<u>Nonparametric approach for measuring the productivity change and assessing the water use efficiency in the irrigated areas of Tunisia</u>

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Nonparametric approach for measuring the productivity change and assessing the water use efficiency in the irrigated areas of Tunisia

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Abstract

In order to cope with the water scarcity, Tunisia has to manage efficiently the demand of the economic and social sectors mainly that of the agricultural irrigated activities. Within this context our investigation aims to analyze the technical efficiency, the water use efficiency and the dynamic of the productivity of the irrigated areas in the Sidi Bouzid region. Hence, farm surveys, regarding the cropping years 2003 and 2007, were carried out. We have assessed the technology performance using the Data Envelopment Analysis approach and we have computed the Malmquist index in order to characterize the productivity change. Our empirical findings showed that the technical efficiency of the farms has increased by 17% during this period leading to an improvement of the water use efficiency up to 22%. Both, the technical efficiency change as well as the technical change have contributed to this improvement. However, the farmers have to enhance further their irrigated practices in order to save more water. Indeed, in 2007, the water use efficiency was only 78%.

Keywords:

Irrigated Area, Technical Efficiency, Water Use Efficiency, Productivity Change, Data Envelopment Analysis

1. Introduction

The Tunisian agriculture remains ones of the dominant sectors for the economic development of the country. In fact the sector contributes with 13% to the GDP and employs 16% of the active population. Given the climate constraints and the limited resources, the development of the agriculture has been stimulated by the development of the irrigated sector. In 2007, the irrigated areas reached 433 000 ha of which 229 000 ha were arranged in irrigated public areas (IPBAs). In such areas, farmers share a common resource according to a collectively organized scheme. The rest, called irrigated private areas (IPRAs), use surface wells as private resources. The total irrigated area accounts for only 8% of the total agricultural land, but it contributes up to 35% of the national agricultural production. This development of the irrigated sector has been achieved goodness to the government efforts in terms of the water harvesting and the development of hydraulic infrastructure. Today the rate of the water mobilization is more than 90%. Therefore, this policy of water supply reaches its limits and the efforts should be turned to the management of the water demand. Over the past two decades, the government has implemented different programs in order to reduce the losses and to control the water demand. In fact, since 1990 a new tariff policy has been put into place. Each year the price of water has been increased by 15% in nominal value (9% in real value) in order to improve managing cost recovery and to encourage farmers to minimize water wasting. Also, since 1990 the management of IPBAs has been transferred to the users through the creation of "Collective Interest Groups" (CIGs) which have the responsibility for selling and managing the distribution of water. In 2007, 1081 CIGs were created to manage 80% of the irrigated public areas (Ministry of Agriculture, 2008b). In 1995, the government launched The "National program of water conservation" which aims to minimize the losses of water at the field level. This program allows farms that introduce the economical irrigation systems (sprinklers, drip irrigation) to get up to 60% of the investment subsidized. However, these programs do not lead to significant changes in the irrigation practices (Daoud, 1995; Ennabli, 1995; Hemdane 2002; Chraga and Chemak, 2003). Indeed, these programs do not focus on the assessment of the technology processes. Hence, their current implementation does not involve the best of water productivity and the best of water conservation. One weakness of the Tunisian water policies undertaken until now is that they do not take into account the motivations and practices of the farmers. These practices involve the cropping system, the kind of access to the water resource and the intrinsic operational conditions of the households (Capital, Skills, livelihoods constraints, futures purposes…). So the question remains how to enhance the process of the technology in order to improve the water use efficiency? This question raises basically two issues regarding the farming practices performance. In fact the water use efficiency depends on the technology itself and on the manner to implement it. Hence, one has to consider the issues of the technology innovation over time and the ability of the farmers to implement this technology in the best way.

For a long time the literature on water use efficiency was mainly based on engineering and agronomic concepts. Depending on the aspects one wishes to emphasize, Shideed et al. (2005) explained that this concept had been defined in various ways by hydrologists, physiologists and agronomists. For example, agronomists are interested in water use efficiency as the ratio of the amount of water actually utilized by the crop to the water quantity applied to the crop (Omezzine and Zaibet, 1998). However, these various definitions did not integrate water as an economic good and did not allow one to assess the economical level of water use efficiency. Thus the economic approach of water use efficiency focuses the analysis on the whole production technology process. Therefore, water consumption was used in combination with a whole set of other inputs, such as land, fertilizers, labour etc. Also, it was assessed according to the production frontier which represents an optimal allowance of the inputs. This economic approach aims to assess the grower's managerial capability to implement technology processes (Omezzine and Zaibet, 1998; Zaibet and Dharmapala, 1999; Karagiannis et al., 2003).

To deal with these issues, we attempt to find out how the water use efficiency may be affected by the dynamic of the productivity through analyzing the case of the irrigated areas in the region of Sidi Bouzid. The remainder of this paper was structured as follows. We devoted the second section to present the theoretical framework to tackle these issues and our approach to collect the database. In the third section we will present the empirical model and we discuss the induced results. Finally the fourth section presents our concluding remarks.

2. Methodology

2.1 Theoretical framework

2.1.1The DEA model for measuring the water use efficiency

Since the pioneer paper of Farrell (1957), the concept of efficiency has been widely used by many authors interested in assessing the global productivity of the DMU (Decision Making Unit) such as a firm or a public sector agency. As a result, empirical studies based on his approach have been multiplied, putting forward the relevance of the concept (Emrouznejad et al., 2008, Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Seiford, 1996). In fact, let consider the DMUs which produce output Y using two inputs X1 and X2. As Farrell (1957) had shown, DMU A (figure 1) which uses x_1^A and x_2^A may produce the same quantity of the output using only x_1^B and x_2^B. Hence, DMU A is inefficient and its index of technical efficiency (TE_A) is measured by the following ratio: $TE_A = \frac{OB}{OA}$

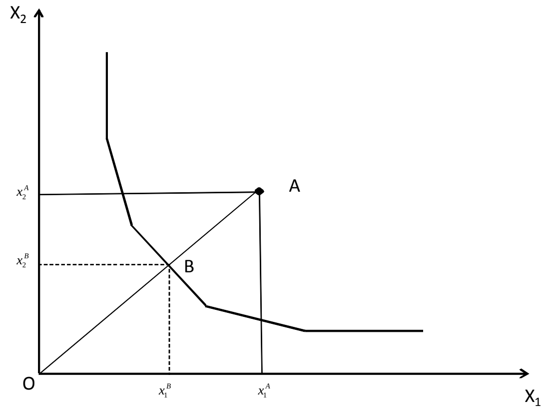

Figure 1: Technical effeciency according to the Input-Oriented Model

To measure this technical efficiency, several studies have applied Data Envelopment Analysis (DEA) due to its advantages. Using the linear programming the DEA model remains the sole approach to assess the multinputs-multiouputs situation without any restriction in the functional form (Farrell and Fieldhouse, 1962; Thanassoulis, 2001; Ray, 2004; Cooper et al., 2006). Until 1984, the DEA approach made the assumption of Constant Returns to Scale (CRS) (Charnes et al., 1978). Banker et al. (1984) investigated returns to scale and proposed the DEA model under Variable Returns to Scale (VRS). This model allows us to compute the pure technical efficiency which cannot be less than the value of technical efficiency obtained by solving the model DEA under CRS.

Let us consider N DMUs that produce the output Y using the input X. To compute the technical efficiency of DMU j_0 under the VRS assumption we have to solve the following linear program (Input oriented model):

$$Min_{(\lambda,k_0,S^-,S^+)}\left[k_0-\varepsilon\left(\sum_{i=1}^{m}S_i^- + \sum_{r=1}^{s}S_r^+\right)\right] \qquad (1)$$

subject to:

$$\sum_{j=1}^{N}\lambda_j x_{ij} = k_0 x_{ij_0} - S_i^- \qquad i=1,...,m$$

$$\sum_{j=1}^{N} \lambda_j y_{rj} = y_{rj_0} + S_r^+ \qquad r = 1,\ldots,s$$

$$\sum_{j=1}^{N} \lambda_j = 1$$

$$\lambda_j \geq 0,\ j = 1,\ldots,N,\ S_i^-,\ S_r^+ \geq 0\ \ \forall\, i \text{ and } r, k_0 \text{ free}$$

ε is a non-Archimedean infinitesimal

The optimal value k_0^* represents the technical efficiency of DMU j_0. Its value lies between 0 and 1 and indicates how much the DMU should be able to reduce the use of all inputs without decreasing its level of outputs with reference to the best performers or benchmarks. *S* represents the slack variables introduced within the constraints to get a Pareto efficient bundle[1] (X, Y). These slack variables represent the difference between the optimal values and the observed values of inputs and outputs at the optimal solution (Thanassoulis, 2001). The first constraint limits the proportional decrease in input, when *k* is minimized, to the input use achieved with the best observed technology. The second constraint ensures that the output produced by the *i*th farm is smaller than that on the frontier. Both these constraints ensure that the optimal solution belongs to the production possibility set. The third constraint, called also convexity constraint, ensures the VRS assumption of the DEA model. Without this constraint the model treats the CRS specification of the DEA model.

However, Färe et al. (1994a) suggest the notion of sub-vector efficiency to deal with the technical efficiency use of each input variable. Hence, they proposed to solve the following linear program:

[1] "It may be recalled that an input-output bundle (x,y) is regarded as Pareto efficient only when (1) it is not possible to increase any output without either reducing some other output or increasing some input, and (2) it is not possible to reduce any input without increasing some other input or reducing some output" (Ray, 2004).

$$Min_{(\lambda,k_0,S)}\left[k_0^v-\varepsilon\left(S_v^-+\sum_{i=1}^{m-v}S_i^-+\sum_{r=1}^{s}S_r^+\right)\right] \quad (2)$$

subject to:

$$\sum_{j=1}^{N}\lambda_j x_j^v = k_0^v x_{j_0}^v - S_v^-$$

$$\sum_{j=1}^{N}\lambda_j x_{ij} = x_{ij_0} - S_i^- \qquad i=1,\dots,m-v$$

$$\sum_{j=1}^{N}\lambda_j y_{rj} = y_{rj_0} + S_r^+ \qquad r=1,\dots,s$$

$$\sum_{j=1}^{N}\lambda_j = 1$$

$\lambda_j \geq 0,\ j=1,\dots,N,\ S\geq 0\ \ \forall\, i$ and r, k_0^v free

ε is a non-Archimedean infinitesimal

Where the optimal value of k_0^v measures the technical efficiency use of the x^v revealed by the farm j_0. It should be analyzed as the water use efficiency if x^v represents the variable of water consumption.

2.1.2 The Malmquist index and the productivity change

As we have presented above the technical efficiency reflects the capability of the farmer to minimize the inputs in order to achieve the targeted outputs or his ability to obtain maximum output from a given set of inputs. This ability was assessed according to the production frontier which represents the benchmark of the technology process. However, this ability as well as the technology process may change over the time. Hence the productivity of the firm may increase, stagnate or decrease (Ray, 2004; Tahnassoulis, 2001). Using the non parametric approach the Malmquist index allows to assess this productivity change. Introduced by Caves et al (1982), this index was defined in terms of the distance functions.

Later, it was operationalized in the DEA framework using the CRS as well the VRS production technology (Färe et al., 1992; Färe et al., 1994b; Ray and Desli, 1997; Griffel-Tatje and Lovell, 1995). The Malmquist index was decomposed to three components in order to measure the contribution of the Technical Efficiency Change (TEC), the Technical Change (TC) and the Scale Change Factor (SCF) (Ray, 2004; Tahnassoulis, 2001).

Let consider the DMU j_0 that produces the output y_t using the input x_t at the period (t). Between the two periods (t) an (t+1) the Malmquist index of this DMU MI(j_0) may be computed as follows:

$$MI(j_0) = \frac{D_v^{t+1}(x_{t+1}, y_{t+1})}{D_v^t(x_t, y_t)} * \left[\frac{D_v^t(x_{t+1}, y_{t+1})}{D_v^{t+1}(x_{t+1}, y_{t+1})} * \frac{D_v^t(x_t, y_t)}{D_v^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} * \left[\frac{\frac{D_c^t(x_{t+1}, y_{t+1})}{D_v^t(x_{t+1}, y_{t+1})}}{\frac{D_c^t(x_t, y_t)}{D_v^t(x_t, y_t)}} * \frac{\frac{D_c^{t+1}(x_{t+1}, y_{t+1})}{D_v^{t+1}(x_{t+1}, y_{t+1})}}{\frac{D_c^{t+1}(x_t, y_t)}{D_v^1(x_t, y_t)}} \right]^{\frac{1}{2}}$$

Where $D_c^t(x_t, y_t)$ and $D_v^t(x_t, y_t)$ are the distance function respectively under CRS and VRS assumptions with reference to the production function in the period t. However $D^{t+1}(x_t, y_t)$ and $D^t(x_{t+1}, y_{t+1})$ measure the cross-period distance function.

The first component outside the brackets captures the technical efficiency change between the periods (t) and (t+1). This term compares the closeness of the DMU j_0 in each time period to that period's benchmark production frontier. The second term, inside the brackets, measures the technical change and reflects the shift in technology between the two periods. The last component, also inside the brackets, measures the scale efficiency change which reflects the extent to which the DMU j_0 has become more scale efficient between the two periods. The distance function is the same as the Farrell measure of technical efficiency and can, therefore, be obtained straightway from the optimal solution of the appropriate CRS or VRS DEA model (Ray, 2004; Tahnassoulis, 2001). Hence, to compute the cross-period radial technical input efficiencies one has to solve the following linear program:

$$Min_{(\lambda, k_0, S^-, S^+)} \left[k_0 - \varepsilon \left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \right) \right] \qquad (3)$$

subject to:

$$\sum_{j=1}^{N} \lambda_j x_{ij}^{t} = k_0 x_{ij_0}^{t+1} - S_i^- \qquad i = 1, \ldots, m$$

$$\sum_{j=1}^{N} \lambda_j y_{rj}^{t} = y_{rj_0}^{t+1} + S_r^+ \qquad r = 1, \ldots, s$$

$$\sum_{j=1}^{N} \lambda_j = 1$$

$\lambda_j \geq 0,\ j = 1, \ldots, N,\ S_i^-,\ S_r^+ \geq 0\ \ \forall\, i$ and r, k_0 free

ε is a non-Archimedean infinitesimal

2.2 Irrigated activity issues and data collection in the Sidi Bouzid region

Located in the Center of the country (Figure 2), the region of Sidi Bouzid owes its economic and social development to irrigation. It consists of approximately 40000 ha of irrigated areas which include 5500 ha of IPBAs. The irrigated sector generates up to 60% of the regional agricultural production (Ministry of Agriculture, 2006) and contributes up to 16% of the national production of vegetables (Ministry of Agriculture, 2008a). However, despite such a development, significant difficulties remain in IPBAs as well as in IPRAs. Certain public irrigation channels have decayed resulting in significant water losses of up to 40% (Ministry of Agriculture, 1995). The use of the flood irrigation system is dominant which leads to significant water losses. The proliferation of surface wells increases the overexploitation of the groundwater that is reflected in folding back[2] and in increased salinity of water as well as soils.

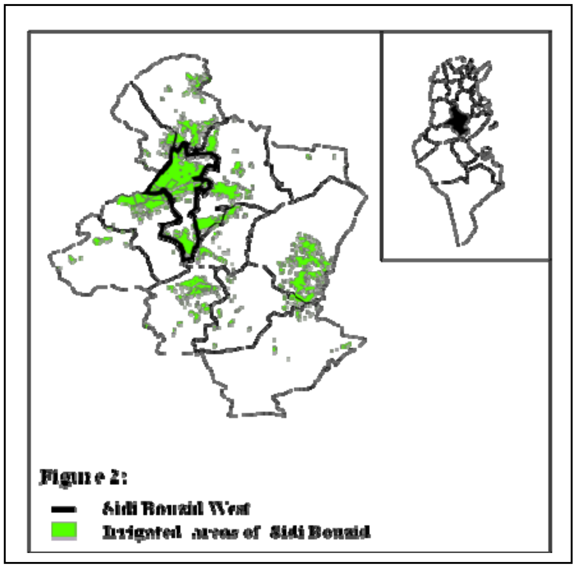

Figure 2:

To investigate our research issues we will analyze the irrigated agricultural activity in the Western region of Sidi Bouzid (Figure 2). Sidi Bouzid West constitutes a representative region from an economical, institutional and social dynamics standpoint of the governorate and in particular the irrigation development (Attia, 1977; Abaab, 1999). In 2003, the region of Sidi Bouzid West counts seven IPBAs which represent a total irrigable surface of 1095 ha belonging to 916 farmers. The main objective of developing the irrigation through the creation of these IPBAs is to mitigate the effects of the drought basically by ensuring the production of the olive trees. The number of surface wells reaches 2500 which allow to irrigate approximately 7500 ha of IPRAs. A rapid appraisal of the IPBAs allowed us to reveal that 18% of the farmers have created their own surface wells as second resource of irrigation (Table 1).

[2] Each year, on average a folding back of approximately 30 cm is noted (Ministry of Agriculture, 2006).

Table 1: Distribution of farms at the IPBAs of Sidi Bouzid West

IPBA	Irrigable area (ha)	Number of farmers	Farms using two resources	
			Number	%
Sidi Sayeh 1	162	101	9	9
Sidi Sayeh 2	240	200	26	13
Ouled Brahim	165	180	37	20
Bir Badra	94	84	37	44
El Houajbia	187	63	3	5
Om Laadham	160	209	51	25
El Frayou	87	79	0	0
Total	**1095**	**916**	**163**	**18**

Within this context and in order to deal with the diversity of the farming system according to the access of the water resources, we have concentrated our investigation around the five IPBAs[3] (Figure 3) where the strategy of sinking surface wells as second resource of irrigation was widely adopted. Hence we have selected 18 farmers who have access to the both resources of water which represent 11% of this category of farmers. In addition we have selected 16 farmers belonging to these IPBAs and 15 farmers belonging to IPRAs whom are located around the concerned IPBAs in order to conserve the homogeneity of the sample. All these farmers are randomly screened.

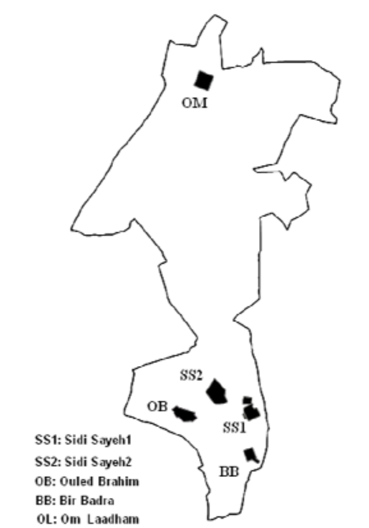

Figure 3: Selected IPBAs for Investigation

[3] Sidi Sayeh 1, Sidi Sayeh 2, Ouled Brahim, Bir Badra and Om Laadham

We had carried out field survey in 2004 and 2008 in order to gather technical and economical data regarding the operational cropping years 2003 and 2007. We have collected the data by plots that reach the number of 94 of which 41 plots are irrigated by public resource.

Between 2003 and 2007, the government has achieved the rehabilitation of the irrigation channels to improve the irrigation facilities. The project aims to improve the availability of the water by converting the open channels into the net of underground pipeline of the water distribution. Hence the project has enhanced the pressure of water what has encouraged some farmers to invest in economical irrigation system. Also, the government has launched the presidential program giving financial supports mainly to small farmers in the irrigated areas. The main components of investment, encouraged by the project, are dairy cows' rearing and the improvement of irrigation equipments. However, this period revealed a substantial increase of the input prices mainly the fuel that may affect the farmers' purposes according to their financial constraints.

3. Discussion of the results

3.1 Descriptive analysis

Descriptive analysis of the data showed that the farm average size was 7.71 ha in 2003 and declined to 7.41 in 2007. Despite this reduction the potential of the irrigable area per farm has increased from 4.38 ha to 4.64 ha (Table 2). More than 80% of this area was planted by the olive-trees which remain the based component of the cropping system. As a result, farmers were constrained to practice excessive cropping. The planted area reveals slight increase (7%) between 2003 and 2007 (Table 3). In 2003, farmers cultivate mainly cereal crops in order to meet their needs as well as those of their animals. In 2007 it appears that this attitude has been changed. In fact we note that the area of the cereal crops has decreased by 59% between 2003 and 2007. Mainly two reasons may explain this change. Firstly, as we have declared above the presidential program has encouraged the dairy cows' rearing leading to the increase of the area of the forage crops which shifts from 17.4 ha in 2003 to 30.55 ha in 2007. Secondly, compared to the others crops, the gross margin of the cereal crops remains very low and the input prices have much increased during this period. The cultivated areas of the horticulture crops did not change due to the importance of their added value which allows the farmers to get the high profit.

Table 2: Descriptive statistics of the irrigated activity

	2003				2007			
	Mean	Min	Max	S.D	Mean	Min	Max	S.D
Total Area per Farm (ha)	7.71	0.4	35	6	7.41	0.4	22	5
Irrigable Area (ha)	4.38	0.25	17	3.5	4.64	0.25	17	3.5
Irrigable Plots	1.91	1	6	1.2	1.77	1	5	1
Irrigable Area per plot (ha)	2.49	0.25	8	2	2.75	0.25	9	1.9
Irrigation (m3/ha)	2157	185	5040	1252	2449	176	5862	1332

Table 3: Dynamic of the cropping system

	2003		2007		
	Area (ha)	%	Area (ha)	%	
Olive trees	187.44	61	201.44	67	+7%
Cereal crops	55.25	18	22.75	8	-59%
Forage crops	17.4	6	30.55	10	+76%
Horticulture crops	45.75	15	44.15	15	-3%
Total	306.14	100	298.89	100	-2%

In 2003, all farmers adopted floodwater as an irrigation system. This caused a high level of water wasting reaching up to 60%. In 2007, only 9 farmers have introduced an economical irrigation system such as sprinklers and drip irrigation to irrigate 10 plots of which 3 plots belonged to the IPBAs. The average water consumption per hectare was 2157 m^3 in 2003 and 2449 m^3 in 2007 (Table 2). Despite this increase, this consumption remains lower than the standard target projected by the planners (6000 to 7000 m^3/ha). It is also less than the volume carried out at the national level which reached on average 5500m^3/ha (Hemdane, 2002). However, for the both cropping years, the share of the irrigation charges remains higher and reached more than 40% of the total charges per hectare.

Regarding the production we note an important increase of the average value of the production per hectare which shifts from 849 TND[4] in 2003 to 1344 TND in 2007 (Table4). The share of the olive production increases from 47% in 2003 to 61% in 2007. The average of the total charges per hectare increases from 479TND in 2003 to 753TND in 2007. The irrigation remains the main component of the expenditures by catching around 40% of the total charges. The share of the different components did not show the great change but the mean value of the irrigation charges was shifted from 180TND per ha to 319TND per ha. This is due mainly to the substantial increase of the fuel price. In addition, irrigation, mechanization and fertilization account for two third in 2003 as well as in 2007. This result shows the importance of these three components regarding the implementation of the technology process.

Table 4: Production and charges of the irrigated activity

	2003				2007			
	Mean	**Min**	**Max**	**S.D**	**Mean**	**Min**	**Max**	**S.D**
Production (TND/ha)	849	0	4000	858	1344	0	5036	982
Total charges (TND/ha)	479	78	1726	361	753	194	1993	417
Gross Margin (TND/ha)	370	-660	2697	659	591	-864	4181	930
Irrigation (TND/ha)	180	20	536	113	319	54	1135	205
Mechanization (TND/ha)	64	0	205	38	112	31	375	73
Fertilization (TND/ha)	47	0	265	56	69	0	556	93
Labor (TND/ha)	87	0	550	119	126	0	471	125
Others (TND/ha)	101	0	803	144	127	0	550	156

3.2 Analysis of technical efficiency and productivity change

According to the results of the descriptive analysis, presented above, we have made the assumption that the technology process may be represented by the following production function:

$$\text{Oliv, Cult} = \boldsymbol{f}\,(\text{Land, Water, Mecan, Fertil, Lab})$$

[4] TND: Tunisian National Dinars which equal approximately US $ 0.77.

where:

- Oliv: Value of olive tree products in TND

- Cult: Value of crop products in TND

- Land: Potential irrigated surface in hectares

- Water: Water consumption quantity in m^3

- Mecan: Expenditure of mechanization in TND

- Fertil: Expenditure of fertilization in TND

- Lab: Expenditure of labour in TND

The following Table 5 presents summary statistics of the variables.

Table 5: Descriptive statistics of the variables

Variables	**farms**	**2003**				**2007**			
		Mean	**Min**	**Max**	**S.D**	**Mean**	**Min**	**Max**	**S.D**
Oliv	49	1454	0	7800	1820	3692	0	16700	3409
Cult	49	3201	0	18894	4186	2849	0	14160	3365
Land	49	4.38	0.25	17	3.5	4.64	0.25	17	3.5
Water	49	12080	369	52940	11482	13083	810	48476	11290
Mecan	49	345	0	1060	299	579	20	2300	473
Fertil	49	245	0	1070	278	339	0	1676	363
Lab	49	506	0	4788	858	730	0	4541	943

To compute the technical efficiency, the water use efficiency and the Malmquist index we have solved respectively the linear programs (1), (2) and (3) using the GAMS software. The obtained measurements are presented in the annex.

Regarding the performance of the production system our empirical findings show that on average farmers use the inputs inefficiently (Table 6). Indeed, the average of the technical efficiency was 0.67 in 2003 and 0.84 in 2007. Therefore farmers might achieve the same level of production and save at the same time up to 33% of the inputs in 2003 and 16% in 2007. This inefficiency lies in an important overconsumption of the water. In fact the water use efficiency was only 0.56 in 2003 and just reached 0.78 in 2007. So, farmers should improve their practices and adjust adequately their demand to save more water. However this period revealed an improvement of the technical efficiency by 17% that may lie in the positive dynamic of the productivity. By analyzing the distribution of the technical efficiency measurements (Table 7), this improvement was well expressed. In fact in 2003 only 17 farms (35%) were perfectly efficient while 25 (51%) farmers were perfectly efficient in 2007. In addition, the farmers, using efficiently the water, were 17 (35%) in 2003 while they reached 27 (55%) in 2007. Despite this improvement, 17 (35%) farmers revealed low water use efficiency that falls under 0.75 in 2007. These farmers involve 7 farmers belonging to the IPRAs and 7 farmers whom have access to both resources of irrigation. This result suggests that the practices of farmers, using water from surface wells, cause more overconsumption of water than those of farmers using public resource. Hence, the government has to give more attention to this category of farmers in implementing the policy of the water demand management.

Table 6: Statistics of the technical efficiency and the water use effeciency

	2003				2007			
	Mean	**Min**	**Max**	**S.D**	**Mean**	**Min**	**Max**	**S.D**
Technical efficiency	0.67	0.18	1	0.28	0.84	0.28	1	0.24
Water use efficiency	0.56	0.10	1	0.35	0.78	0.12	1	0.30

Table 7: Distribution of the efficiency measurements

	Technical efficiency				Water use efficiency			
	2003		**2007**		**2003**		**2007**	
	Number	%	**Number**	**%**	**Number**	**%**	**Number**	**%**
E<0.5	17	35	9	18	24	49	10	21
0.5 ≤ E< 0.75	11	22	2	4	7	14	7	14
0.75 ≤ E<1	4	8	13	27	1	2	5	10
E=1	17	35	25	51	17	35	27	55
Total	49	100	49	100	49	100	49	100

However, the question remains how to catch up more efficiency leading to the best management of the water demand. In order to make clear the answer, we analyze the Malmquist index and its components (Annex). In fact our results suggest that the Malmquist index reaches an average of 1.60. This implies that the productivity of the farms has increased by 60% between 2003 and 2007. The decomposition of this index shows that the technical efficiency change reached an average of 1.49. This lies in an improvement of the capability management of the farmers that contributes with 49% to the dynamic of the productivity of the irrigated activity. The average of the technical change reached 1.41 and suggests a positive shift in the technology production. This technology change contributes with 41% to the improvement of the productivity. Finally, the result suggests that the scale change factor contributes also to the improvement of the productivity 11%.

4. Concluding remarks

Water demand management is an increasingly crucial issue. So far, the irrigation development allowed Tunisia to ensure up to 35% of its agricultural production whereas recently, decision makers planned a target contribution of 50%. The achievement of such an objective faces some management difficulties related to an increasingly scarce water resource. To deal with this scarcity and achieve the targeted production, farmers have to improve their irrigated practices in order to minimize the water losses and to increase their production.

Following our investigation, the farmers of the irrigated areas in the Sidi Bouzid region experienced this attitude change by improving their farming system performance. In fact their technical efficiency has increased by 17% between 2003 and 2007 leading to the improvement of the water use efficiency by 22% for the same period. The Malmquist index showed that this improvement has occurred mainly goodness to the improvement of their capability management (49%) and the positive shift in the technology (41%).

On the other hand, despite this improvement the average of the water use efficiency was only 0.78 in 2007. So, farmers have to enhance further their irrigated practices in order to save more water. Hence, the decision makers have to take into account this alternative to achieve the best management of the water demand. The government has to provide farmers with the requested financial support and technical assistance in order to encourage them to improve their irrigated system and to adopt the suitable technology. The extension services should work closely with farmers to cope with the water scarcity by achieving the optimal of the water use efficiency.

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ANNEX

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