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An Econometric Estimation of Irrigation Water Demand in Nadhour region (Tunisia)

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Abstract - Irrigated agriculture has been analysed in Tunisia in recent years because of its high-water consumption and its apparent inefficiency. Several possibilities for water policy have been debated, in particular the pricing of irrigation water. This paper aims to contribute to this discussion by addressing the irrigation water demand and testing the effects of water costs, production value, inputs expenditures, and crop production acreages. Limited surface water supplies, increased pumping costs, and a growing concern over declining groundwater levels are identified as key economic and environmental challenges facing the Nadhour region in Tunisia. The goal of this study is to develop and apply an econometric analysis to examine the expected effect of water price (cost) and others factors on water use. Data area are collected by a survey conducted nearby 140 farmers in the public and private perimeters at Nadhour region in the north of Tunisia. The price elasticity of irrigation water demand and other elasticity were also estimated using Ordinary Least Squares facilitated SPSS.13. main findings show that irrigation water demand is less responsive to water price changes. Thus, the estimated elasticity is -0.655. Results also show that irrigated area and vegetable acreage are the most determinants of water demand. It's showed too, that water, seeds and mechanization are complementary inputs. The results of this study indicate that the economic value of water used. Based on the findings, this paper recommends that emphasis should be put on effective and efficient use of water in order to improve its productivity. Various water management strategies should be practiced to boost up the water productivity. Furthermore, if possible, restrict crops cultivation to only rainy season by making more effective use of rainfall. Decision maker can apply a seasonal water pricing.

Keywords: Water Demand Elasticity, Water Pricing, Irrigation, Water scarcity, Arid area.

1. Introduction

Rising international needs for food security as a result of growing populations, climate change, and increased economic values of water inside and outside irrigated agriculture continue to challenge policy making worldwide. These concerns challenge the sustainability of growth, viability of key natural assets, and welfare of the small farmers who bear a large part of the costs of water shortages that could face irrigated agriculture. Moreover, by conventional economic valuation standards, irrigated agriculture can produce low economic values of water at the margin compared to uses of water by competing sectors (Bakhtiyari et al., 2014). The agricultural sector is the largest user of water in many parts of the world (Wallace, 2000). This is particularly true in Tunisia where agriculture consume more than 80% of the water resources. Tunisia has mobilized practically all of its water resources, including groundwater resources, whether renewable or not. This mobilization has enabled the development of irrigation and the diversification of agricultural production and to ensure the supply of drinking water to cities and most rural areas. Indeed, the continued process of mobilization at the level of the national territory and the development of the different uses at the level of irrigation, but also of industry, tourism, as well as the needs of drinking water supply of cities and rural areas, makes the management of resources more and more conflicting with demands for local use of resources. Groundwater resources contribute with strongly to meet the needs of various sectors of use. In 2010, this contribution reached 75% of total consumption, all sectors combined, and nearly 80% of consumption in the irrigated sector. In addition, there is the impact of climate change which should result in an increase in global temperature and consequently in evapo-transpiration and an increase in the irregularity of precipitation with an increase in extremes, factors acting in particular on the scarcity of water resources, on the one hand, and the increase in water demand, on the other hand. Although concerns of water shortages have been ongoing for decades, policy makers are still in search of effective policy instruments to induce water conservation or to improve water use efficiency. In recent years, policy makers have turned their attention from supply-side approaches such as building reservoirs or lining canals to water demand management (Huang, 2010). More efficient irrigation technologies and best management practices have been promoted in most countries. However recent studies have shown unexpected results from the use of more effective practices. although a more efficient irrigation technology may cut down irrigation application rates, farmers may also increase irrigated area or switch to more water-intensive crops while the effective price of water is lower (Sun et al, 2017). The promotion of more efficient irrigation technologies has increased the overexploitation of groundwater resources (Abdelhafidh et Bachta, 2016; Huang et al, 2017). Some regions implemented water use quota at the level of the irrigated shemes. Increasing water price is suitable for rural Tunisia. Tunisian's irrigation water users are characterized by thousands of small farms that are less than one hectare and private status. Since groundwater use is largely unregulated in rural Tunisia where groundwater seems free acceded by farmers. Since the cost of groundwater is largely the energy cost of pumping it out, the price of groundwater can be influenced by the government through the price of energy. Increasing water price or water withdrawal cost can provide the economic incentive for households to cut their water use. Knowledge of water demand is the key information needed in designing a water pricing policy. Water demand analysis is a vital part of water resource planning because it serves to identify where future development of supplies will provide the greatest benefit. The economics of water involves understanding its scarcity and its value, as well as human needs, and ensuring that the costs and benefits of choices are clear and that the impacts of alternative pricing schedules are determined. Insight into the value of water is essential to support policy decision making about investments in the water sector, efficient allocation of water and water pricing. However, information on irrigation water demand at small-scale schemes is scarce and in general little attention is paid to the determinants of these values (Abdelhafidh et Bachta, 2017). In addition, a topic which need also investigated and related to forecasting water demands concerns how water resource development influences economic growth of an area. Rational decision making about water management issues requires reliable estimates of the water demand. Specifically, for the agricultural sector, this knowledge is important to design fair, informed and rational pricing systems, providing incentives to irrigators to use water rationally and efficiently and allowing recovering costs. In Tunisia, irrigated agriculture is seen as an important rural development factor, creating employment opportunities, generating income and enhancing food security. Extended irrigated area and drought cause increasing pressure on groundwater resources. Moreover, to formulate a new water policy, and the near future farmers will have to pay for the water they use. In this context, knowledge about water demand can contribute to the objective of improving efficiency through better water management at the farm and local levels. As a dominant regional consumer of groundwater, irrigated agriculture in Tunisia encounters several signals of water scarcity, including decreased well yields, higher pumping costs due to increasing lift, and water quantity constraints imposed by irrigation districts on annual extraction levels. Planning for efficiency use of water resource has special importance and prices can play an effective role in achieving both efficient water use and conservation. Considering the amount of irrigation water needs met by groundwater in the Tunisia, it is hypothesized that agricultural water use is sensitive to the variable costs irrigation (water price paid by farmers whose are member of Water use Association or water pumping cost paid by private farmers).

The overall objective of this study was to develop a method of precisely predicting agricultural water demand for irrigating and to examine the expected effect of water costs on water use.

2. Water resources and use in Tunisia

Tunisia is considered one of among the driest countries in Africa and in the Mediterranean basin is characterized by limited water resources. Average annual rainfall ranges from less than 100 mm per year in the south to 1,500 mm/yr in the north-west. Tunisia receives 230 mm/year of rainfall on average, the equivalent of 36 billion cubic meters. However, this volume is temporally and spetially irregular. Annual precipitation varies from 594 mm on average in the north to 289 mm in the center, to only about 150 mm in the south. Surface water resources are estimated at 2,700 million cubic meters (MCM) per year distributed over three natural areas distinguished by their climatic and hydrological conditions. The north covers about 26% of the total area of the country, provides regular and important surface water evaluated at 2,190 MCM from the major basins of the Medjerda River (1,000 MCM/yr), the extreme north (585 MCM/yr), Ichkeul and Bizerte (375 MCM/yr) and Cap Bon and Meliane (230 MCM/yr). These basins contribute 82% of the country's total surface water potential (ITES, 2014). The centre covers the same area as the north and provides irregular surface water resources of 320 MCM/yr. The southern part of the country, which accounts for approximately 62% of the total area, is the poorest in surface water. It provides very irregular resources at 190 million m3, only 7% of the country's total surface water potential. The groundwater resource is estimated at 2,125 million m3, 745 million m3 of which is confined within 212 shallow aquifers and the rest in 267 deep aquifers, 50% of them non-renewable. It is estimated that 650 million m3 of this resource, located mainly in the south, is non-renewable. Groundwater is also characterized by unequal distribution. While the north has 55% of the shallow groundwater resources, the center has only 30% and the south 15%. However, the south has more of the deep groundwater resources at 58% whereas the north and center only have 18% and 24%, respectively. The treated wastewater resource is estimated at 120 million m3 that is still misallocated. Currently, about 8,000 hectares are being used as orchards and for livestock feed. With expanded urban and land development, the volume of treated wastewater used is expected to grow to 450 million m3 in 2030, the equivalent of 10% of the total conventional resources of the country, making it possible to irrigate 100,000 hectares (M.A, 2010).

Agriculture, which accounts for approximately 12% of the GDP, is the largest consumer of water (80%) from the available resources. Today, about 450 thousand hectares (9% of useable agricultural land) are irrigated in Tunisia (M.A, 2010). The volume of water used for irrigation is estimated at 2,100 million m3, with average consumption per hectare of approximately 5,500 m3/year. Consumption reaches 20,000 m3/hectare/year in the southern oases whereas is about 4,000 m3/hectare/year in the north. Irrigation supports 35% of total agricultural production, 22% of export crops and 26% of agricultural employment (Mahdhi et al. 2014). In addition, the demand for water for domestic, touristic, and industrial purposes continues to increase. Drinking water demand was estimated at 400 million m3 and 150 million m3 for industry and tourism, respectively (Chahed et al, 2014).

Conflict between various water users will become more and more acute in the future. There will be pressure on the agricultural irrigation sector to transfer water to the urban, industrial, and tourist sectors. The agricultural sector will need to compensate for the water shortage by boosting water conservation efforts and water efficiency programs. In recent decades, concerns regarding the efficient use of water resources in the country have increased. These concerns have been addressed particularly by transferring government water management systems to water user associations (Mahdhi et al., 2014; Abdelhafidh and Bachta, 2016; Abdelhafidh and Bachta, 2017).

3. Theoretical Framework

A production structure can be studied empirically using either a production function or a cost function. However, the choice should be made on statistical grounds (Chembezi, 1990; Kant & Nautiyal, 1997). Direct estimation of the production function is more convincing in the case of endogenously determined output levels; in the case of exogenous output levels, cost function estimation is preferable (Christensen & Greene, 1976; Mutuku et al, 2009, Abdelhafidh et Bachta, 2016). In most cases agriculture competes with other enterprises for factors of production, and this makes factor prices exogenous. Since the arguments of the cost function are the output and the factor prices, its estimation is statistically more logical than that of the production function. On the other hand, duality theory allows us to recover from the cost function all information regarding the production structure. For the purpose of this study, the direct method approach will be used to estimate the water demand function associated with farm product.

Conditional factor demand is a function that gives the optimal demand for each of several inputs as a function of the output expected, and the prices of inputs. Conditional demand functions are obtained using the Shepard's Lemma where the cost minimization problem is the production of a specified level of output with the least expenditure on inputs (Arrigada 2004). Suppose that the production function is Cobb-Douglas. (Nicholson, 2004, sadeghi, 2010).

The general mathematical form of the Cobb-Douglas production function is given by:

$$\boldsymbol{Y = A\prod_{i=1}^{n} X_i^{\beta i}} \qquad (1)$$

Where Y and X_i denote respectively the production and the inputs used. A and β_i are parameters to be estimated.

So, if K and V are two inputs, then we can write the Cobb Douglas production function in a simple way:

$$\mathrm{Q = K^{\alpha}V^{\beta}} \qquad (2)$$

Total costs for the firm are given by:

$$\mathrm{TC = \gamma V + \eta K} \qquad (3)$$

Where, γ and η are the parameters associated with V and K, respectively.

Thus, from the two equations above, (2) and (3), the minimization problem can be formulated as follows:

$\mathrm{Min}\ : \gamma V + \eta K$

Subject to :

$$\mathrm{Y = K^{\alpha}V^{\beta}} \qquad (4)$$

The Lagrangian expression for cost minimization of producing Q_0 is:

$$\mathrm{L(k, V, \mu) = \eta K + \gamma V + \mu\left(Q_0 - K^{\alpha}l^{\beta}\right)} \qquad (5)$$

The first-order conditions for a minimum are:

$$\frac{\partial \mathrm{L}}{\partial \mathrm{k}} = \eta - \alpha\mu \mathrm{k}^{\alpha-1}\mathrm{V}^{\beta} = 0 \qquad (6)$$

$$\frac{\partial \mathrm{L}}{\partial \mathrm{V}} = \gamma - \beta\mu \mathrm{k}^{\alpha}\mathrm{V}^{\beta-1} = 0 \qquad (7)$$

$$\frac{\partial \mathrm{L}}{\partial \mu} = \mathrm{Q}_0 - \mathrm{k}^{\alpha}\mathrm{V}^{\beta} = 0 \qquad (8)$$

Thus, the rate of technical substitution (TRS) can be determined. This rate measures the greater or lesser difficulty of the technical substitution of the K factor for the V factor. It is equal to the change in the amount of K needed to compensate for the reverse change in a unit of V, while production is remaining constant.

$$TRS_{ij}(x) = \frac{\frac{\partial f(x)}{\partial x_i}}{\frac{\partial f(x)}{\partial x_j}}$$

Then dividing the equation (7) by (8), we obtain

$$TRS_{k,v}(k, v, \mu) = \frac{\frac{\partial f(k,v,\mu)}{\partial k}}{\frac{\partial f(k,v,\mu)}{\partial v}} = \frac{\gamma}{\eta} = \frac{\beta k^{\alpha} v^{\beta-1}}{\alpha k^{\alpha-1} v^{\beta}} \qquad (9)$$

$$\frac{y}{\eta} = \frac{\beta}{\alpha} \cdot \frac{k}{v} = TRS \qquad (10)$$

We obtain k and substitute into the production function and solve for v, we will get

$$\boldsymbol{k = \frac{\alpha}{\beta} \cdot \frac{\gamma}{\eta} \cdot v}$$

And

$$Q = (\frac{\alpha}{\beta}\frac{\gamma}{\eta} v)^{\alpha} v^{\beta} \qquad => \qquad Q = (\frac{\alpha}{\beta}\frac{\gamma}{\eta})^{\alpha} v^{\alpha+\beta} \qquad (11)$$

From equation (11) solving for v we get:

$$\mathbf{v} = \mathrm{Q}^{1/(\alpha+\beta)}.\left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}.\gamma^{\frac{-\alpha}{\alpha+\beta}}.\eta^{\frac{\alpha}{\alpha+\beta}} \qquad (12)$$

A similar method will yield

$$\mathbf{k} = \mathbf{Q}^{\frac{1}{\alpha+\beta}}\left(\frac{\alpha}{\beta}\right)^{(\frac{\beta}{\alpha+\beta})}\boldsymbol{\gamma}^{(\frac{\beta}{\alpha+\beta})}\boldsymbol{\eta}^{(-\frac{\beta}{\alpha+\beta})} \qquad (13)$$

Then, we can derive total costs as

$$C(\eta,\gamma,Q) = \eta\left[Q^{\frac{1}{\alpha+\beta}}\left(\frac{\alpha}{\beta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(-\frac{\beta}{\alpha+\beta}\right)}\right] + \gamma\left[Q^{\frac{1}{\alpha+\beta}}\left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(-\frac{\alpha}{\alpha+\beta}\right)}\eta^{\frac{\alpha}{\alpha+\beta}}\right] \tag{14}$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\left[\eta\left(\frac{\alpha}{\beta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(-\frac{\beta}{\alpha+\beta}\right)} + \gamma\left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(-\frac{\alpha}{\alpha+\beta}\right)}\eta^{\frac{\alpha}{\alpha+\beta}}\right] \tag{15}$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\left[\left(\frac{\alpha}{\beta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\frac{\alpha}{\alpha+\beta}}\right] \tag{16}$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\left[\left(\frac{\alpha}{\beta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\right] \tag{17}$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}J\,\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)} \tag{18}$$

Where

$$J = \left(\frac{\alpha}{\beta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}} = (\alpha+\beta)\alpha^{\left(-\frac{\alpha}{\alpha+\beta}\right)}\beta^{\left(-\frac{\beta}{\alpha+\beta}\right)} \tag{19}$$

which is a constant that includes only the parameters α and β.

Economists studying the behavior of firms find that it is easier to determine its cost function than its production function. Thus, the possible demand functions for all factors can be derived from the cost function. Shephard's lemma is particularly useful for deriving the production function corresponding to a given cost function. Thus, with the help of Shephard's lemma, the eventual demand function for any input is given by the partial derivative of the total cost function with respect to the price of that factor. The possible demands for factors depend on the prices of these factors. As mentioned above, the cost function is:

$$C(\eta,\gamma,Q) = \eta k + \lambda v = Q^{\frac{1}{\alpha+\beta}}J\,\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)} \tag{21}$$

The partial derivatives of the cost function are as follows:

$$v^c(\eta,\gamma,Q) = \frac{\partial c}{\partial \gamma} = \frac{\alpha}{\alpha+\beta}Q^{\frac{1}{\alpha+\beta}}J\,\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\gamma^{\left(\frac{-\alpha}{\alpha+\beta}\right)} = \frac{\beta}{\alpha+\beta}Q^{\frac{1}{\alpha+\beta}}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{-\alpha}{\alpha+\beta}\right)} \tag{22}$$

And

$$k^c(\eta,\gamma,Q) = \frac{\partial c}{\partial \eta} = \frac{\alpha}{\alpha+\beta}Q^{\left(\frac{1}{\alpha+\beta}\right)}J\,\eta^{\left(-\frac{\beta}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)} = \frac{\alpha}{\alpha+\beta}Q^{\left(\frac{1}{\alpha+\beta}\right)}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)} \tag{23}$$

From the partial derivatives and by applying the natural logarithm on both sides, gives:

$$\ln l(\eta,\gamma,Q) = \ln\left[\frac{\beta}{\alpha+\beta}Q^{\frac{1}{\alpha+\beta}}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{-\alpha}{\alpha+\beta}\right)}\right] \tag{24}$$

$$\ln k(\eta,\gamma,Q) = \ln\left[\frac{\alpha}{\alpha+\beta}Q^{\left(\frac{1}{\alpha+\beta}\right)}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)}\right] \tag{25}$$

From equation (24) and (25), then we can generalize the following:

$$\ln l(\eta,\gamma,Q) = \ln A + a\ln(Q) - \alpha\ln(\gamma) + \beta\ln(\eta) \tag{26}$$

Where α is water price elasticity, and, β is cross-price elasticity of water demand, and a indicates the elasticity of water use given changes in output quantity. Given that information on production was collected for every farmer included in this study, the conditional factor demand approach will be used to estimate the water demand.

4. Study area and Data collection

4.1. Study area:

The research was conducted at the Nadhour region, situated in Zaghouan governorate which is located in the centre of Tunisia. Nadhour region is facing growing problems of water scarcity. It is located in the semi-arid bioclimatic lower stage with moderate winter. The average rainfall in the area is 400 mm/year with high annual variability and significant evapo-transpiration. The agricultural area of Nadhour is around 38.200 ha shared by around 2800 farmers, 60 % of farms area are less than 5 ha and 28 % ranging from 5 to 10 ha. The irrigated systems were installed since 1980 and the irrigated area is about 3250 ha. Most irrigated areas are devoted to summer crops (watermelon, pepper, melon, season tomato…). The average annual volume of withdrawal water is about 14 million m^3. Two-thirds of these resources are groundwater. Demand management in the irrigated public area is ensured by 24 irrigation

WUAs grouping 1858 farmers sand irrigating 1400 Ha. These WUAs ensure the sale of water to users and network maintenance. The volumetric pricing method is the most used. The irrigated private area is about 1830ha owned by 933 farmers. The variable cost of irrigation water is formed by the energy cost. Data collection was carried by a survey conducted at the study area. Direct interviews addressed to 90 farmers operating in the irrigated public perimeters and 50 farmers in the private. Groundwater depletion has been a concern in the study area for many years, but increased demands on the groundwater resources have overstressed the aquifer, because it is the largest source of usable, fresh water. Water table was lowered by about 2.5 m yearly. The water table was at the level of -20.4 m in 2002 and its lowered to the level of -55.92 m in 2016. The majority of the drinking water in the region comes from groundwater, and in the last half century, there has been an amazing, if largely ignored, boom in agricultural groundwater use that has provided improved livelihoods and food security to the local population of farmers and consumers. However, increased use of groundwater has also created problems, and there are fears, sometimes challenged, that the boom may soon turn to bust.

4.2 Empirical model

Assuming that the irrigation water demand will be estimated using the Cobb-Douglas functional form and through an econometric analysis method of panel data. It is assumed that, by virtue of cost minimization, the water demand function is a function in terms of the quantity consumed as a function of the water price P, the per hectare Capital factor , (seeds expenditures , treatment products, chemical fertilizers, mechanization costs), the land factor T (irrigated area), and the labour factor L (labour costs) and irrigation production value which explain the effect of the physical production and the effect of the products prices. The irrigation water demand function can be written as follows:

$Ln(Q)= \beta_0 - \beta_1 ln(P)+ \beta_2 ln(sup)+ \beta_3 ln(S)+ \beta_4 ln(F)+ \beta_5 ln(TR)+ \beta_6(ME) + \beta_7 ln(L)+ \beta_{10} ln(Sc)+ \beta_9 ln(Sarb)+ \beta_{10} ln(Sleg)+ \beta_{11} ln(Sveg)+ \beta_{12} ln(y)+b_{13}(Type)+ \beta_{14} ln(NI) +\varepsilon_i$

Where:

Q, is the irrigation application rate on the i^{th} farm;
P is the price of water;
NI is the education level
Sup: irrigated area
S: per hectare seeds expenditures
F: per hectare fertilizers expenditures
TR: per hectare pesticides expenditures
ME: per hectare mechanization expenditures
L: per hectare labour expenditures
Sc: Irrigated cereals acreage
Sarb: irrigated Trees area
Sleg: irrigated leguminous acreage
Sveg: irrigated vegetable acreage
Y: gross product value
Type: 1 if farm belongs to public scheme, 2 if it belongs to private scheme.
ε_i: the disturbance term ~ $N(0, \sigma^2)$.

The estimation of water demand function using the methodology presented previously will permit to identify the significant variables that explain its consumption, and it will provide important information on the factors that influence the water use associated with irrigated agriculture in Tunisia. According to the functional form presented in above, we should expect a negative impact of water price. Following the cost minimization problem, output value (Y) should have a positive impact on water demand.

5. Results and discussion

5.1 Descriptive statistics of variables used in the study

The average water demand was estimated to be 27846 m3/farm and the average area cultivated was estimated to be 6.65ha, while the water price was estimated to be 0.160/m3.

Table 1: Statistical Analysis of the Study Variables

Variables	**Average**	**Min**	**Max**	**STD**
Q: Water used /farm (m3)	27 846	1 200	246 240	36 239
Price (cost): D/m3	0.16	0.12	0.34	0.039
Sup: Irrigated area (ha)	6.65	0.5	60	8.66
S: seeds expenditures (TND/ha)	613	237	4 636	671
F: Fertilizers expenditures (TND/ha)	715	26	2 000	393
TR: Pesticide expenditures (TND/ha)	397	0	1 714	364
ME: Mechanization expenditures (TND/ha)	690	150	2300	367
L: Labour expenditures (TND/ha)	935	84	2480	597
SC: Irrigated cereals acreage (ha)	1	0	30	3.41
Sarb: Irrigated Trees area (ha)	1.78	0	46	5.3
Sleg: Irrigated leguminous acreage (ha)	0.71	0	15	1.6
Sveg: Irrigated vegetable acreage (ha)	3.22	0	30	3.9
Y: Gross Product value	41220	1320	514780	61950
Type: (1 public, 2 private)	1		65%	
	2		35%	
NI : Education level : (1 illiterate, 2 primary, 3 secondary, 4 high)	1		20%	
	2		45%	
	3		30%	
	4		5%	

The average per hectare expenditures varies from 397 TND for pesticides and 935 TND for the labour input. The vegetable crops are the most acreaged with about 48% of the irrigated area. The leguminous and cereals acreage do not exceed 15% of the irrigated area. The mean gross product per far was estimated to be 41220 TND which is important but it can be improved. Since the water productivity was estimated to be 0.950 TND/m3. This much exceeds the practiced water pricing. The farmers belonging to the irrigated public perimeters represented 65% of the total farmers at the region of Nadhour and most of them have an education level under secondary level.

5.2 Regression results

The most prevalent form used to estimate derived demand is the Cobb-Douglass form as it allows the price elasticity of the factors used to be determined. The parameter estimates of the irrigation water demand are presented in table 2. The coefficients of determination, R^2 for the irrigation water demand equation is 89.9% indicating the repressors in the model explained 89.9% of the variation in irrigation water demand. The F-test statistic for the equation was significantly different from zero at the 1% level. This suggests a strong rejection of the null hypothesis that all parameters except the intercept were zero. According to obtained result, the most notably, the estimated coefficient for the water price effect is negative and significant at the 5% level. That means, although this coefficient is very low but farmers will use less water when the price is higher. In the other word, ten percent increase in water price will be caused that water demand 6.55 percent decrease. The relative magnitude of the water price elasticity in Nadhour region, and compared to estimates from previous researches supports our expectations. The statistical insignificance and magnitude of the water price elasticity reinforce the notion of irrigation serving a largely supplemental role in Nadhour. Farmers appear not to be adjusting water use based on water prices to any significant degree. This suggests that the amount of water needed to fulfill a crop's water needs has been sufficiently inexpensive that farmers have been making water use decisions based on crop water needs rather than water price. In addition to that, despite of low response of farmers to the price of water, again farmers tend to reduce the use of water as price becomes higher although in small amount. Likewise, the coefficients of seeds, is negative and significant at level of 5%. This also shows that as seed price increases, farmers will not be able to buy reasonable quantity of seeds and automatically will decrease the area for cultivation as a result of decreasing the amount of water demanded. The coefficient of mechanization and labour are negative but not significant. The negative sign of these inputs indicates that seeds, mechanisation and labour and water input are complementary. The estimated coefficient for production value is positive and significant at 5% level. The estimated parameter coefficient suggests the elasticity of water use, with respect to the value of output, is 0.078. This also means that a 10 percent increase in the output will result in a 0.78 percent increase in the use of water. Results show that irrigated area is with the greater effect on the consumed water and significant at 1% level.

Table 2: Regression results

Variables	Coefficients	Std	t-Statistic	Prob
(Constant)	2,560	0,401	6,383	0,000
Ln(PRICE)	-0,655	0,238	-2,750	0,007
Ln(sup)	0,683	0,085	6,383	0,000
Ln(S)	-0,088	0,031	-2,820	0,006
Ln(F)	0,052	0,055	0,946	0,346
Ln(TR)	0,059	0,023	2,590	0,011
Ln(ME)	-0,014	0,035	-0,402	0,688
Ln(L)	-0,067	0,056	-1,195	0,234
Ln(Sc)	-0,023	0,065	-0,352	0,725
Ln(Sarb)	0,043	0,035	1,238	0,218
Ln(Sleg)	-0,129	0,089	-1,458	0,147
Ln(Scrop)	0,325	0,076	4,268	0,000
Ln(Y)	0,078	0,036	2,173	0,032
Ln(type)	-0,254	0,114	-2,222	0,028
Ln(NI)	0,158	0,081	1,963	0,052
R-squared	89.9	Adjusted R-squared		88.8
F-statistc	694	Prob(F-statistic)		0.00

The estimated coefficient is 0.683 meaning that an increase of 10% in the irrigated area will result with 6.83 % in 6.83 % increase in water use. The vegetables acreage is the variable with the second most effect on water demand and significant at 1% level. Its correspondent coefficient is 0.325 indicating that an increase of this variable by 1% wills results by 0.325 % increases in the water demand. Findings chow too that the parameter of cereal and leguminous areas are with negative effect on water demand but not significant. This implies that these crops do not generate sufficient net income compared to other crops which explains the low areas and water resources allocated to them. The coefficient of the variable type indicates that when a farmer belongs to the private shames the irrigation demand will increase by 25.4%.. This finding reveals that farms under public districts don't have enough access to irrigation water resources as well as at the moment or the volume they want. This suggests that policy maker have to put more regulation on the groundwater extraction when he wants to reduce and control the water demand. As a result of reducing total irrigated area, policy makers have been anticipating a certain level of decrease in irrigation water demand. The decrease in water demand is then, in turn, assumed to benefit both the interregional and intraregional allocation of water. Education level (NI), also has a significant effect on water use. Its coefficient is 0.158. This suggests that when the education level increases by one step this will results by 15.8% increase water use. This may explain that the more educated farmers use more intensive crops. Economic benefits from increases or decreases in water allocated to irrigation are measured as the change in value of agricultural products less changes in associated production costs. Despite this simple concept, establishing values for irrigation water presents several practical problems. As is the case with water generally, market prices for irrigation water are rarely available so estimates of value must often be based upon indirect approaches.

6. Conclusion

In this study the structure of irrigation water demand in Tunisians' farms was investigated. Irrigation water demand is estimated by data related to 140 farms at Nadhour district in Tunisia during 2019. The major results of the analysis concluding that, the water price significantly influences water consumption. However, farmers are not sensitive to water price change because the irrigation water demand is inelastic. Findings show that the principal determinants of the irrigation water demand are water price, irrigated area, crops acreage, farmers' status. These relationships could be used to determine the impact of the production system on water use and reformulation of policies on water use. Based on the findings, this paper recommends that emphasis should be put on effective and efficient use of water in order to improve its productivity. Famers should apply water at a right time avoiding water loss specifically in the private schemes. Various water management strategies should be practiced to boost up the water productivity. For example, improving the water use in the field operations and reducing water use during crop growth by maintaining the soil in sub-saturated condition by alternating drying and wetting the cropped field without affecting yields, instead of continuous submergence methods. Furthermore, if possible, restrict crops cultivation to only rainy season by making more effective use of rainfall. Decision maker can apply a seasonal water pricing. Therefore, it is suggested that striving to boost irrigation efficiency and improve the productivity, which is considered one of the most important strategies toward tackling water scarcity. To achieve large-scale yield and water saving benefits, there is a need to develop easy-to-understand water management recommendations for farmers. In addition, socio-economic factors including market prices, soil type, water availability, and existing irrigation infrastructure will have to be considered for wide-scale acceptance of new management measures of the irrigation water demand.

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