,056	950	1000	1,732	779	779
Water Productivity Indicators:								
Water Unit Productivity (Kg/CM)	1.97	1.37	10.82	9.97	1.02	1.54	12.46	13.43
Water Unit Net Return (L.E/CM)	3.49	1.74	0.38	0.36	0.73	1.72	0.39	0.55

- Ton = 1000 kg, L.E Egyptian Pound and it is a currency of Egypt.

Source: - Calculated from the survey data of agricultural year 2007/2008.
Central agency for Public Mobilization and Statistics, Bulletin of irrigation and water requirement, 2004.

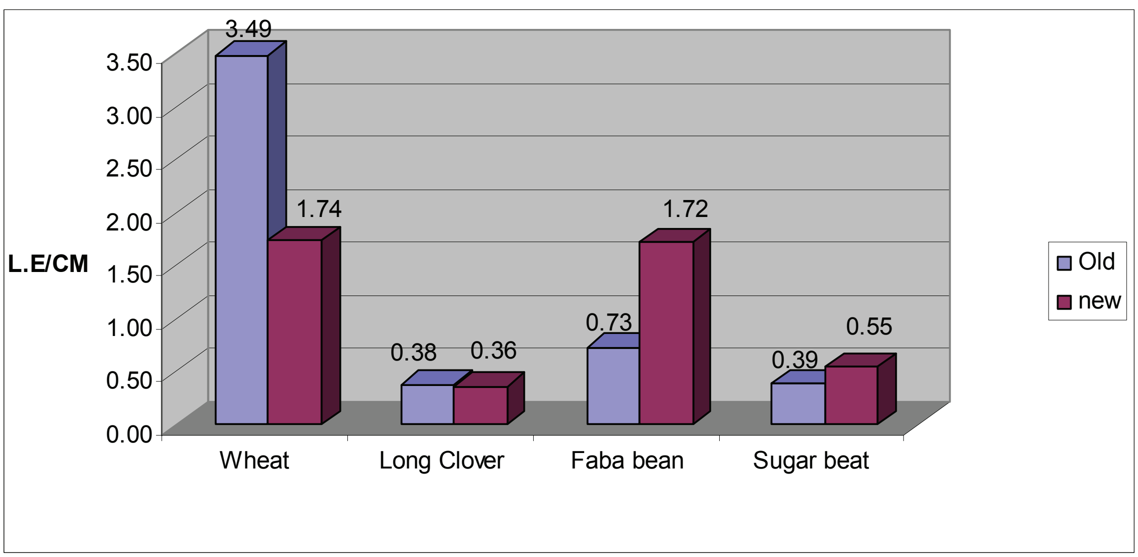

Figure 7. Crop Water Productivity for Main Winter Field Crops in Old and New Lands under Different Irrigation Methods.

RESULTS OF SUMMER FIELD CROPS

In the case of summer field crops, there is a high variation of production among the different crops. This variation is mainly due to the high response of these crops to water in summer because of the high temperature compared to the winter season. However, there is no area planted to cotton and rice in new lands for technical reasons. The variation in the water productivity in physical unit is low for maize and sugarcane while it is higher in onion crop (5.88 against 4.1 Kg/CM) and consequently the net return of water is 2.23 versus 1.61 L.E/CM for the same comparison. Table 9 and Figure 8 show the crop water productivity in both terms for the main summer crops.

Table 9. Crop Water Productivity for Main Summer Field Crops in Old and New Lands under Different Irrigation Methods.

	Maize		Rice		Cotton		Sugarcane		Onion	
Crop	Old Land	New Land	Old Land	New Land	Old Land	New Land	Old Land	New Land	Old Land	New Land
Irrigation Method	**Flood**	Drip	**Flood**	0	**Flood**	0	**Flood**	Drip	**Flood**	Drip
Water Requirement (CM/Feddan)	3914	2171	5821	0	3102	0	8854	0	3658	0
Total Production (Ton/Feddan)	4.37	2.85	4	0	1.26	0	51	46	15	10
Net Return (L.E/Feddan)	734	500	1,783	0	2,523	0	3998	2700	5898	3,796
Water Productivity Indicators:										
Water Unit Productivity (Kg/CM)	1.58	1.31	0.69	0	0.41	0	5.8	5.11	4.10	5.88
Water Unit Net Return (L.E/CM)	0.25	0.23	0.31	0	0.81	0	0.45	0.3	1.61	2.23

Source: - Calculated from the survey data of agricultural year 2007/2008.
CAPMAS, Central Agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.

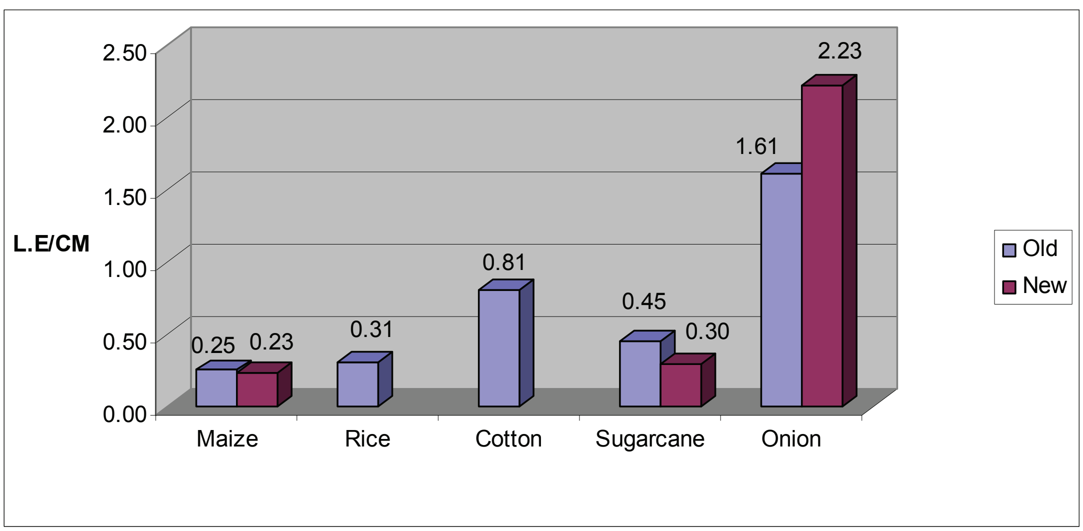

Figure 8. Crop Water Productivity for Main Summer Field Crops in Old and New Lands under Different Irrigation Methods.

RESULTS OF VEGETABLE CROPS

Vegetables are considered the promising agriculture crops in new lands. The vegetable production mainly depends on the technology applied from land preparation until the post harvest of these vegetable crops. There are technical logistics for the different vegetable crops - each one has a specific package of technology. The productivity of any input, i.e. land, labor, capital and water depend on the level of the technology applied. Total production here is recorded for small farmers and graduates categories, i.e. not including investors as mentioned previously in the sample design section. Actually, the production for investors' category is very high but it cannot be used for comparison within the current study. Results, presented in table (10) and figure (9), indicate that there is a high variation in the physical water productivity among the three crops. It was higher in new land compared with old. On the other hand, the net return of water in new land is less than in old land in the case of green peas and tomato because of their lower of net return. The low aspect of this net return is due to the low price of production as a result of the plentiful supply at the time of sale.

Table 1. Crop Water Productivity for Main Vegetable Crops in Old and New Lands under Different Irrigation Methods.

Crop	Tomato		Pepper		Green Peas	
	Old Land	New Land	Old Land	New Land	Old Land	New Land
Irrigation Method	**Flood**	Drip	**Flood**	Drip	**Flood**	Drip
Water Requirement (CM/Feddan)*	2532	2532	2532	2532	2532	2532
Total Production (Ton/Feddan)	15	32	6	6.7	2.8	1.86
Net Return (L.E/Feddan)	6,383	4,615	5,433	6000	3500	3,291
Water Productivity Indicators:						
Water Unit Productivity (Kg/CM)	5.24	14.91	2.10	2.72	0.14	0.85
Water Unit Net Return (L.E/CM)	2.23	2.15	1.90	2.44	1.75	1.50

Source: - Calculated from the survey data of agricultural year 2007/2008.
CAPMAS, Central agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.
* Water requirements for vegetables are considered 2532 cubic meters because of the absence of accurate data for each crop.

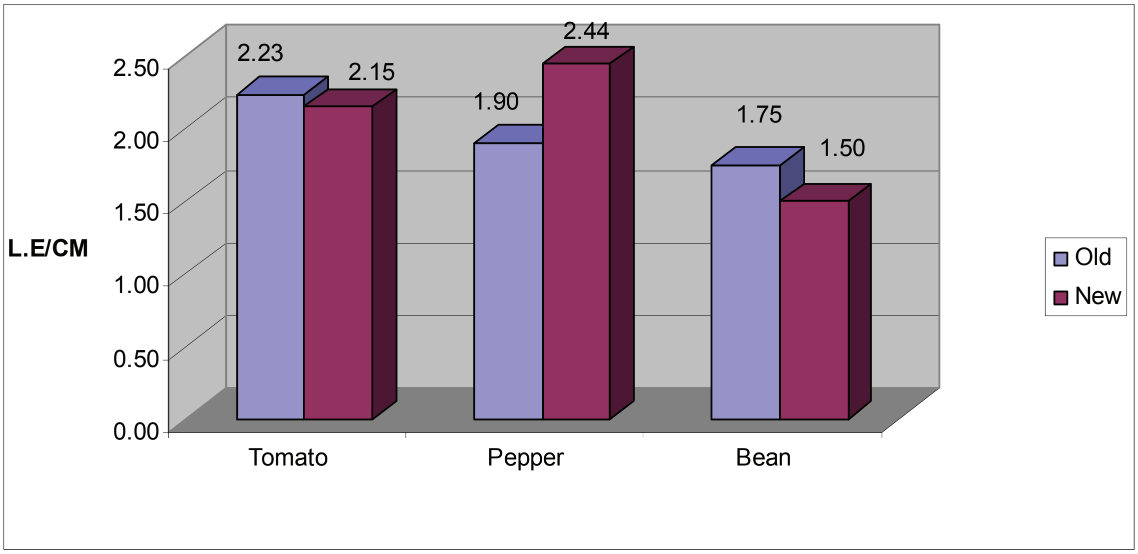

Figure 9. Crop Water Productivity for Main vegetable Crops in Old and New Lands under Different Irrigation Methods.

RESULTS OF FRUIT CROPS

Fruit production activities need a huge investment through establishing the nursery and preparing farms till the final phase of production and marketing. As mentioned above, the current study dealt with the graduates and small farmers in new lands. Table (11) and figure (10) show that water productivity in physical and net return units are lower in the case of new land compared with old for the three crops because of the age of trees, the experience of farmers and the ability to finance.

Table 11. Crop Water Productivity for Main Fruit Crops in Old and New Lands under Different Irrigation Methods

	Orange		Grapes		Peach	
	Old Land	New Land	Old Land	New Land	Old Land	New Land
Crop	**Flood**	Drip	**Flood**	Drip	**Flood**	Drip
Water Requirement (CM/Feddan)	5280	3500	4400	2800	4000	2800
Total Production (Ton/Feddan)	10	8	10	9	4	3
Net Return (L.E/Feddan)	3,128	3,599	10,371	3,922	3000	2,634
Water Productivity Indicators:						
Water Unit Productivity (Kg/CM)	1.74	1.29	2.15	1.82	0.86	0.65
Water Unit Net Return (L.E/CM)	***0.54***	0.62	2.22	0.79	0.64	0.66

Source: Calculated from the survey data of agricultural year 2007/2008. CAPMAS, Central agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.

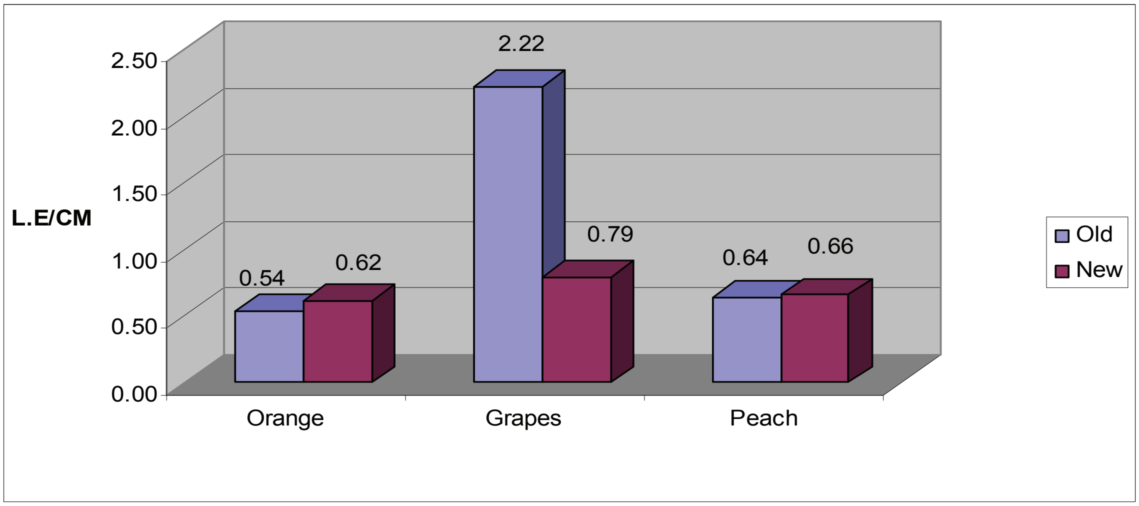

Figure 10. Crop Water Productivity for Main fruit Crops in Old and New Lands under Different Irrigation Methods.

RESULTS OF NET RETURN OF WATER TO CROP ROTATIONS

Crop rotation refers to the sequence of crops among the three seasons; winter, summer and nili. The current study focused on the dominant rotations for winter and summer crops because nili season's area for crop rotation is limited and was found only in Upper Egypt. To evaluate the net return of water, the study estimated the total net return of different crop rotations and their water requirements, ie. divided the total net return of crop rotations by their water requirements. However, the estimation of net water return allowed for the comparison of the different rotations and to determine which of them is more profitable in addition to comparing these crop rotations with sugarcane as a perennial crop.

As could be seen from table (12) and figure (11), the wheat + maize rotation is the highest one according to its profitability in both old and new lands. Wheat + rice rotation is the second one and cultivated only in old land. The main reason for high wheat rotation is mainly due to the high prices of wheat during the last year. The procured price of wheat was sharply increased from L.E/Ton 1200 to 2500; (i.e. L.E / Ardab, Ardab = 155 kg, 175 to 380). In general, the wheat and long clover rotations are the main ones in all Egypt; particularly after the Egyptian reform policy program and decreasing the area planted by cotton. As it is known, sugarcane is mainly planted in Upper Egypt and this affects its net return due to its limited cultivated area. From table (12), it is clear that short clover + cotton and wheat + maize rotations are higher in their net return of water than sugarcane while long clover + maize is less than sugarcane.

Table 12. Net return of water for different crop rotations.

Crop Rotation	Net Return (L.E)		Water Requirement (Cubic meters per feddan)		Net Return of water per crop rotation (L.E/CM)	
	Old land	New land	Old land	New land	Old land	New land
Short Clover + Cotton	2839.8	0	3933.9	0	0.72	
Long clover + Maize	1790	1450	6687.0	4779.0	0.27	0.30
Long clover + Rice	2838.8	0	8594.0	0	0.33	
Wheat + Maize	6584	3554	5591.0	3922.0	1.18	0.91
Wheat + Rice	7632.8		7498.0		1.02	
Sugar beat + Maize	1512.5	1279	5921.0	3586.0	0.26	0.36
Sugar beat + Rice	2561.3		7828.0		0.33	
Sugarcane	3998		8854.0		0.45	

Source: - Calculated from the survey data of agricultural year 2007/2008.
CAPMAS, Central agency for Public Mobilization and Statistics, Water Resources and Irrigation Bulletin, 2004.

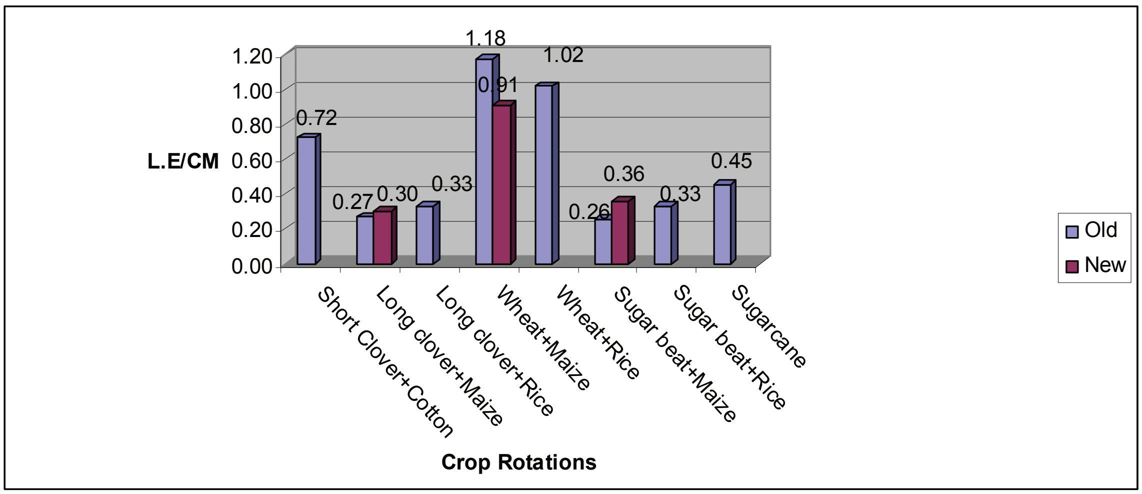

Figure 11. Net return of water for different crop rotations

SUMMARY AND CONCLUSION

With scarce water conditions, crop water productivity and its net return play a vital role in developing sustainable agricultural and water policies. Crop water productivity and its net return depend on many factors, both local and international. Therefore, their accurate determination has to be carried out through various field agriculture and water requirement investigations as well as their economic aspects. The authors of the current study designed a questionnaire for collecting the required data for crop budget and other field conditions in addition to the other collected data and information from various agricultural and water organizations. After several analyses were performed for the collected data and information to accurately determine the crop water productivity and its net return for the various cultivated crops in Egypt within the three seasons (winter, summer, and nili) and for old and new lands. All results of the investigated items were tabulated and graphed in a certain specific format that can assist decision makers in drawing future sustainable agricultural and water policy for Egypt and maximizing national water resource productivity in different agricultural activities considering the resource supply and demand and based on the efficient utilization of the water resources.

According to the results of individual crops' net return from water, presented in the current manuscript, it can be concluded that onion and cotton crops have the highest net return from one cubic meter of water compared with rice. On the other hand, maize net return is currently less than rice. This fact is due to the low local price of maize. It is expected that maize prices will increase with the Bio-fuel initiative that will force the international prices for maize to increase.

According to the results of crop rotations, presented in the current manuscript, it can be concluded that wheat + maize rotation has the highest water productivity according to its profitability in both old and new lands. Wheat + rice rotation is the second one and cultivated only in old land. The main reason for high wheat rotation is mainly due to the high price of wheat during the last year. The procured price of wheat was sharply increased from L.E/Ton 1200 to 2500; (i.e. L.E / Ardab 175 to 380). In general, wheat and long clover rotations are dominant in all Egypt; particularly after the Egyptian reform policy program and decreasing the area planted to cotton. As it is known, sugarcane is mainly planted in Upper Egypt and this affects its net return due to its limited cultivated area. To compare the sugarcane water productivity, it has to be compared with other rotation productivity since it is considered a perennial crop. In addition, short clover + cotton and wheat + maize rotations are higher in their net return for water than sugarcane while long clover + maize rotation is less than sugarcane regarding its water net return.

Based on the study's conclusions, it is very important to activate the role of agricultural extension as well as water users' associations in providing the various farmers with the necessary information about the most financially rewarding crops' rotations and individual crops; and educate farmers how to cultivate the maximum profitable crops and in which season and area.

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