Impacts of Irrigation on Agricultural Productivity in Egypt

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Abstract
This paper investigates the impacts of the main primary production factors (e.g., seeds, nitrogen, phosphorus, etc.), on the total production of the main crops in Egypt (Cotton, berseem, maize, rice and wheat), with special emphasis on the role of irrigation. Specifically, it estimates the isoquant curves of irrigation water and fertilizer factors of productivity for these crops and assesses the value of marginal products of irrigation water with special emphasis on elasticity of the production factors and the economics of returns to scale. Farm level data for 2011-2012 were collected for a sample of 152 producers in South El Husainia Plain, Egypt. The data was used to estimate the Cobb-Douglass production function and isoquant curves. Empirical findings showed increasing returns to scale for berseem and cotton, but decreasing returns to scale for wheat, rice and maize production was identified. The irrigation water productivity for wheat, rice, cotton and maize has been relatively low. Overall, marginal productivity of irrigation water for the studied crops, especially for cotton, has been low. This implies that farmers may be over-irrigating, and suggests that farmers could increase the production of these crops by applying water more efficiently. This highlights the need to enhance the governmental programs for more efficient water management and allocation.

Key-words: Cobb-Douglas, irrigation water, agricultural productivity, returns to scale, Egypt.

1. Introduction

Irrigation water is becoming an increasingly scarce resource for the agricultural sector in many arid and semi-arid countries. Factors such as rapid urbanization, population growth and climate change are placing these resources in a continuous challenge. To combat the physical scarcity of water, increasing its use efficiency, improving its productivity in every production sector, and its allocation to the most valuable uses remains the most effective strategies.

Egypt is the largest and most populous economy in the North African region. The rapid increase of population growth and its corresponding economic activities caused a reduction of the per capita share of the already limited fresh water resources, as well as degradation of the water quality (Abdel-Shafy and Aly, 2002). Despite the fact that the vast majority of Egyptian land is desert, with agricultural land constituting less than 5% of the total land area, the agricultural sector is highly important for the country's economy. In 2012 agriculture accounted for 16% of GDP and 29% of total employment (World Development Indicators 2013). Due to very sparse and erratic rainfall, crop production in Egypt is almost fully depending on irrigation. Irrigation water is taken from the Nile River, and so far the government has provided it to farmers free of charge. However, with increasing expansion of the agricultural areas due to population growth, water scarcity is likely to grow in the near future. It is, therefore, important to identify efficient ways of using scarcely available irrigation water resources.

According to Khalifa *et al.*, (2010), irrigation management of crops in Egypt is characterized by the application of more water than the crops require. In fact, large volumes of water are supplied without any estimates of the soil water content at the root zone. The rationale for doing so is that farmers assume that more irrigation water means a greater yield. Eliminating unnecessary irrigation water beyond the crop requirement would help saving water, provided that this can be done with low yield losses (Khalifa *et al.*, 2010).

Water productivity, which is computed by the amount of water applied and crop productivity, which is also influenced by crop management, is critical element in managing and allocating water to maximize the economic and social returns to limited water resources. This is critical decision facing Egypt both at the farm level and at the national level at water supply administration department. As production factor, water can be characterized by several features, which make the issues of efficient utilization of this resource different from those pertaining to other production factors. The overall objective of this study is to assess the water use efficiency by Egyptian farmers in the major irrigated crops. It is within this framework that the objectives of the study are the following: (i) to estimate the impacts of the primary production factors (e.g., seeds, nitrogen, phosphorus, irrigation water) on the total production of the main produced crops in Egypt (e.g; wheat, rice, cotton, maize and berseem). More specifically, to estimate the isoquant curve of irrigation water and fertilizer factors that produce certain quantities of the production for the studied crops; (ii) measure the value of marginal products of irrigation water in the studied crops, and (iii) measure the production elasticities for the production factors, with special emphasis on the assessment of the economic return to scale regarding the production of the analyzed crops.

The remainder of this paper is organized into five sections: Section 2 shows a comprehensive review of past studies on economic impact of irrigation around the world and in Egypt; Section 3 describes the research methodology; Section 4 presents and discusses empirical results; and the last section (Section 5) highlights the main concluding remarks and policy implications.

2. Review of past studies regarding the economic impact of irrigation

Crop yields everywhere in the developing world are consistently higher in irrigated than rainfed areas (Lipton *et al.,* 2005); naturally making irrigation water a necessary input of agricultural production in dry areas, thus in many developing countries water needs for crop production are covered partly or fully by irrigation (Calzadilla *et al.*, 2011). The use of irrigation can generate a number of benefits for the agricultural sector (Hamilton and Chaipant, 1983). Most importantly, irrigation allows expansion of cultivatable areas beyond what is possible under rain-fed conditions. Secondly, irrigation results in substantial yield increases due to prevention of crop water stress and to the combined effect of using irrigation with high yielding crop varieties, fertilizers, and pesticides (Turner *et al.,* 2004). And thirdly, irrigation reduces risks due to climatic factors.

In the literature, the concept of water use efficiency (WUE) and water productivity (WP) are considered as different terms. Hence, they are used differently by different professionals (economists, agronomists, etc.). The first use of the term 'water use efficiency' to mean the ratio of crop production to evapotranspiration was by Viets in 1966 (Kijne *et al.*, 2000). For instance, Willardson *et al.,* (1994), introduced the concept of consumed fractions and others such as Perry (1996a), Clemmens and Burt (1997), and Molden (1997), have referred to beneficial and non-beneficial depleted or consumed fractions of water.

As the concept of water productivity is different from one topic to another (engineering, social science, agronomic) it is worth to indicate that economists use factor productivity as the value of output divided by the value of all inputs. Most analysts in the water sector agree to the statement that water use efficiency "*includes any measures that reduce the amount of water used per unit of any given activity, consistent with the maintenance or enhancement of water quality*" (Tate, 1994 in Pereira *et al.,* 2002). Depending on how the terms in the numerator and denominator are defined, water productivity can be expressed in general physical or economic terms (Seckler *et al.,* 1998a in Kijne et *al.,* 2000). Economic efficiency of irrigation water is defined as maximizing social net benefits from water resources, which often requires improved water management (Wichelns, 2002). In the same line, optimal irrigation management includes the choice of crops, varieties of seeds, management framework and techniques, cultural practices, policy, and institutions that may increase the productivity of each unit of water used for irrigating the cultivated crops (Pereira *et al.,* 2002). Thus, in order to improve water productivity, there is a need to combine on-farm irrigation techniques with the agronomic (better crop selection and appropriate cultural practices) and management practices (improved irrigation management options and timely socioeconomic interventions). Conventional water management guidelines should be revised to ensure the maximization of water productivity instead of land productivity (Oweis and Hachum, 2005).

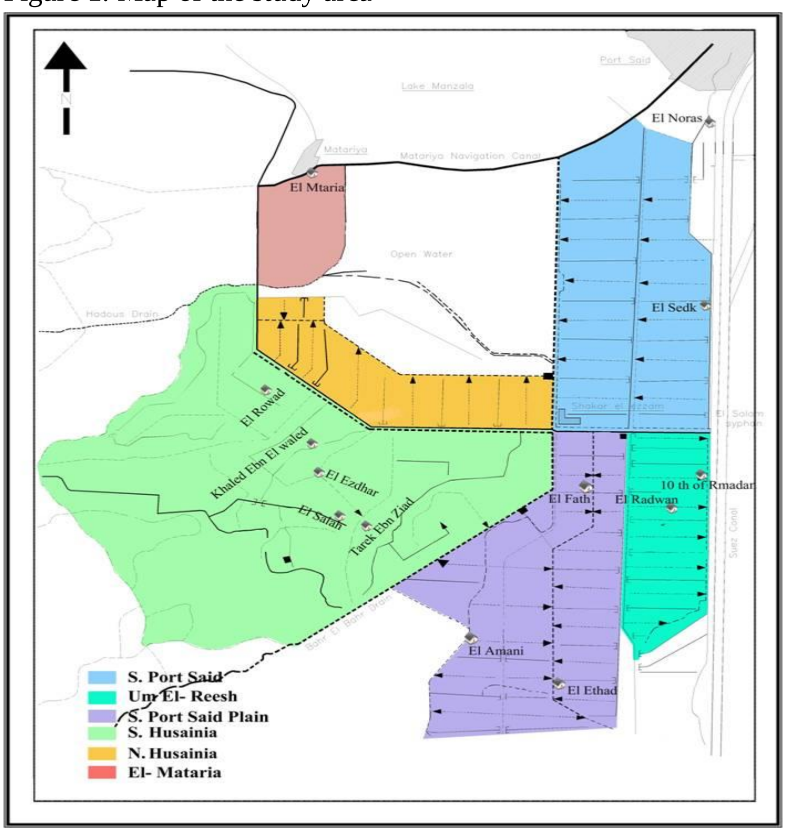
Playan and Mateos (2006) report that particular attention has to be paid to the improvement of irrigation management, which shows much better economic return than the improvement of the irrigation structures. They particularly, note that the hydrological effects of these improvements may be deceiving, since they will be accompanied by larger crop evapotranspiration and even increased cropping intensity. As a consequence, less water will be available for alternative uses. Clemens and Burt (1997) indicated that evaluation of the irrigation system performance should rely on accurate hydrologic water balance over the area considered. They provided equations, 330 procedures and examples for making these calculations and recommended that confidence interval be included in all reporting of irrigation performance parameters. Sadras (2009) reports that considering the cost and management complexity of implementing partial root-zone drying, it is critical to identify the rare conditions where this method could be economically justified.

3. Methodological framework

3.1. Data sources and data collection procedure

The Study area: The target site of this research is located at South El Husainia Plain, El Husainia District, Sharkia Governorate, South East of Delta region in Lower Egypt (Figure 1). South El Husainia Plain is one of six newly reclaimed areas in East Delta Region and covers an area of about 24,000 ha, of which about 16, 000 ha (representing 66.5% of the total area) are cultivated (Sayaf, 2011; East Delta Newlands Agricultural Services Project "EDNASP", 2009). However, gradual settlement occurred in South El Husainia in 1993/94. This region is inhabited by recent settlers who received plots of land from the government. The soil structure and lack of fresh irrigation water, in addition to poor social and cultural services, made the region unattractive for many farmers.

Figure 1. Map of the study area



Source: WLI-Water Livelihood Report – Egypt (2012).

Sample selection and data collection: Data was collected based on a socio-economic household survey conducted during 2011/2012 in El Husainia Plain. A sample of 152 households, representing 7.7% of the total number of land holders were randomly selected for this purpose. The distribution of farm households across the defined five Villages (clusters) was determined based on the weighted proportional importance of the total number of holders in each Village (proportional to the number of holders of each holding category in the population). Stratified sampling approach was employed based on holding categories (graduates, beneficiaries, small investors and new holders), to ensure the representativeness of each holder category. Interviewed farmers were randomly selected using lists obtained from census offices.
The questionnaire consists of eight sections: the first is related to agricultural activities and costs of production. The remaining sections focus on outputs and revenue of crop production, institutional framework, sustainable water saving and soil conservation practices using recommended water management technologies, support and extension services, the most problems facing farmers in addition to the main socio-economic characteristics of the farmers.

3.2. Model specification

According to Ekpebu (2002), there are many functional forms that could be used to describe production relationship, but in practice the commonly used forms are linear, quadratic, Cobb-Douglas and *translog* functional forms. In this research, we used the linear, double logarithmic (i.e., Cobb-Douglass[2]), production function and isoquant curve approaches.

The linear production function is used to measure linear relationships between inputs and outputs. Given four variable inputs (X_1 to X_4), the function can be mathematically expressed as:

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + u \qquad (1)$$

Where Y is the production quantity of the selected crop (ton/feddan[3]); α_0 is a constant parameters to be estimated; X_1 represents the seeds quantity- (kg/feddan); X_2 is quantity of phosphorus fertilizer (kg/feddan); X_3 is labor (man/day/feddan) and X_4 represents the water volume (cubic meter/feddan). Parameters α_1, α_2, α_3, and α_4 are to be estimated and they determine efficiency of the inputs on output; and *u* is an error term. This linear function was criticized and according to Kalaitzandonakes *et al.*, (1992), this function is not a good measure of an optimum production because the coefficients assume constant marginal productivity. However, we present the results for illustration.

The Cobb-Douglas production function is then used to deal with such shortcomings of linear specifications. It is widely used to represent the technological relationship between the amounts of two or more inputs, particularly physical capital and labor, and the amount of output that can be produced by those inputs (Miller, 2005). This function is explicitly specified as follows (for four variables):

$$Y = AX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}e \qquad (2)$$

[2] For more details on the Cobb-Douglass production function, see Miller (2005).
[3] One feddan = 0.42 hectares.

Where Y A; X_1; X_2; X_3 and X_4 are as defined in equation 1 and *e* is an error term. The coefficients of X_1, X_2, X_3 and X_4 represent direct measures of elasticity of the respective factors of production. In double logarithmic form, the CD is specified as:

$$Log(Y) = \beta_0 + \beta_1 Log(X_1) + \beta_2 Log(X_2) + \beta_3 Log(X_3) + \beta_4 Log(X_4) + u \quad (3)$$

The production elasticity measures the responsiveness of output to a change in the level of one factor used in production, ceteris paribus. The total, average, and marginal physical product are just one way of showing production relationships. They express the quantity of output relative to the amount of variable input used, while holding fixed inputs constant. The returns to scale show the productive factor shares of the production. The Marginal Rate of Technical Substitution (MRTS) is the amount by which the quantity of one input must be reduced when one additional unit of another input is used, so that output remains constant. In other words, it shows the rate at which one input (e.g. nitrogen fertilizer or irrigation water) may be substituted for another, while maintaining the same level of output.

Regarding the case of water, economists consider the value of marginal product of irrigation water as a very good estimate of its opportunity cost. The value of marginal product is a measure of a firm's revenue contributed by the last unit of a productive factor employed. The value of marginal products of irrigation water for a given crop can be derived from the estimated production functions.

For the linear form, the production elasticities of irrigation water for each crop are calculated by dividing the marginal product of the irrigation water on the corresponding average product of irrigation water for each crop. For double logarithmic form, the marginal products are calculated by multiplying the production elasticity of the irrigation water by the corresponding average products for each crop. The values of marginal products of irrigation water are calculated by multiplying the marginal product by the farm-gate price of the corresponding crop.

The last step of the analysis is the use of the isoquant curves in order to assess all possible combinations of two inputs that result in the production of a given level of output. It is used to measure the influence of inputs on the level of production or output that can be achieved. There are important relationships between irrigation water and the nitrogen fertilizers utilization at different points of the production surface. Therefore, all possible combinations of irrigation water and nitrogen fertilizer which yield equal output or production to producer can be derived from the double logarithmic production function.

4. Results and discussion

4.1. Relationship between crop yield and inputs

The strength and direction of the relationship between the yield of the studied crops and the inputs used have been measured by calculating the simple correlation coefficient matrix among the quantities produced from the selected crops and the quantities used from the studied inputs. Results in table 1 showed that the relationships among the produced quantities of cotton, and maize, and the quantities used of seeds, nitrogen and phosphorus fertilizers, labor and irrigation water were positive and in majority statistically significant at a significance level of 5% (t-statistics). In addition, positive and statistically significant relationships were observed between produced quantities of wheat, rice, and berseem and the used quantities of inputs (seeds, phosphorus fertilizers, labor, and irrigation water). This indicates that using more inputs leads to increased crop yields for the studied crops, which is a confirmation that the data is consistent with agronomic expectations and model assumptions.

Table 1: Correlation coefficients between the crops yields and the quantity used of inputs (Logarithmic vs Linear)

		Berseem		Wheat		Rice		Maize		Cotton	
Inputs	Units	Log	Lin	Log	Lin	Log	Lin	Log	Lin	Log	Lin
Seeds	kg/feddan	0.37*	0.38**	0.54**	0.54**	0.51**	0.52**	0.74**	0.76**	0.97**	0.98**
Nitrogen	kg/feddan	0.11	0.12	0.51**	0.50**	0.51**	0.58**	0.65**	0.75**	0.94**	0.94**
Phosphorus	kg/feddan	0.55**	0.58**	0.13*	0.12	0.09	0.10	0.66**	0.66**	0.72*	0.84**
Labor	Manday/feddan	0.61**	0.60**	0.50**	0.56**	0.37**	0.34*	0.75**	0.54**	0.73*	0.97**
Irrigation water	M^3/feddan	0.68**	0.71**	0.42**	0.43**	0.38**	0.38*	0.53**	0.75**	0.96**	0.96**

Source: Compiled and calculated from field survey, 2011/2012.

*Note: *Significance at 5%; **Significance at 10% and ***Significance at 1%.*

4.2. Results from production functions analysis

The estimated parameters of the linear and CD production function for the five crops are presented in table 2. From this table it appears that all the first-order parameters (α_i and β_i) have the anticipated (positive) signs and magnitudes. Given that the CD results fit better with the collected data, in our discussion of regression analysis, will focus on the findings from the indicated production function.

The elasticity coefficient of the "effectively irrigated area" of berseem is positive (equal to 0.31) and significant at 5% level. It is also found to be the second highest production factor affecting the berseem output among the four input factors. The highest factor is phosphorus (with 0.58) followed by irrigation water and seeds (with 0.15), while labor (with 0.057) have relative small influence on the wheat production. The sum of elasticity of the four input factors is 1.108 (>1) which showed that the returns to scale (RS) is increasing. This suggest that berseem farmers in the area can increase their berseem output by increasing the use of phosphorus, water and seeds as they are producing at the first stage of production. In other words this is the stage of production function where the additional production for additional unit of input is successively increasing. That implies more inputs should be applied for production that exhibits this property.

The results in Table 2 revealed that seeds are the most influential factor on wheat production (with a positive and significant coefficient: 0.252). The water coefficient is also positive and significant at 5% level. The returns to scale value indicates that wheat production exhibits a decreasing return to scale (with RS=0.623). This implies that an increase in all inputs leads to a less than proportional increase in wheat production. In other words, if these resources are increase by 1%, the wheat production would only increase by less than 1%. As noted above, the situation was on the contrary (it was increasing returns to scale situation in other words more inputs will more than pay off in production).

The analysis of the rice production function indicates that all inputs were positively related to the output of rice. The R^2 of 0.46 implies that 46% of rice output variation in the area is explained by the inputs specified in the production function. Furthermore, water and seeds significantly affect the output of rice at 10% level of significance. The rest of inputs (labor and nitrogen) affect the production of rice to a lower extend (lower significance level). It can be inferred that a unit increase in seeds will lead to 33.4% increase in the output of rice, while an increase of one cubic meter of irrigated water will lead to an increase of 24.8% in the quantity of rice produced. For rice production, results also show a decreasing return to scale (with 0.88) which indicates that productivity of the inputs is decreasing and the increasing of inputs factors should be addressed in more efficient way.

Table 2: Parameters estimates of the linear and Cobb Douglas production functions

Cobb- Douglas Production Function			Linear Production Function		
Variables	*Parameters*	*Coefficients*	*Variables*	*Parameters*	*Coefficients*
Dependent Variable: Log (Y)			*Dependent Variable: Y*		
Berseem					
Intercept	β_0	2.71	Intercept	α_0	14.79**
Ln(seeds)	β_1	0.15 **	Seeds	α_1	0.167**
Ln(phosphorus)	β_2	0.586***	Phosphorus	α_2	0.019**
Ln(labor)	β_3	0.057***	Labor	α_3	0.0257**
Ln(water)	β_4	0.315***	Water	α_4	0.003***
R^2		0.65	R^2		0.65
F-ratio		15.25**	F-ratio		15.5**
Wheat					
Intercept	β_0	0.11	Intercept	α_0	1.64*
Ln(seeds)	β_1	0.252***	Seeds	α_1	0.008***
Ln(labor)	β_2	0.034**	Labor	α_2	0.02***
Ln(nit)	β_3	0.089***	Nitrogen	α_3	0.0003**
Ln(water)	β_4	0.248***	Water	α_4	0.004***
R^2		0.50	R^2		0.49
F-ratio		30**	F-ratio		22.8**
Rice					
Intercept	β_0	0.022	Intercept	α_0	0.691
Ln(seeds)	β_1	0.334***	Seeds	α_1	0.014***
Ln(labor)	β_2	0.099**	Labor	α_2	0.013**
Ln(nit)	β_3	0.101**	Nitrogen	α_3	0.008***
Ln(water)	β_4	0.346**	Water	α_4	0.002**
R^2		0.46	R^2		0.48
F-ratio		24**	F-ratio		26.9**

		Maize			
Intercept	β_0	0.078	Intercept	α_0	1.184
Ln(seeds)	β_1	0.24***	Seeds	α_1	0.049**
Ln(nit)	β_2	0.08**	Nitrogen	α_2	0.003***
Ln(phos)	β_3	0.057**	Phosphorus	α_3	0.03**
Ln(water)	β_4	0.34**	Water	α_4	0.0004**
R^2		0.80	R^2		0.81
F-ratio		36.4**	F-ratio		37.5**
		Cotton			
Intercept	β_0	0.013	Intercept	α_0	0.37**
Ln(seeds)	β_1	0.563***	Seeds	α_1	0.011***
Ln(nit)	β_2	0.973***	Nitrogen	α_2	0.02***
Ln(phos)	β_3	0.021**	Phosphorus	α_3	-0.001***
Ln(labor)	β_4	0.001**	Labor	α_4	-0.001***
Ln(water)	β_5	0.24**	Water	α_5	0.00008***
R^2		0.85	R^2		0.87
F-ratio		483.6**	F-ratio		356.78**

Source: Own elaboration based on survey data (2013).
*Notes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level*.

The examination of the maize production function shows a decreasing return to scale (with 0.71). Results of this function also show that water and seeds significantly affect the production of maize at 10% level. The elasticity coefficient of water (0.34) is the highest among other factors indicating that water is the major determinant of maize output followed by seeds (with 0.24), while nitrogen and labor have small influence on maize production. This suggests that maize farmers in the study area can increase their maize output by increasing the using efficiency of water and nitrogen. For the cotton production function, the results showed that all inputs are positive and significant at 5 and 10% level. The R^2 of 0.85 indicates that 85% of variation in the cotton production in the area is explained by the use of seeds, nitrogen, phosphorus, labor and water but with different magnitudes. Nitrogen application, seeds and water are the main determinant of cotton production, while labor and phosphorus have small effect. The total production elasticity is about 1.79 indication increasing return to scale of cotton production in the area.

4.3. Opportunity costs of irrigation water

The average and marginal physical products, production elasticities of the irrigation water, farm-gate prices and the marginal monetary (value) products of the five studied crops are presented in Table 3. Empirical findings from the linear production function indicate that irrigation water consumption for the studied crops are economic utilization where the production elasticities of the irrigation water are positive and less than one. This means that production increases at a decreasing rate, and the average and marginal physical product are declining. Therefore, irrigation water productivity for wheat, rice, cotton and maize crops were relatively low, i.e., 1.9 kg/m^3, 0.7 kg/m^3, 0.4 kg/m^3, 1.2 kg/m^3, respectively. The estimated marginal values of water for these crops are 1.14 LE/ m^3, 0.45 LE/m^3, 0.74 LE/m^3, and 0.56 LE/m^3 in the same order. On the other hand, marginal productivities of irrigation water for these crops are positive and more importantly more that the cost of water. SO, from the perspective farmers aiming to maximize their outputs and incomes, this implies farmers would increase their production and income by using more irrigation water until the marginal products value is equal to the cost of water which is currently very low. This low marginal value products of irrigation water in monetary terms (i.e., less than one Egyptian pound[4]/M^3) for all the studied crops (wheat is exception) is the major driving force of farmers' water use behavior and may lead to over irrigation and inefficient use of water.

Table 3: Elasticities of production, average and marginal physical products, farm-gate prices and value of marginal products of irrigation water during the cropping season 2011-2012 (CD production function)

Crops	production Elasticity	Average physical product (kg/m^3)	Marginal physical product (kg/m^3)	Farm-gate price (LE/kg)	Marginal monetary (value) product (LE/M^3)
Berseem	0.32	9.40	2.96	0.29	0.85
Wheat	0.25	1.90	0.47	2.42	1.14
Rice	0.35	0.70	0.24	1.87	0.45
Cotton	0.24	0.40	0.10	7.72	0.74
Maize	0.34	1.20	0.40	1.39	0.56

Source: Compiled and calculated from field survey, 2011/2012.

Influence on water and nitrogen on yield

In order to help farmers on the optimizations of the inputs use in their farms, this section discusses the isoquant curves and their use in the economic modeling of the firm. How these curves are designed, and the economic interpretation of each of these curves for the selected crops is presented. The following section then examines their use in determining the optimal combination between the water and nitrogen use for a farm to choose in its production process. Water–nitrogen relationships or production functions are considered as useful tools in the management of water and nitrogen application for optimization of crop productivity. These functions can be used in managing water resource for achieving maximum returns with minimum amount of water application as irrigation (English and Raja, 1996).

Substituting the averages of quantities of seeds used, labor, and quantity produced of the selected crops (wheat, rice, maize, cotton and berseem) is analyzed. The relationship between the quantities used of nitrogen and irrigation water which yields the same level of wheat (rice, maize, cotton and berseem, respectively) can be estimated using the following equations (Table 4).

Table 4: Isoquant curves equation results (water versus nitrogen)

Crops	Isoquant curves: water vs nitrogen
Wheat	$wat_w = (1.1\ (nit_w)^{-0.089})^{1/0.248}$
Rice	$wat_r = (3.22\ (nit_r)^{-0.1})^{1/0.346}$
Maize	$wat_m = (2.51\ (nit_m)^{-0.075})^{1/0.337}$

[4] 1 Egyptian pound = 0.13 US$. (Average Jan-Sep 2015).

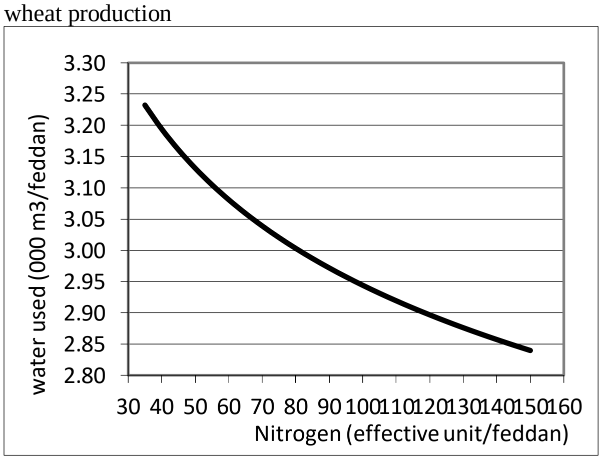
Cotton	$wat_c = (111.69\ (nit_c)^{-0.973})^{1/0.240}$
Berseem	$wat_b = (11.69\ (nit_b)^{-0.568})^{1/0.315}$

Source: Compiled and calculated from field survey, 2011/2012.

The previously estimated relationship between nitrogen fertilizer and irrigation water for the six selected crops can be illustrated in the following figures (fig 1-6). For the analysis of this relationship, the Marginal Rate of Technical Substitution (MRTS) was used. The assessment of the figures below indicates that the marginal rate of technical substitution among the nitrogen and irrigation water is declining for the six studied crops.

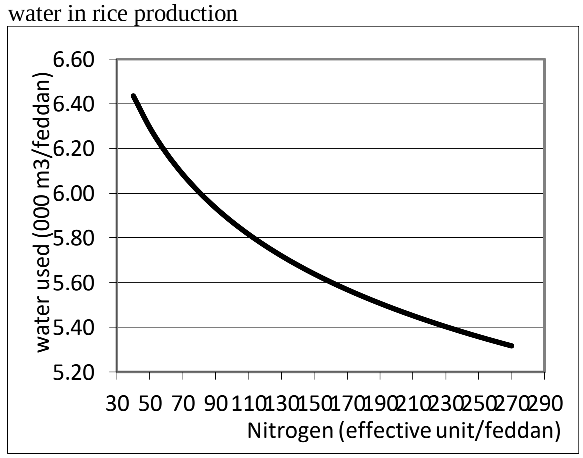
It is clear that from an agronomic perspective, pesticides are typically complementary to water use. However, our results show a substitution relationship, which indicates one possible fact that liquid pesticides are diluted excessively with increased irrigation application. Our results are in concordance with the findings of Cai *et al.,* (2008). Indeed, both water and nitrogen are subjected to losses by many pathways if not managed properly. Therefore, there is a considerable interest in strategies that enhance nitrogen use efficiency and productive use of applied irrigation water leading to increased productivity.

Figure 1: Relationship between nitrogen and irrigation water in wheat production



Source: Own elaboration (2014).

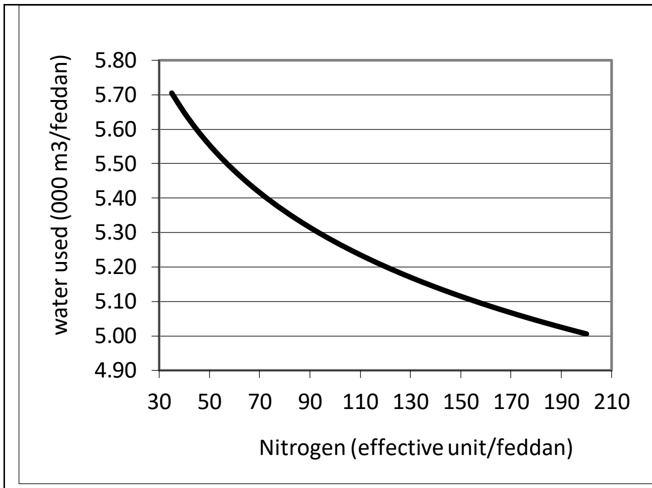
Figure 2: Relationship between nitrogen and irrigation water in rice production



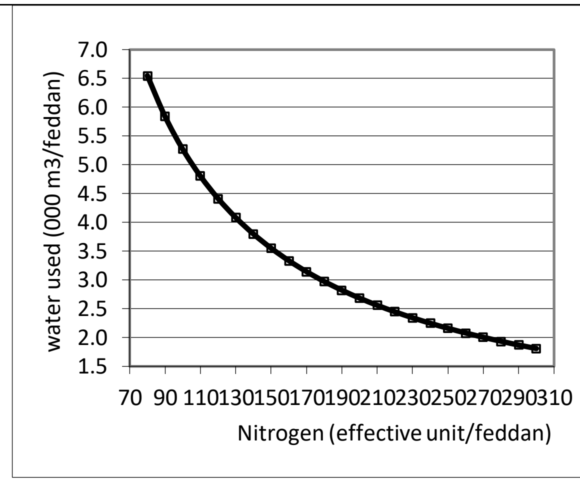
Source: Own elaboration (2014).

Figure 3: Relationship between nitrogen and irrigation water in Maize production

Figure 4: Relationship between nitrogen and irrigation water in cotton production

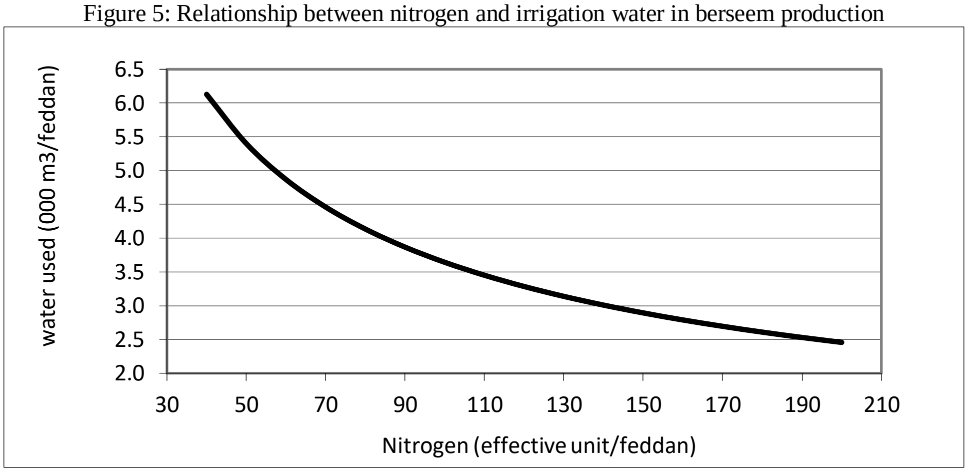


Source: Own elaboration (2014).



Source: Own elaboration (2014).

Figure 5: Relationship between nitrogen and irrigation water in berseem production



Source: Own elaboration (2014).

5. Concluding remarks and policy implications

This paper aims to estimate the impacts of the main primary production factors (e.g., seeds, nitrogen, phosphorus, irrigation water) on the total production of wheat, rice, cotton, maize and berseem crops with special emphasis on the examination of the potential substitution between water and other agricultural inputs (such as nitrogen). This analysis was conducted through an empirical analysis using a linear and Cobb Douglas production function (generated from survey data on 150 farms located in two villages in Sharkia governorate, Egypt) and taking into consideration farmers' objectives about crop yield, production and net profit in their own farms.

Based on the empirical findings of this study, few conclusions can be drawn:

- The correlation coefficient matrix shows positive and significant relationships between the quantities produced of studied crops (i.e., wheat, rice, cotton, maize, and berseem) and the quantities used from seeds, nitrogen, phosphorus, labor and irrigation water. This shows that the data are consistent on the expected agronomic relations and model expectations and would provide meaningful results.

- Irrigation water productivity in terms of marginal productivities of irrigation water in wheat, rice, cotton and maize crops are relatively low. The estimated values of marginal products for irrigation water for berseem, wheat, rice, cotton and maize production at 0.85 LE/M^3, 1.14 LE/M^3 0.45 LE/ M^3, 0.74 LE/M^3 and 0.56 LE/M^3, respectively. These values of marginal products of irrigation water in monetary terms are important in factors in farmer decision-making. In the situations where water cost is very low or much lower than value of marginal product of water, farmers would benefit in increasing irrigation water applications. This could explain farmers' water use behavior and may lead to inefficient use of water.

- These findings indicate that wheat, rice and maize farmers in the study area are technically inefficient regarding the use of farm resources. This could be as a result of high cost of fertilizers, seeds, labor and herbicides. The berseem and cotton farmers are more efficient on the use of resources. This implies that technical efficiency of wheat, rice and maize production could be enhanced through better management and use of such inputs. To ensure efficiency in the use of resources in rice production in the target area, concerted efforts from farmers, research, extension and governmental institutions is highly imperative.

- Water and seeds are found to be the highest influential factors for the production of the five crops. This implies that farmers should increase their efforts for better management of water use. Research institutions should intensify efforts on these crops in order to have improved varieties that give high farm yield. The government should ensure that farm inputs are made available to the farmers at the right time and at appropriate prices.

- The results in this study has provided relevant information for developing efficient use of inputs mainly irrigation to improve crop water productivity and help to maintain sustainable development of agriculture in the studied area. Given limited water resources in Egypt, great efforts have been and are being conducted to increase water use efficiency and water productivities. The current water use efficiency exceeds 70% on the national level. However, plans are being prepared to increase this level of efficiency in order to increase the cultivated area by about 40% by year 2017. These plans include improvement of irrigation delivery systems, introducing low-water-consuming crops, introducing salt tolerant crops, and reuse of drainage water. Intensifying cropping pattern was one of the factors contributed to increasing the water productivity. This analysis shows that at the farm level there is still much improvement is needed. The high efficiency noted above does not consider water quality as water in Egypt is recycled multiple and excess water applied in the fields go into the drainage systems which is recycled, times and its environmental and long term and quality impacts are also important.

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