Technical change performance and water use efficiency in the irrigated areas: Data Envelopment Analysis Approach

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Abstract

In order to cope with the water scarcity, Tunisia has to manage efficiently the water 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 cropping 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 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 reveal a positive impact on the productivity change. However, in 2007, the water use efficiency was only 78%. 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

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 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 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 cropping 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 manner to implement it. Consequently, one has to consider the issues of technology innovation over time and farmer's ability to implement it efficiently.

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).

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 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: $TE_A = \frac{OB}{OA}$

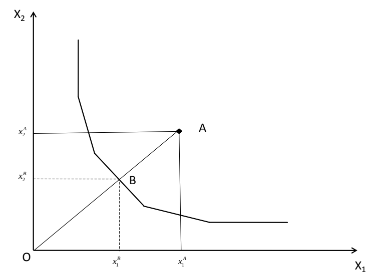

Figure 1: Technical effeciency according to the Input-Oriented Model

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 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 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:

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

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

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

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

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 approach.

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[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).

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:

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

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

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

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

$$\lambda_j \geq 0,\ j = 1,\ldots,N,\ S \geq 0\ \forall i \text{ and } r, k_0^v \text{ free}$$

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 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 implemented 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 into 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:

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

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 in a 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:

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

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

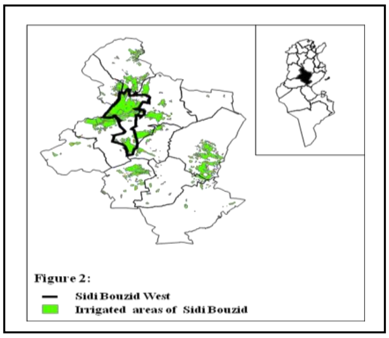
$$\sum_{j=1}^{N}\lambda_j = 1$$

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

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.



To investigate our research issues we 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 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. The main objective of developing the irrigation through the creation of these IPBAs is to mitigate drought effects 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).

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 water resources access nature, 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. Hence we have selected 18 farmers who have access to both water resources 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

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

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

whom are located around the concerned IPBAs in order to conserve the homogeneity of the sample. Hence the total number of farmers, randomly chosen, is 49.

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 cropping years 2003 and 2007. We have collected data relative to 94 plots of which 41 plots are irrigated by public water resources.

Between 2003 and 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 a 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 7.71 ha in 2003 and declined to 7.41 in 2007. Despite this reduction the irrigable area per farm has increased from 4.38 ha to 4.64 ha (Table 2). More than 80% of this area was occupied by the olive-trees which remain the major 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 cultivated cereal crops for self sufficiency in order to meet their needs as well as those of their animals. In 2007, this behaviour has changed and cereal crops area has dropped by 59% 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 remained very low since that the output price is administered by the government and has not been adjusted to take into account the high increase in energy prices during the same period. The cultivated areas of horticultural crops did not change because of their high profitableness.

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 method. This caused a high level of water wasting reaching up to 60%. In 2007, only 9 farmers have introduced a water saving system such as sprinklers and drip irrigation to irrigate 10 plots of which 3 belong 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 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). However, both cropping years (2003 and 2007) revealed water cost share average reaching 40% of the total cost per hectare.

Regarding the production, important increase of the average production value per hectare has been achieved (from 849 TND[4] in 2003 to 1344 TND in 2007 (Table4)). The share of the olive production increased from 47% in 2003 to 61% in 2007. The total charges average per hectare increased from 479TND in 2003 to 753TND in 2007. Irrigation cost share remains the main component of farmer’s expenditures with about 40% of the total charges. Furthermore, the cost structure didn’t change over time but the mean value of the irrigation charges shifted from 180TND per ha to 319TND per ha. This is due mainly to the substantial increase of fuel prices. In addition, irrigation, mechanization and fertilization account for two third of total cost in 2003 as well as in 2007.

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

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:

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

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	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 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 the inputs inefficiently (Table 6). Indeed, the average of the technical efficiency is estimated at 0.67 in 2003 and 0.84 in 2007. Therefore, farmers can reach the same production level while reducing their inputs use by 33% in 2003 and 16% in 2007. This inefficiency lies in important water over consumption since that water use efficiency was only 0.56 in 2003 and reached 0.78 in 2007. Hence, farmers should improve their practices and adjust adequately their demand to save more water. However, this period revealed technical efficiency improvement by 17% that could be the result of a positive productivity dynamic. The distribution of the technical efficiency measurements (Table 7) shows that this improvement is well expressed. Indeed, in 2003 only 17 farms (35%) were perfectly efficient while 25 farms (51%) were perfectly efficient in 2007. In addition, farms using water efficiently were 17 (35%) in 2003 while they reached 27 (55%) in 2007. Despite this improvement, 17 (35%) farms revealed low water use efficiency that falls under 0.75 in 2007. These farms involve 7 belonging to the IPRAs and 7 having access to both resources of irrigation water. This result states that farmers supplied by water from surface wells, over consume the resource more than those using public water. Hence, water authorities have to give more attention to this category of farmers when implementing the policy of water demand management.

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	0.67	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 a better water demand management?

The analysis of Malmquist index and its components give some insights to this important issue (Annex 1). Our results show that the Malmquist index reaches an average of 1.60. This implies that farms productivity 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 is likely to be the result of an improvement of farmer's management capability which contributes up to 49% of the productivity dynamic of the irrigated activity. The average of the technical change reached 1.41 and suggests a positive shift in the production technology. This technology change contributes by 41% to the productivity improvement. Finally, regarding the scale change factor, results show that it contributes also by 11% to the productivity change.

4. Concluding remarks

Water demand management is increasingly a 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 of Sidi Bouzid region experienced this situation and have improved 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%. The Malmquist index showed that this improvement has occurred thanks to the upgrading of farmer's management capability (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 a better water demand management. 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 adjust their technologies. The extension services should work closely with farmers to cope with the water scarcity by achieving the optimal water use efficiency.

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.

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. $20^{ème}$ 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.

Grifell-Tatje, E., Lovell C.A.K., 1995. A note of the Malmquist productivity index. Economics Letters, 47, 169-175.

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

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.

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

Ray, S.C., Desli, E., 1997. Productivity growth, technical progress and efficiency change in industrialized countries: Comment. American Economic Review, 87:5, 1033-1039.

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

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

ANNEX 1

	Technical efficiency		Water Use Effeciency		Malmquist Productivity Index			
Farms	**2003**	**2007**	**2003**	**2007**	**MI**	**TEC**	**TC**	**SCF**
1	1	1	1	1	0.462	1	0.77	0.6
2	0.438	0.918	0.3795	0.59	1.133	2.09	0.724	0.746
3	0.256	0.491	0.177	0.364	3.068	1.912	4.986	0.321
4	0.463	0.279	0.244	0.188	0.422	0.602	0.79	0.886
5	1	0.872	1	0.606	0.715	0.872	1.05	0.78
6	1	0.418	1	0.161	0.265	0.418	0.095	6.612
7	0.807	1	0.538	1	2.676	1.238	9.377	0.23
8	0.422	0.282	0.135	0.123	0.51	0.668	0.628	1.214
9	1	1	1	1	1.339	1	2.402	0.557
10	0.719	0.977	0.227	0.959	1.304	1.358	1.236	0.776
11	0.319	0.356	0.23	0.241	0.783	1.114	0.716	0.981
12	0.752	1	0.507	1	1.414	1.329	1.917	0.554
13	0.306	0.367	0.16	0.134	1.044	1.198	0.849	1.026
14	0.286	1	0.098	1	3.119	3.484	0.988	0.9057
15	0.266	0.883	0.237	0.836	3.066	3.312	1.293	0.715
16	0.463	0.858	0.337	0.658	1.083	1.851	1.433	0.408
17	1	0.956	1	0.883	0.963	0.956	1.053	0.957
18	0.274	1	0.127	1	5.103	3.639	1.0371	1.352
19	1	1	1	1	1.352	1	1.076	1.256
20	1	1	1	1	0.767	1	0.289	2.65
21	1	1	1	1	2.6143	1	1.077	2.4253
22	0.319	1	0.183	1	3.781	3.132	0.761	1.584
23	0.567	0.782	0.366	0.717	1.355	1.378	1.129	0.87
24	1	1	1	1	0.499	1	0.492	1.012
25	0.179	0.417	0.106	0.248	1.762	2.326	0.762	0.993
26	0.593	1	0.395	1	1.561	1.684	0.898	1.032
27	0.66	1	0.375	1	1.5233	1.513	0.883	1.139
28	0.616	1	0.503	1	2.385	1.623	2.057	0.714
29	0.678	0.999	0.508	1	1.337	1.473	1.122	0.809
30	1	1	1	1	1.822	1	2.125	0.857
31	1	1	1	1	0.693	1	0.626	1.106
32	1	0.833	1	0.833	0	0.833	0.524	0
33	0.569	0.597	0.541	0.585	0.635	1.049	0.623	0.971
34	0.84	1	0.833	1	2.08	1.189	2.203	0.793
35	1	0.481	1	0.459	0.315	0.481	0.724	0.902
36	1	1	1	1	0.79	1	0.594	1.328
37	0.625	1	0.462	1	nd	1.6	1.102	nd
38	0.277	0.333	0.215	0.333	0.31	1.202	0.819	0.315
39	1	0.93	1	0.713	2.114	0.93	1.405	1.616
40	0.706	1	0.598	1	6	1.415	3.112	1.361
41	0.804	1	0.127	1	4.348	1.243	6.785	0.515
42	0.351	1	0.224	1	3.627	2.848	1.829	0.696
43	0.434	1	0.248	1	1.624	2.299	0.824	0.856
44	0.605	0.885	0.479	0.88	0.68	1.462	0.601	0.773
45	1	0.999	1	1	0.659	0.999	0.223	2.944
46	0.454	0.723	0.237	0.247	1.073	1.592	0.507	1.329
47	0.282	1	0.197	1	0.695	3.54	1.277	0.153
48	0.698	1	0.679	1	1.429	1.432	0.734	1.359
49	1	0.759	1	0.667	0.667	0.759	0.646	1.358
Mean	**0.674**	**0.845**	**0.565**	**0.784**	**1.603**	**1.491**	**1.412**	**1.111**

nd: undefined