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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, this 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. Farm surveys have been carried out during 2003 and 2007 harvesting years and technology performance has been assessed using Data Envelopment Analysis approach. Malmquist index has been also computed in order to characterize the productivity change. Empirical findings showed that the technical efficiency of the farms has increased by 19% during this period leading to an improvement of the water use efficiency up to 24%. Both, the technical efficiency change as well as the technical change reveal a positive impact on the productivity change. However, in 2007, the water use efficiency was only 79%. Therefore, farmers have to improve further their irrigated practices in order to save more water.

Keywords:

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

JEL codes: C14 ; Q12 ; Q25

1. Introduction

The Tunisian agricultural activity remains one of the dominant economical sectors of the country. In fact, the sector contributes up to 13% of the GDP and employs 16% of the active population. Given the climate constraints (mainly semi-arid) 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. The expansion of the irrigated sector has been achieved thanks to huge government efforts in terms of water harvesting and hydraulic infrastructure improvements.

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 implemented. 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 is a farmer’s association having the responsibility of selling and managing water distribution. 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 water saving irrigation systems (sprinklers, drip irrigation) to benefit from investment subsidies which varies between 40 and 60% of its cost according to the investment category.

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 farmers. These practices involve the farming system, the kind of access to the water resource and the intrinsic operational conditions of households (Capital, Skills, livelihoods constraints, futures purposes…). Hence the arising question is how to enhance the technology process 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 implementation process. Therefore, one has to consider the issues of technology innovation over time and farmer's ability to implement it efficiently.

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 used by the crop to the water quantity applied to the crop (Omezzine and Zaibet, 1998). However, these various definitions did not encompass 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, labor 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).

In order to tackle 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 Sidi Bouzid irrigated areas. The remainder of this paper is structured as follows. The second section presents the theoretical framework and our approach to collect data. The third section presents the empirical model and the discussion of the obtained results. The last section concludes with a formulation of some policy recommendations.

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, Odeck, 2009; Wang 2010; Lansink and Reinhard, 2004, Gorton and Davidova, 2004).

In fact, let consider the DMUs which produce the output Y using two inputs X_1 and X_2. As Farrell (1957) had shown, DMU A (figure 1) which uses x_1^A and x_2^A quantities of X_1 and X_2 respectively may produce the same quantity of the output using only x_1^B and x_2^B quantities of X_1 and X_2 respectively. Hence, DMU A is inefficient and its index of technical efficiency (TE_A) is measured by the following ratio: $TE_A = \frac{OB}{OA}$

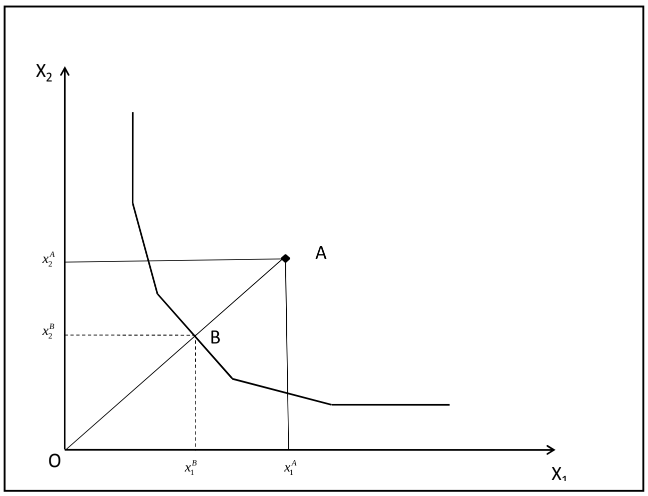

Figure 1: Technical efficiency according to the input oriented model

In order 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 multi-inputs / multi-ouputs technologies without any restriction on the functional form (Farrell and Fieldhouse, 1962; Thanassoulis, 2001; Ray, 2004; Cooper et al., 2006). Until 1984, the DEA approach was based on the Constant Returns to Scale (CRS) assumption of (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 under CRS.

Let us consider N DMUs that produce the output vector $Y(y_1,...,y_s)$ using the input vector $X(x_1,...,x_m)$. 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:

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

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

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

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

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

(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 ith 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 approach.

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:

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

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. This is different from the technical efficiency k_0^* computed by solving the linear program (1). In fact if we get back to the figure 1, the technical efficiency regarding the use of the input x_1^A is the ratio $TE_{x_1^A} = \frac{Ox_1^B}{Ox_1^A}$. Hence, the optimal value of k_0^v should be analyzed as the water use efficiency if x^v represents the variable of the water consumption.

2.1.2 The Malmquist index and the productivity change

As stated earlier, the technical efficiency reflects the capability of the farmer to minimize 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 time. Hence the firm productivity may increase, stagnate or decrease (Ray, 2004; Tahnassoulis, 2001).

Using the nonparametric approach the Malmquist index (MI) allows assessing this productivity change. Introduced by Caves et al. (1982), this index was defined in terms of the distance functions. Later, it was implemented in the DEA framework using the CRS as well the VRS production technology (Färe et al., 1992; Färe et al., 1994b).

The Malmquist index was decomposed into four components (Balk, 2001) in order to measure the contribution of the Technical Efficiency Change (TEC), the Technical Change (TC) and the Scale Efficiency Change Factor (SEC) and the Input Mix Effects (IME) .

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:

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

$$* \left[\frac{D_c^t(x_t, y_{t+1}) * D_v^t(x_t, y_t)}{D_v^t(x_3, y_{t+1}) * D_c^t(x_t, y_t)} * \frac{D_v^{t+1}(x_{t+1}, y_t) * D_c^{t+1}(x_{t+1}, y_{t+1})}{D_c^{t+1}(x_{t+1}, y_t) * D_v^{t+1}(x_{t+1}, y_{t+1})} \right]^{\frac{1}{2}}$$

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

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 frontier of 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 TEC 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. If this ratio is larger (smaller) than 1, the DMU uses the inputs more (less) efficiently. The second term, inside the brackets, measures the technical change and reflects the shift of the production frontier between the two periods. A value larger (smaller) than 1 indicates technical progress (regress). The third 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. A value larger (smaller) than 1 indicates, with respect to the period t technology and conditional on a certain input-mix, that the input combination X^{t+1} lies closer to (farther away from) the point of optimal scale than X^t did. Finally, the last component captures the input-mix effect. Given the uncontrolled practices of the farmers this ratio is, basically, relevant in order to avoid the biased analysis of the productivity change. The distance function is the same as the Farrell measure of technical efficiency and can, therefore, be obtained in a straightway from the optimal solution of the appropriate CRS and 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:

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

subject to:

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

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

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

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

ε is a non-Archimedean infinitesimal

2.2 Irrigated activity issues and data collection in 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 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.

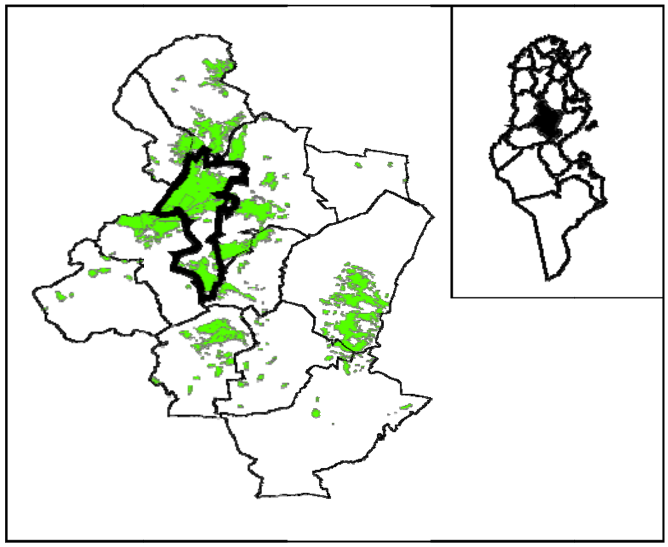

Figure 2: Potential irrigable area of the Sidi Bouzid Region

To investigate our research issues we analyze the irrigated farming system 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 basically in terms of 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 (Table 1). The main objective of the development of the irrigation in the IPBAs was the alleviation of the drought effects basically by ensuring the production of the olive trees.

The number of surface wells reaches 2500 which allow the irrigation of 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 farming system diversity according to the water resources access,, we have concentrated our investigation around five IPBAs[3] (Figure 3) where the strategy of sinking surface wells as second resource of irrigation was widely adopted. In fact this strategy gives the farmers more freedom to manage their farming system and therefore we expect wise uses of the water resources. Hence we have, randomly, selected 17 farmers who have access to both water resources which represent 10% 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 preserve the homogeneity of the sample. Hence the total number of farmers is 48.

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

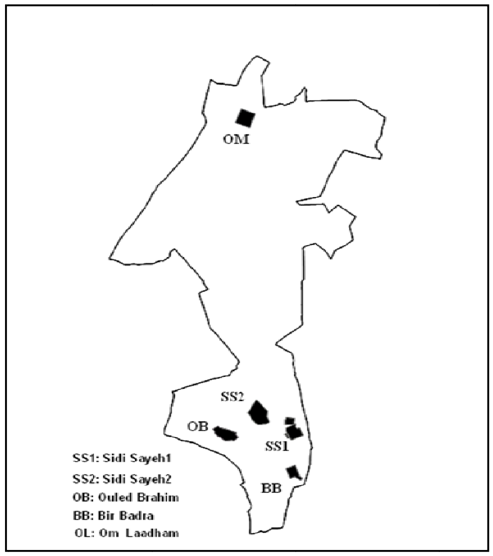

Figure 3: Selected IPBAs for investigation

We have carried out field surveys in 2004 and 2008 in order to gather technical and economical data regarding the operational harvesting years 2003 and 2007. We have collected data relative to 92 plots of which 40 plots are irrigated by public water resources.

During the period 2003-2007, the government has achieved the rehabilitation of the irrigation channels to improve irrigation facilities. The project aims to improve water availability by converting the open channels into underground pipeline of water distribution. Hence, the project has enhanced the flow of the water that allows farmers to invest in water saving systems. Simultaneously, the government has launched the presidential program granting financial supports mainly to small farmers in the irrigated areas. The main investment components supported by the project are: dairy livestock and irrigation equipments improvement. However, during this period a substantial increase of energy prices has been recorded which harmed farmers' financial capacity.

3. Discussion of the results

3.1 Descriptive analysis

Descriptive analysis of the data showed that the farm average size was 7.66 ha in 2003 while declined to 7.42 ha in 2007. Despite this reduction the irrigable area per farm has increased from 4.36 ha to 4.63 ha (Table 2). More than 80% of this area was occupied by the olive-trees which remain the major component of the farming 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 cultivated cereal crops in order to meet their needs as well as those of their breeding animals. In 2007, this behaviour has changed and cereal crops area has dropped by 63% compared to 2003. Two main reasons can explain this change. Firstly, as previously stated, the presidential program has encouraged dairy livestock investment through subsidies leading to an increase of forage crops area from 17.4 ha in 2003 to 30.55 ha in 2007. Secondly, compared to other crops, the gross margin of cereals remains very low. In fact the sale price of the cereal products was fixed by the government and it has not been accurately adjusted to take into account the high increase of the fuel prices during the same period. Finally, the cultivated areas of horticultural crops did not change because these kinds of products provide farmers 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)	7.66	0.4	35	6.17	7.42	0.4	22	5.2
Irrigable Area (ha)	4.36	0.25	17	3.59	4.63	0.25	17	3.5
Irrigable Plots	1.91	1	6	1.21	1.77	1	5	0.99
Irrigable Area per plot (ha)	2.49	0.25	8	2.05	2.76	0.25	9	1.98
Irrigation (m3/ha)	2177	185	5040	1257	2461	176	5862	1344

Table 3: Dynamic of the cropping system

2003	**2007**

	Area (ha)	%	Area (ha)	%	
Olive trees	182.74	61	196.44	67	+7%
Cereal crops	54.25	18	19.75	7	-63%
Forage crops	17.4	6	30.55	11	+76%
Horticulture crops	45.75	15	44.15	15	-3%
Total	300.14	100	290.89	100	-3%

In 2003, all farmers adopted floodwater as an irrigation method. This caused a high level of water wasting reaching up to 60%. In 2007, only 9 (19%) farmers have introduced a water saving system such as sprinklers and drip irrigation to irrigate 10 (12%) plots of which 3 belong to the IPBAs. The average water consumption per hectare was 2177 m^3 in 2003 and 2461 m^3 in 2007 (Table 2). Despite this increase, this consumption remains lower than the standard target projected by water authorities (6000 to 7000 m^3/ha). It is also less than the volume consumed at the national level which reached on average 5500m^3/ha (Hemdane, 2002).

Regarding the revenue, an important increase of the average revenue per hectare has been achieved (from 863 TND[4] in 2003 to 1366 TND in 2007, see Table4). The share of the olive production increased from 47% in 2003 to 61% in 2007. The average total charges per hectare increased from 488TND in 2003 to 764TND in 2007. Irrigation cost share remains the main component of farmer’s expenditures with about 40% of the total charges. However, the mean value per hectare of the irrigation expenditures increases from 181TND in 2003 to 321TND in 2007. This is due mainly to the substantial increase of the fuel prices. In addition, irrigation, mechanization, fertilization and labor, represent more than 80% of the total production cost in 2003 as well as in 2007.

Table 4: Revenue and production cost of the irrigated activity (TND/ha)

	2003	**2007**

[4] TND: Tunisian National Dinars which equal approximately US $ 0.72 (update).

	Mean	Min	Max	S.D	Mean	Min	Max	S.D
Revenue	863	0	4000	861	1366	0	5036	981
Total production cost	488	78	1726	362	764	194	1993	418
Gross Margin	378	-660	2697	663	602	-864	4181	936
Irrigation	181	20	536	114	321	54	1135	207
Mechanization	65	7.5	205	38	114	31	375	73
Fertilization	48	0	265	57	70	0	556	94
Labor	89	0	550	120	128	0	471	126
Others	103	0	803	145	129	0	550	157

3.2 Analysis of technical efficiency and productivity change

We assume that the technology process may be represented by the following production function:

Oliv, Cult = ***f*** (Land, Water, Mecan, Fertil, Lab)

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: Mechanization expenditures in TND

- Fertil: Fertilization expenditure in TND

- Lab: Labor cost in TND

Table 5 presents summary statistics of the variables.

Table 5: Descriptive statistics

Variables	farms	2003				2007			
		Mean	**Min**	**Max**	**S.D**	**Mean**	**Min**	**Max**	**S.D**
Oliv	48	1468	0	7800	1837	3692	0	16700	3431
Cult	48	3265	0	18894	4207	2886	0	14160	3391
Land	48	4.36	0.25	17	3.59	4.64	0.25	17	3.5
Water	48	12183	369	52940	11581	13043	810	48476	11406
Mecan	48	352	12	1060	298	585	20	2300	476
Fertil	48	251	0	1070	279	344	0	1676	366
Lab	48	515	0	4788	865	739	0	4541	951

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 GAMS software (General Algebraic Modelling System). The obtained measurements are presented in annex 1.

Regarding the performance of the production system, our empirical findings show that on average, farmers use inputs inefficiently (Table 6). Indeed, the average of the technical efficiency was estimated at 0.66 in 2003 and 0.85 in 2007. Therefore, farmers can reach the same production level while reducing their inputs use by 34% in 2003 and 15% in 2007. This inefficiency lies in an extensive water over consumption since the water use efficiency was only 0.55 in 2003 and reached 0.79 in 2007. In order to investigate the actual weight of the irrigation water in the technology process, we have analyzed the spearman correlation statistic between the technical efficiency and the water use efficiency (Table 7). The result has shown strongly dependence which is significant at 1%. Hence, the irrigation management plays the paramount role in the technology process and farmers should improve their practices and adjust adequately their needs to save more water.

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

2003	2007

	Mean	Min	Max	S.D.	Mean	Min	Max	S.D.
Technical efficiency	0.66	0.18	1	0.28	0.85	0.28	1	0.23
Water use efficiency	0.55	0.10	1	0.35	0.79	0.12	1	0.29

Table 7: Spearman's rho

		Technical efficiency	
		2003	**2007**
Water use efficiency	**2003**	0.9156***	
	2007		0.9879***

*** Significant at 1%

However, this period revealed technical efficiency improvement by 19% that could be the result of a positive productivity dynamic. The distribution of the technical efficiency measurements (Table 8) shows that this improvement is well expressed. Indeed, in 2003 only 16 farms (33%) were perfectly efficient while 25 farms (52%) were perfectly efficient in 2007. In addition, farms using water efficiently were 16 (33%) in 2003 while they reached 27 (56%) in 2007. Despite this improvement, 16 (34%) farms revealed low water use efficiency that falls under 0.75 in 2007. These farms involve 7 belonging to the IPRAs and 6 having access to both resources of irrigation water. This result states that farmers, using water of surface wells, revealed an overconsumption more important than those using public resource. Hence, water authorities have to give more attention to this category of farmers when implementing the policy of water demand management.

Table 8: Distribution of the efficiency measurements

	Technical efficiency				**Water use efficiency**			
	2003		**2007**		**2003**		**2007**	
	Number	%	**Number**	%	**Number**	%	**Number**	%
E<0.5	17	36	8	17	24	50	9	19
0.5 ≤ E< 0.75	11	23	2	4	7	15	7	15
0.75 ≤ E<1	4	8	13	27	1	2	5	10

E=1	16	33	25	52	16	33	27	56
Total	48	100	48	100	48	100	48	100

Regarding the relationship between farms' performance and the water use efficiency, the analysis of the Malmquist index and its components give some insights and may provide guidelines to set up suitable strategies to cope with the water scarcity (Table 9). Our results show that the Malmquist index reaches an average of 1.67. This implies that farms productivity has increased by 67% between 2003 and 2007. The decomposition of this index shows that the technical efficiency change and the technology progress are the main factors of the productivity improvement. On average the TEC represents 51% while the TC represents 43%. This result suggests a positive shift of the production frontier as well as further efficiently use of the inputs. Regarding the scale efficiency change the results showed slight decrease estimated at 2% meant the input combinations in 2007 have been slightly moved far away of the optimal scale. Finally, the input mix effect was estimated at 1%. This low value confirmed the homogeneity of the implemented technology even though the data base take into account wide space and two different cultivated periods.

Table 9: Mean values of the Malmquist index components

	Mean	Min	Max	S.D.
MI	1.67	0	8.46	1.51
TC	1.43	0.22	9.37	1.63
TEC	1.51	0.48	3.63	0.80
SEC	0.98	0	2.37	0.40
IME	1.01	0.22	2.19	0.36

4. Concluding remarks

This paper has analyzed the overall technical efficiency of the irrigated farms in the Sidi Bouzid region for the two harvesting years 2003, 2007 using the DEA model. The water use efficiency has been also computed using the sub-vector approach and the

Malmquist index has been investigated in order to characterize the productivity change. The results showed that the inputs use in the sample farm households was in a state of inefficient productive allocation. The irrigation water use revealed an over consumption up to 45% in 2003. This water irrigation inefficiency is strongly correlated to the technical inefficiency and therefore the irrigation management is likely to be the main factor of the technology process. The analysis of the efficiency over the harvesting years 2003, 2007 showed an improvement of the technical efficiency by 19% leading to an extensively saving water of 29%. Hence, we suggest that significant reductions in water waste could be achieved if the farmers improve their technical performance.

From 2003 to 2007 the sample farmers had, on average, an encouraging productivity increase of 67% which implies an average growth of about 17% per year. This increase is mainly due to the technical and the efficiency improvements among producers. In fact, the technical change was estimated at 43% while the technical efficiency change captures 51% of the productivity change. On the other hand, the Scale Efficiency Change revealed slight decrease which did not exceed 2%. These results demonstrate the usefulness of the Malmquist index and its components for analysing the productivity change. However, additional research is required to explain the determinants of this productivity change and to identify suitable options to improve it where decreases.

Given these empirical findings, the challenge of reconciliation between production targets and saving irrigation water appears affordable. In fact the state intervention should take into account two streams. The first one encompasses the improvement of the farmers' capability as the main factor of saving water at the field level. Within this context an operational farmers' capacity building program seems very useful to sensitise them about the relationship between water saving and profitability in order to encourage farmers to participate in irrigation management. Additional research on allocative and economic efficiency would confirm this linkage. The second stream of the state intervention should takes into account the extent weight of saving irrigation water for implementing the policy of the water management demand. According to our results, by saving 20% of the irrigation water, currently used, one might alleviate water scarcity. Therefore, in order to generalize this suggestion it will be useful to extend this research by analysing more irrigated areas of other regions. However, the government has to provide financial support and technical assistance in order to encourage farmers to optimize the management of their irrigated system and to adjust their technologies towards the optimal scale. Moreover, the extension facilities should be enhanced in order to develop suitable options helping farmers to achieve the optimal water use efficiency and to cope with the water scarcity.

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References

Abaab, A., 1999. Modernisation agricole et ses effets sur les systèmes de production agricole: cas de la région de Sidi Bouzid en Tunisie centrale. Ph.D, University of Gent, Belgium.

Attia, H., 1977. Les hautes steppes tunisiennes…de la société pastorale…à la société paysanne. Ph.D, University of Paris VII, France.

Balk, B.M., 2001. Scale Efficiency and Productivity Change. Journal of Productivity Analysis, 15, 159-183.

Banker, R. D., Charnes, A. Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science 30, 1078-1092.

Battese, G.E., 1992. Frontier production functions and technical efficiency: a survey of empirical application in agricultural economics. Agricultural economics 7, 185-208.

Bravo-Ureta, B.E., Pinheiro, A.E., 1993. Efficiency analysis of developing country agriculture: a review of the frontier function literature. Agricultural Research Economic Review 22, 88-101.

Caves, D.W., Christensen, L.R., Diewert, E., 1982. The economic theory of index numbers of the measurement of input, output and productivity. Econometrica 50:6, november, 1393-1414.

Cooper, W.W., Seiford, L.M., Tone, K., 2006. Introduction to Data Envelopment Analysis and its uses. Springer, United States of America.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of Decision Making Units. European Journal of Operational Research 2, 429-444.

Chraga, G. et Chemak F., 2003. Les groupements d'intérêt collectif, un outil stratégique pour une gestion participative de la ressource en eau cas des GIC de Mahdia. 20ème Europeen Conference of CIID Montpellier, France.

Daoud, A., 1995. Les périmètres publics irrigués de la région de Sidi Bouzid (hautes steppes tunisiennes) politiques de l'Etat et stratégie paysannes- In Elloumi M. (Ed), Politiques agricoles et stratégies paysannes au Maghreb et en méditerranée occidentale. 483-502.

Emrouznejad, A., Parker, B., Tavares, G., 2008. Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. Journal of Socio-Economics Planning Science 42 (3), 151-157.

Ennabli, N., 1995. L'irrigation en Tunisie. National Agriculture Institute of Tunisia.

Farrell, M.J., 1957. The measurement of technical efficiency. Journal of the Royal Statistical Society, 120, 253-281.

Färe, R., Grosskopf, S., 1992. Malmquist productivity indexes and Fisher productivity indexes. Economic Journal 102, 158-160.

Färe, R., Grosskopf, S., Lovell, C.A.K., 1994a. Production Frontiers. Cambridge University Press, Cambridge.

Färe, R., Grosskopf, S., Norris, M., Zhang, Z., 1994b. Productivity growth, technical progress and efficiency change in industrialized countries. American Economic Review, 84, 66-83.

Gorton, M., Davidova, S., 2004. Farm productivity and efficiency in the CEE applicant countries: a synthesis of results. Agricultural Economics 30, 1-16.

Hemdane, A., 2002. L'irrigation en Tunisie. Ministry of agriculture (DGGR), Tunisia.

Karagiannis, G., Tzouvelekas V., Xepapadeas, A., 2003. Measuring irrigation water efficiency with a stochastic production frontier: An application to Greek out-of-season vegetable cultivation. Environmental and Resource Economics 26, 57-72.

Lansink, A.O., Reinhard S., 2004. Investigating technical efficiency and potential technological change in Dutch pig farming. Agricultural Systems 79, 353-367.

Ministry of Agriculture, 2008a. Agricultural statistics of 2007. DGEDA's report in Arabic.

Ministry of Agriculture, 2008b. Statistics of Irrigated Pubic Areas. DGGR's report in Arabic.

Ministry of Agriculture, 2006. The reality and perspectives of the agricultural sector in governorate of Sidi Bouzid. Final report in Arabic, the National Center of Agricultural Studies, Tunisia.

Ministry of Agriculture, 1995. Etude de la gestion et de la tarification de l'eau d'irrigation au niveau des périmètres irrigués. Global report in Frensh, the National Center of Agricultural Studies of Tunisia.

Odeck J., 2009. Statistical precision of DEA and Malmquist indices: A bootstrap application to Norwegian grain producers. Omega37, 1007-1017.

Omezzine, A., Zaibet, L., 1998. Management of modern irrigation systems in Oman: Allocative vs. Irrigation efficiency. Agricultural water management 37, 99-107.

Ray, S.C., 2004. Data Envelopment Analysis: Theory and techniques for economics and operation research. Cambridge University Press, United Kingdom.

Seiford, L.M., 1996. Data Envelopment Analysis: the evolution of the state of the art (1978-1995). Journal of Productivity Analysis 7, 99-138.

Shideed, K., Oweis, T.Y., Gabr, M., Osman, M., 2005. Assessing On-Farm water-Use Efficiency: A New Approach. ICARDA (Aleppo), Syria.

Thanassoulis, E., 2001. Introduction to the theory and application of Data Envelopment Analysis: A foundation text with integrated software- Kluwer Academic Publishers, the Netherlands.

Zaibet, L., Dharmapala P.S., 1999. Efficiency of Government-supported horticulture: the case of Oman- Agricultural Systems 62, 159-168.

Wang X-y., 2010. Irrigation Water Use Efficiency of farmers and its determinants: Evidence from survey in Northwestern China. Agricultural Sciences in China 9(9), 1326-1337.

ANNEX 1

Farms	Technical efficiency		Water use efficiency		Malmquist Index Components				
	2003	**2007**	**2003**	**2007**	**MI**	**TEC**	**TC**	**SEC**	**IME**
1	1	1	1	1	0,462	1	0,77	0,51	1,177
2	0,438	0,918	0,379	0,59	1,133	2,094	0,724	0,715	1,043
3	0,256	0,491	0,177	0,364	3,068	1,912	4,986	0,797	0,403
4	0,463	0,279	0,244	0,188	0,422	0,602	0,79	1,014	0,873
5	1	0,872	1	0,606	0,715	0,872	1,05	0,452	1,723
6	0,807	1	0,538	1	2,676	1,238	9,377	1,008	0,228
7	0,422	0,282	0,135	0,123	0,51	0,668	0,628	1,003	1,21
8	1	1	1	1	1,339	1	2,402	0,502	1,109
9	0,719	0,977	0,227	0,959	1,304	1,358	1,236	0,721	1,076
10	0,319	0,356	0,23	0,241	0,783	1,114	0,716	1,046	0,937
11	0,752	1	0,507	1	1,414	1,329	1,917	0,592	0,936
12	0,306	0,367	0,16	0,134	1,044	1,198	0,849	1,041	0,985
13	0,286	1	0,098	1	3,119	3,484	0,988	0,775	1,167
14	0,266	0,883	0,237	0,836	3,066	3,312	1,293	0,819	0,872
15	0,466	0,858	0,337	0,658	1,077	1,841	1,436	0,536	0,759
16	1	0,956	1	0,883	0,963	0,956	1,053	1,016	0,941
17	0,274	1	0,127	1	5,104	3,639	1,037	1,495	0,903
18	1	1	1	1	1,352	1	1,076	1,534	0,818
19	1	1	1	1	0,767	1	0,289	1,314	2,016
20	1	1	1	1	2,614	1	1,077	2,37	1,023
21	0,319	1	0,183	1	3,781	3,132	0,761	1,973	0,803
22	0,567	0,782	0,366	0,717	1,355	1,378	1,129	0,994	0,875
23	1	1	1	1	0,499	1	0,492	1,072	0,943
24	0,179	0,417	0,106	0,248	1,762	2,326	0,762	0,96	1,034
25	0,593	1	0,395	1	1,561	1,684	0,898	0,858	1,202
26	0,66	1	0,375	1	1,523	1,513	0,883	1,079	1,055
27	0,616	1	0,503	1	2,385	1,623	2,057	0,933	0,765
28	0,678	1	0,508	1	1,338	1,473	1,122	0,992	0,815
29	1	1	1	1	1,823	1	2,125	0,951	0,9
30	1	1	1	1	0,693	1	0,626	1,045	1,058
31	1	0,833	1	0,833	0	0,833	0,524	0	nd
32	0,569	0,597	0,541	0,585	0,635	1,049	0,623	0,968	1,003
33	0,84	1	0,833	1	2,08	1,189	2,203	1,078	0,736
34	1	0,481	1	0,459	0,315	0,481	0,724	0,99	0,911
35	1	1	1	1	0,79	1	0,594	1,488	0,892
36	0,625	1	0,462	1	nd	1,6	1,102	nd	nd
37	0,277	0,333	0,215	0,333	0,797	1,202	0,819	0,587	1,377
38	1	0,93	1	0,714	1,341	0,93	1,405	1,019	1,006
39	0,706	1	0,598	1	8,465	1,415	3,112	1,104	1,739
40	0,804	1	0,127	1	2,151	1,243	6,785	1,02	0,249
41	0,351	1	0,224	1	5,024	2,848	1,829	1,069	0,902
42	0,434	1	0,248	1	2,045	2,299	0,824	0,892	1,208
43	0,605	0,885	0,479	0,881	0,88	1,462	0,601	1	1,001
44	1	1	1	1	0,443	0,999	0,223	1,671	1,184
45	0,454	0,723	0,237	0,247	0,846	1,592	0,507	1,275	0,821
46	0,282	1	0,197	1	1,091	3,54	1,277	0,294	0,818
47	0,698	1	0,679	1	1,589	1,432	0,734	0,686	2,199
48	1	0,759	1	0,667	0,6	0,759	0,646	1,176	1,038

nd: undefined