Marginal value of irrigation water in Wheat production systems of central Tunisia

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Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia

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Abstract

Recent studies on the economics of agricultural water management in Tunisia report a low water productivity of some presently widely cultivated crops such as durum wheat. The objective of this study is to estimate water productivity and marginal value of irrigation water applied to durum wheat in central Tunisia, region of Kairouan. We develop a production function, in which the irrigation revenue of farmers per hectare is expressed in terms of the used water volume in addition to other production factors. Results show that 31.7 % of farmers were applying water volumes above the economic optimal volume (more than 2900 mm/ha). Moreover, 50 % of farmers were found to be applying less irrigation water than this optimal volume. Applying water above the optimal volume means that the benefit farmers generate from each supplementary unit of irrigation water is lower than the market price of irrigation water currently applied in the region (0.110 TND/m3). Water is then wasted. However, using less water than this optimal volume means that farmers can make further supplementary irrigations and generate more benefit from it (extra-yield). The study also shows that most of farmers in the study area are not performing the irrigation scheduling and the appropriate irrigation doses. Improving these irrigation performances will surely preserve the water resources and enhance the food security in Tunisia.

Key words: Durum wheat, Central Tunisia, marginal water value,

1. Introduction

The portion of fresh water currently available for agriculture (72%) is globally decreasing (Cai and Rosegrant, 2002) while the agricultural production from irrigated areas is needed to increase in order to satisfy the growing food demand, especially in developing countries. The search for sustainable methods to increase crop water productivity becomes more urgent especially in arid and semi-arid regions (Debaeke and Aboudrare, 2004). This productivity issue is mainly important in irrigated areas where deficit irrigation is used as alternative production strategy.

Optimal techniques and management practices of irrigation water at farm and local level is determinant factor of its productivity (Oweis and Hachum, 2005). Wichelns (2002) states that economic efficiency of irrigation water, which is defined as maximizing social net benefits from water resources, often requires improved water management even when basin-wide measures of irrigation efficiency are relatively high. Optimal irrigation management includes the choice of crops, varieties, techniques, institutions, etc, that may increase the productivity of each unit of water used for irrigating the cultivated crops (Pereira et al., 2002).

In Tunisia, during the last 30 years, irrigated agriculture has increased from 250,000 ha in 1990 to 450,470 ha in 2010 (MA, 2011). Although the irrigated areas represent only 8% of the total agricultural surface, irrigation contributes with 35% of total agricultural production and 20% of agricultural exports. The growth of the agricultural production in the recent years is mainly due to the expansion of irrigated areas (Al-Atiri, 2009). However, the increase of irrigated area has clear consequences on country's water resources. The issues of improving agricultural water management and increasing water savings are highly debated and undertaken by policy makers and researchers. Recent studies on irrigation economics in Tunisia focus on the assessment of the current efficiency of the resource use (Frija et al, 2009; Chemak et al., 2010; Dhehibi et al., 2007; Albouchi et al., 2007 chebil et al., 2012), on the impact of some agricultural policies, such as pricing, on water allocation and use (Bachta and Talbi, 2005; Zekri, 2005; Frija, et al., 2010), and on the effectiveness of local collective irrigation water management (Frija et al., 2010 and 2008; Ben Salem et al., 2005). While most of these researches call for the encouragement of farmers to adopt higher valued crops as a strategy to face water scarcity in the country, little research was done to evaluate irrigation water productivity and to analyze the marginal benefit of water use for different crops and seasons. Moreover, in some cases the cultivation of some low-valuing crops, such is the case of durum wheat, can be considered as obligation due to the specificities of a given agricultural system.

In this study, we are interested to investigate about the productivity of water used for the irrigation of durum wheat in central Tunisia. Wheat is a major cereal in Tunisia in terms of its output and cultivated land area. It occupies about 50% of all cereals area (800,000 Ha on average) and represents almost 55% of the total cereals production (average wheat production is around 1.8 million tons) (MA, 2010). Irrigated wheat area is covering around 80,000 ha (MA, 2011). Considering the social and economic strategic importance of the wheat sub-sector in Tunisia, the potential increase of water value used in the irrigation of this crop is crucial in Tunisia.

Indeed, crop choice is important because some crops use less water than others and others generate higher net returns. Thus, substantial economic gains could be made by reallocating water from lower to higher valued crops (Keller and Seckler, 1996), especially in areas where water availability is a real constraint; such is the case of our study region.

However, durum wheat, even though important in terms of surface, is considered as marginal crop by most local farmers due to its low per-hectare net benefit compared to other crops. Because of the cultivation period of this crop and its low input requirement, farmers usually cultivate it as intercalary crop. This usually resulted in very low yields compared to the potential yield of the region. When looking at the cropping system in the study area, we find out that most of farmers do not provide supplementary irrigation to the durum wheat during the month of April which corresponds to the grain filling stage of the wheat. The reason is that due to water constraint, and to the starting of the cultivation of tomato in beginning of month of April farmers prefers to forward irrigation water to tomato plots and loosed a large part of potential wheat yield because of this practice. Agronomists state that irrigation at this important stage of durum wheat cycle is highly affecting its final grain yield. In fact, wheat yield is affected by many factors, including grain weight, which is determined at the grain-filling stage. In this period, water has important impact for wheat grain filling process and grain weight. Irrigation during flowering and grain filling stages of wheat may provide an option for minimal yield reduction (Ishag et al., 1992). However, to attain maximum yield, moisture stress should be avoided all over the durum wheat cycle including the booting period, anthesis, and grain filling stage (Farah, 1987).

The main objective of this paper is then to calculate the marginal value of water used in the irrigation of durum wheat in the region of Chebika (governorate of Kairouan). This will be done through the estimation of a cob Douglas production function using field data from 171 farmers located in the region of Chebika.

The rest of the paper is divided into 3 further sections. The next section presents the Cobb Douglas production function used for the estimation of the marginal water value; as well as the study area characteristics. Third section presents results, and fourth one discusses them. A last section concludes

2. Methodology

Two main indicators are used to describe the valorization irrigation water in this study: the average water productivity and the marginal water value. Economic water productivity of durum wheat will be calculated in order to estimate the average profitability of each cubic meter of irrigation water used for the irrigation during the whole cycle of durum wheat. Marginal water value will be estimated in order to see if farmers are producing at the economic optimum where the marginal value of irrigation water is equal to market price of this resource. Moreover, marginal value of irrigation water is indicator of the extra income generated by additional unit of irrigation water applied to the crop.

2.1. Average economic water productivity

In crop production systems, water productivity is generally used to define the relationship between crop produced and the amount of water involved in crop production, expressed as crop production per volume of water. Molden et al., (2010) distinguish between physical (agricultural) water productivity defined as the ratio of agricultural output to the amount of water consumed, and economic water productivity defined as the value derived per unit of water used for producing given agricultural output. The crop production used to calculate water productivity may be expressed in terms of total yield (kg) of seed (grain) or, when dealing with different crops (e.g. water productivity at the farm level, all crops included), yield may be transformed into monetary value (Ali and Talukder, 2008; Hellegers et al. 2009). The economic formulation of water productivity used in this study can then be written as follows (based on Hellegers et al., 2009 and Ali and Talukder, 2008):

$$WP = \frac{NFI}{W} \qquad (1)$$

Were *WP* is the water productivity, and *W* is the volume of water applied per ha of durum wheat. NFI is the net farm income defined as in equation (2):

$$NFI_i = P_y Y - \sum_j P_{xj} X_j - \sum_k F_k \qquad (2)$$

Where,

NFI: net farm income per ha of durum wheat
Y_i: Gross output (Kg) per ha
P_{yi}: Unit price of durum wheat
X_j: quantity of variable inputs ($j = 1, 2, \ldots, n$) used per ha of durum wheat (non- water input)
P_{xj}: Price per unit of variable input X_i
$F_{k,i}$: Cost of fixed inputs ($k = 1, 2, \ldots, K$) per ha of crop *i*

WP calculated using equation (1) gives useful information about average income generated by one cubic meter of water used to produce durum wheat. However, for a policy maker who may need to act to change the water use pattern, this information is not sufficient. In fact, policy makers need to have information about the marginal value of water or productivity of one-unit-increase (decrease) of water use on the income of different crops. This is called the marginal productivity of irrigation water. Marginal productivity analysis would be used as a guide for potential re-allocation of water through appropriate policies. Ali et al, (2007) define the marginal Productivity of irrigation water as the addition to the gross output caused by the use of one extra unit of water while other inputs are held constant. According to the economic theory, as long as the marginal value of water applied for the irrigation of a given crop, is higher than the market price of this water (unitary water cost for surface water or pumping cost per cubic meter for groundwater), it will be still profitable to apply supplement doses of irrigation to the crop.

Marginal (economic) productivity of irrigation water (MWP) can be then calculated as:

$$MWP = \frac{\Delta Y}{\Delta W} \qquad (3)$$

Where ΔY is the variation of the gross output due to the variation of irrigation water *(*ΔW*) applied*.

Based on this latter definition, "marginal profitability of irrigation water" in our study will be equal to (Hellegers et al., 2009):

$$MWP = \frac{\Delta(NFI)}{\Delta W} \qquad (4)$$

NFI used in the equation 4 only include non-water inputs (see Young, 2005). ΔNFI is the variation (change) of the net farm income per ha after addition of one unit of irrigation water.

2.2. Production function

In agricultural water management production functions are mostly used to predict the yield of crops given some input parameters (Igbadun, et al., 2007). For agronomists the crop-water production function expresses the relationship between yield (Ya) and water applied (Wa). For our study, considering the economic and policy-advising perspective, water production function is used to model revenue response to various levels of irrigation (Oweis and Hachum, 2009). Our production function is expected to relate the income generated by durum wheat in the region of Chebika to the water volumes used by this crop in addition to other production factors. The general production function used can be implicitly presented in the following form:

$$Y = f(W, X_j) \qquad (5)$$

Where (Y) is the output value per hectare; (W) is the volume of water (m^3) used per hectare and (X_j) are the quantities of other *(j)* productions factors.

The most widely used functional forms for production functions in the analysis of agricultural production are the Cobb-Douglas and Translog function (Sahibzada, 2002). The second functional form can be approximated by a second order Taylor series and requires a large number of parameters to be estimated. For this reason, large datasets are usually needed when estimating a Translog production function, otherwise multi-collinearity will be often a major problem. We therefore rely on the Cobb-Douglas production function. Advantages of the Cobb-Douglas function are the parsimony in parameters, the ease of interpretation, and the computational simplicity (Sahibzada, 2002).

The general logarithmic form of the production function presented in (5), thus becomes:

$$Ln(Y_i) = a + b.Ln(w_i) + \sum_{j=1}^{J} c_j .Ln(X_{i,j}) + u_i, \quad \text{i (1, …, n) farmers} \qquad (6)$$

Where *Ln* is the Natural logarithm, u is the error term, *(a)* is a constant and *(b), (c)* are the estimates of the production function. *(b)* can also be considered as the output elasticity of the water variable. Output elasticity measures the responsiveness of output to a change in the volume of water applied to the crop. The marginal value of irrigation water used in the irrigation of durum wheat is calculated from the coefficient *(b)* in the equation (6) above. In fact, since *(b)* is expressing the elasticity of water use, it can be then written as follows:

$$b = \frac{\Delta Y}{\Delta W} \frac{W}{Y} \qquad (7)$$

For a given water volume, if we multiply *b* by $\frac{Y}{W}$, we may obtain $\frac{\Delta Y}{\Delta W}$ which can also be written as :

$$\frac{Y_2 - Y_1}{W_2 - W_1}. \qquad (8)$$

This latter term is interpreted as the variation of the output value (Y) due to a given change of the water input (W). The result will be a value expressed in TND/m^3, which is corresponding to the marginal value of irrigation water at a given level of water use.

2.4. Data and study area

Chebika region, considered for this study, is located in central Tunisia within the governorate of Kairouan. Chebika has an annual average rainfall above 290 mm. This average is varying between 250 and 400 mm. The main crops cultivated in the area are: wheat, vegetables (especially Tomato and chilli pepper), fodder and olives. The numbers of farmers in the irrigated area of Chebika region is about 1000 farmers. The total cereal area is about 17500 ha. The irrigated cereal area is around 4500 ha. The average regional yield of the irrigated wheat is about 3.9 tons/ha (CRDA, 2009).

The data employed in this study consists of the information about the production structure of 170 wheat farms located in the irrigated area of Chebika. Farmers were randomly selected. In order to ensure homogeneity in land and weather conditions, the farms in the sample have been chosen from the same region and are located in a 15 Km diameter. Chebika is facing growing problems of water scarcity. It is located in the semi-arid bioclimatic lower floor and characterised by moderate winter. Groundwater represents the main water source. The data used in the study was collected in 2011 with the collaboration of the extension service in the region, through a questionnaire to cereal-growing farmers.

3. Results

In this section we first present the different characteristics of the cropping system in the studied area based on the results of our survey. This is in order to be able to discuss the results of the production function in relation to these characteristics. Results of the Cobb Douglas function parameters estimation will be presented in a second part of this section.

3.1. Cropping system, water use patterns, and water productivity

Average land distribution in the studied sample shows that the average farm size is around 16.19 ha with 88% of this area cultivated under irrigation and the rest under rainfed conditions. The farming structure is characterised by the predominance of small-size farms and land fragmentation. Farms with a size lower than 20 ha represent about 80 percent of the total number of farms in Chebika. 38 % of the surveyed farms have a size lower than 10 hectares.

Regarding the land use, the most cultivated crops in the target area are the legumes (especially tomatoes and Chilli pepper) followed by the durum wheat crop. They occupy, respectively, 30.24% and 27.46% of the total cultivated area in the sample farms.

Concerning irrigation sources, both surface and groundwater resources are available for irrigation in the study area. GW is used when surface water is not sufficient, and in remote areas. GW is suitable for all uses. Surface water is used from the dam of EL HOUAREB and is accessible only for 24% of our surveyed farms. The rest of farms are irrigated from deep and shallow aquifers. Sprinklers constitute the only irrigation system used by the surveyed farmers for wheat irrigation. The number of irrigations done during the durum wheat cycle varies from one to six applications (table 1). The volume of irrigation water applied per hectare varies between farmers. It ranges from 480 m^3/ha to 6172 m^3/ha (Table 2). The average is approximately estimated to 2720 m^3/ha.

Table.1 Farmers distribution based on the frequency of irrigations

Frequency (number) of irrigations	*Number of Farmers*	*Percentage of farmers*	*Average applied volume per irrigation (m^3)*	*Total water applied during the durum wheat cycle (average/m^3)*
1	23	13,5	1039,13	1039,13
2	5	2,9	580	1160,1
3	16	9,4	725	2175,2
4	20	11,7	578,5	2314,1
5	39	22,9	556,6	2783,3
6 and more	67	39,4	577,7	3567,6

Table 1 shows that 13.5 % of farmers irrigate their cereal parcel only one time during its cropping period. This can be due to the fact that the first irrigation of durum wheat in the public irrigated areas in Tunisia is free of charge. However, a cumulated percentage of 25 % of farmers in our sample also irrigate their wheat parcel three times and less. This may deeply affect the yield of wheat especially if we know that physiologically, the rainfed wheat yield under this climate deeply depends on both the amount and distribution of rain. In center region of Tunisia, especially at chebika, the amount of rainfall is low and generally poorly distributed, and periods of water deficit correspond almost every year to the emergence and to the grain filling stages of wheat. For this purpose, supplemental irrigation is necessary all over the development cycle of wheat, with the exception of a few years, where rain can be important enough.

The average net farm income per ha in ours ample is equal to 2226.26 TND, corresponding to an average yield of 3.9 Tons/ha. Seeds and mechanization expenditures are almost used in similar quantities among farmers of our sample (it is for this reason that they were not considered in the production function). The average volume of irrigation water applied per ha is found to be equal to 2720.2 m^3 which is a bit less that the estimated water needs of the wheat crop in the region (around 3000 m^3). This volume varies between a lowest value of 480 m^3 and a highest value of 6172 m^3.

Tableau.2 Descriptive statistics of variables used for the estimation of the production function

Variables	Unit	Average	SD	Min	Max
Net Farm Income	TND/ha	2226.2	636.4	1016.0	4370.0
Water	M^3/ha	2720.0	1110.8	480.00	6172.00
Seeds	TND/ha	114.2	31.71	55.00	154.00
Fertilizers	TND/ha	142.2	60.02	33.00	338.00
Labor	TND/ha	66.46	22.30	31.50	178.75
Mechanization	TND/ha	378.6	117.41	165.00	1300.00

The calculation of water productivity shows that the average economic productivity of water used for the irrigation of durum wheat in the study area is around 0.971 TND/m3. However, this value ranges from a minimum of 0.064 TND/m^3 to a maximum value of 2.840 TND/m^3. We also remark that water productivity decreases when the total volume of water applied during the durum wheat cycle increase. Moreover, the gross margin of farmers who have low water productivity is usually higher than these having high water productivity. This can be explained by the fact that this water productivity indicator is not enough expressive of the performance of water use at the farm level.

3.3. Results of the production function

Average values of output and production factors (water, fertilizers, and labor) used in the estimation of the Cobb Douglas production function are presented in the table 3. This table shows that the average output value per ha is about 2226.26 TND/ha, with relatively low standard deviation indicating that the technical knowledge and practice of cereal cultivation among farmers is comparable. Moreover, the use of deficit irrigation in the region varies between 500 m^3 and 4500 m^3 with an average value of 2696 m^3. This average value corresponds to the recommendation of scientists for deficit irrigation doses, however, the irrigation scheduling remains problematic and its effect on the wheat yield remains very important.

Table.3 Coefficients of the production function and *t*-test

	Coefficients	*Standard Error*	*t*	*P-value*
(Constant)	4,305***	0,328	13,092	0.000
Ln (water)	0,151***	0,036	4,189	0.000
Ln (fertilizers)	0,170***	0,045	3,729	0.000
Ln (labor)	0,324***	0,070	4,596	0.000
Multiple R	*0,655*			
R Square	*0,42998*			
Adjusted R Square	*0,419679*			
Standard Error	*0,218653*			
Observations	*170*			

The parameters of the CD production function were estimated using Eviews (econometric views) software. Results of the coefficients and related tests are shown in table 3. Based on the estimated coefficients presented in the table 3, the linear regressed equation can be expressed as follows:

$$Ln(Y) = 4.305 + 0.151.Ln(w) + 0.170 Ln(fertilizers) + 0.324 Ln(Labor).$$

Using the estimated parameters and the equations 7 and 8, we calculated the marginal value of supplementary irrigation water used in the wheat production in Chebika region. Marginal value of irrigation water varies according to the quantity of water applied, which is shown in Figure 1. The curve of marginal water value in the figure is corresponding to the theoretical expectations, where this marginal value is negatively correlated to the volume of water applied. According to the economic theory, farmers will use water until the marginal value of water will be equal to the market price of this factor. Average water price in the study area is 0.120 TND/m^3. On our estimated curve (figure 1), this value corresponds to 3000 m^3 of water use, which is also the physiological need of wheat in the study area (MA, 2000; Rezgui, 2005).

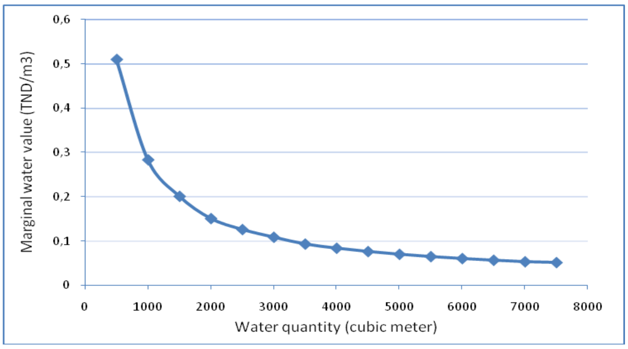

Figure.1 Marginal value of water applied to the wheat crop in the study area.

Moreover, in order to test the effect of the nitrogen fertilisation on the marginal value of water applied to the wheat crop, we made a sensitivity analysis based on fertilization scenarios. Three scenarios were considered for this sensitivity analysis, intensive fertilizers use (the maximum quantity of nitrogen applied by the farmers in the study area), average fertilizers use (the average value of nitrogen used by our sample farmers), and low fertilizers scenario, which corresponds to the lowest quantity of nitrogen applied by our sample farmers.

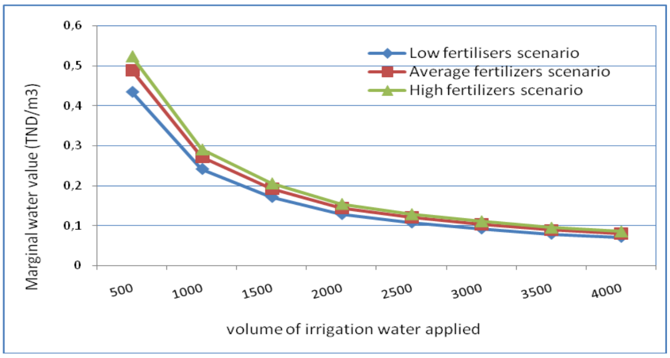

Figure.2 Marginal water value under different fertilizers scenarios

Results also correspond to the theoretical expectations, where the marginal water value increases with the increase of the quantity of applied nitrogen. This proves that water and nitrogen are complementary production factors in the wheat crop production. However, this observed positive correlation was not very intense and the marginal water value changes only a bit when moving from the lowest to the highest fertilizers scenarios.

4. Discussion

In This study, many relevant results rises from the analysis of the cereal cropping practices and the estimation of production function for the cereal producers of Chebika region.

First, some wrong cropping practices related to the irrigation of durum wheat in the study region have to be stressed. In fact, the average supplemental irrigation of durum wheat reaches 2700 m3/ha in average; which is a bit lower than the crop need in the region (after consider the average annual rainfall). Also, 44.6 % of the surveyed farmers apply less than 2500 m3/ha (figure 3). Moreover, we find out that 25% of farmers irrigate durum wheat less than three times applying in average 780 m3 per irrigation. Irrigation scheduling in the study area was also random and only few farmers are aware about the importance of scheduling irrigation and fertilization supplements.

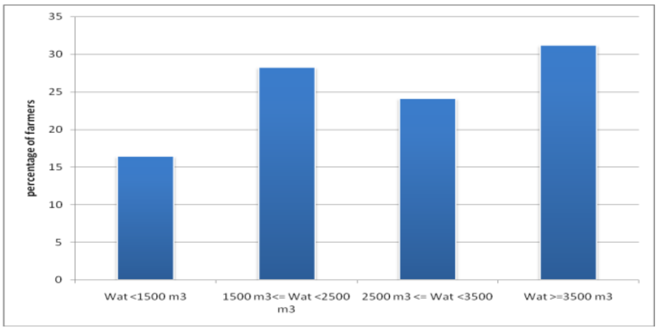

Figure.3 Farmers distribution according to their total supplement irrigation water applied during durum wheat cycle

Figure 3 shows that most of farmers in the sample are either applying less than the water requirement (44.6 %) or more than this requirement (31.1%).

Table.4 Distribution of average irrigation and nitrogen variables (per ha) according to water-applied classes

Catégories of water use	*nbr (%)*	*Dose of Nitrogen (Kg)*	*Average water use (m3)*	*Average irrigation cost (Dt)*	*Irrigation frequency*	*Av dose per irrigation (m3)*	*Valeur de production (Dt)*
W<1500	28(16.4)	162,1	1040,7	80,5	1,57	851,4	1719,6
1500<=W<2500	48(28.2)	231,2	2054,5	200,6	4,12	558,1	2211,4
2500<=W<3500	41(24.1)	256,7	2849,7	281,9	5,24	557,0	2367,0
W>=3500	53(31.1)	241,5	4033,2	397,9	5,98	696,6	2362,9

W: water volume applied per ha of durum wheat

Results derived from this descriptive analysis of the water use pattern in the study region shows that most of the farmers are not technically efficient. More comprehensive extension of farmers about irrigation techniques and scheduling is needed.

“The estimation of the marginal water value in the study region shows that some farmers are currently producing at the economic optimum. In fact, the average volume of water currently applied per ha of durum wheat in the region is around 2800 M^3/ha. In figure 1, this amount of water corresponds to a marginal return of 0.119 TND/ha, which is the current market price of irrigation water in the region. This value indicates that the latest unit (one extra-unit) of irrigation water used to irrigate durum wheat in the region generates 0.119 TND of extra-revenue. This result shows that our model estimates are good enough and reflecting the real situation in the study area since the marginal return of water is equal to the market price of this resource, which corresponds to the economical theoretical expectations. According to these expectations, each unit of water applied beyond 2800 M3/ha, which is the economic optimum of producers, will generate less return than its price indicating a loss of the farmers from these latest irrigation. This is also true in our case study where we can see that the average per ha production value of the farmers applying more than 3500 m3/ha is lower than the average per ha production value of farmers irrigating with less than 3500 m3/ha (see table 4 and figure 4).

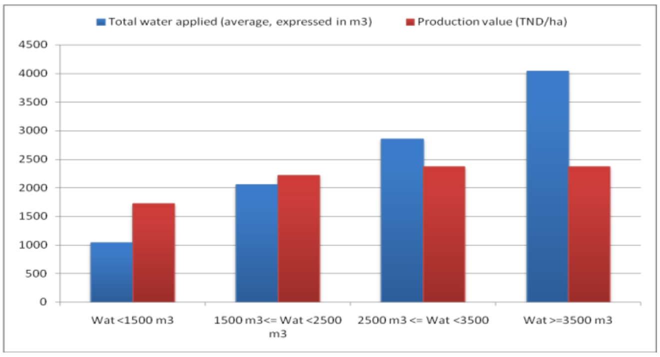

Figure 4. Average production value per ha of different types of farms.

The nitrogen and water are in fact the essential elements of the production of wheat. Unreasoned nitrogen intake could lead, under optimal conditions of soil moisture in biomass development at the expense of performance and negatively affect WUE. For this reason, we were simulating the impact of nitrogen fertilization on the marginal water value in the study area. Fertilization scenarios were described in section 3.3. Results of the scenarios of nitrogen fertilization show that the interaction between water and nitrogen are without significant impact on marginal water return in the study area. However, it is important to notice that nitrogen fertilization is moderately affecting this marginal value at low water use levels (Figure 2).

Nitrogen fertilization of wheat in supplementary irrigation must be reasoned in terms of quantity and date of application to properly observe the positive effect of irrigation on yield. Within the Mediterranean areas, N deficiency is ubiquitous. As Nitrogen fertilizer responses are directly related to rainfall under dryland conditions (Ryan et al., 1991; Campbell et al., 1993; Pala et al., 1996), N use should be correspondingly greater, when supplemental irrigation is also applied. This is not the case in our study which shows that appropriate extension and farmer's education in the study area is absolutely needed. We also notice that the response of wheat to irrigation water is also dependent on the cultivar (Nachit et al., 1992).

5. Conclusions

The objective of this paper is to evaluate the valorization of irrigation used for the irrigation of durum wheat in central Tunisia. Water use patterns as well as the water productivity and marginal water profitability were calculated and estimated for this purpose.

Results show that farmers in our study region are not respecting the appropriate water doses and scheduling adapted to their area. In fact, we found that most of farmers are using less or more water than the crop requirements.

Marginal value of the irrigation water calculated for a dose of water corresponding to the average volume applied to durum wheat, in the studied area, was found to be equal to the current market price of this resource in the region. However, we observed that 31.7 % of farmers were using water above the economic optimum (more than 3000 mm/ha), and 50 % of farmers were found to be using irrigation water beyond this optimum. Using water beyond the optimal volume means that the benefit farmers generate from each supplementary unit of irrigation water is lower than the market price of irrigation water currently applied in the region (0.110 TND/m3). Using less water than this optimum means that farmers can make further supplementary irrigation and take more benefit from it (extra-yield). The study also shows that most of farmers in the study area are not performing the irrigation scheduling and appropriate irrigation doses.

Acknowledgment

This work was done in the framework of the project "Eau virtuelle et sécurité alimentaire en Tunisie (EVSAT)" funded by the IDRC and coordinated by the "Ecole Supérieure d'Agriculture de Mograne" (ESAM). We gratefully acknowledge the financial support of the IDRC to accomplish this research. Some of the early data used in this study was also collected in the framework of "FSAC project" coordinated by the ICARDA.

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