PERFORMANCES AND EFFICIENCIES OF THE IRRIGATION WATER USERS' ASSOCIATIONS IN TUNISIA

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Abstract

This article analyzes the efficiency of Water Users Associations (WUA) in the Cap Bon region (Tunisia) and studies its main determinants. The analysis is performed in two stages. First, the efficiency is measured via the nonparametric "Data Envelopment Analysis" (DEA) technique. The DEA models are constructed not only to assess the overall WUA efficiency but also to evaluate the management and engineering sub-vectors efficiencies separately through a mathematical modification in the initial DEA model. In a second stage critical determinants of efficiency are determined using a Tobit model. In this analysis the focus is on technical (characteristics of the irrigation area and network), organizational and administrative variables. Results show that on average 18.7% of the used inputs could be saved if the WUA would operate on the frontier. The average scale efficiency, which can be calculated as the ratio between Constant and Variable Returns to Scale efficiency measures was around 71%, indicating that many WUAs are not operating at an efficient scale. Sub-vectors efficiencies show that WUAs present better performances in maintenance activities than in management. The inefficiency found can furthermore be mainly attributed to the number of years of experience in operating a WUA in addition to the number of water pumping stations managed and the rate of the exploited area. The scale inefficiencies are mainly due to administrative and organizational variables.

Key words: WUA, irrigation, efficiency, DEA method.

1. Introduction

Decentralization processes in irrigation water management need some judicial, institutional and administrative reforms aiming to frame the organization of formal user groups known as water users associations (WUAs). Knox and Meinzen-Dick (2001) emphasize the need for formal rules and procedures when it comes to allocations and pricing schemes of resources. Those rules and procedures constitute the heart of the devolution programs, where rights and responsibilities are transferred to a common local level, supervised and managed by WUAs. The actual outcomes of irrigation water management devolution programs in various countries have however been mixed. The objectives of achieving a positive impact on resource productivity, equity, full cost recovery and environmental sustainability are not always met. In fact, WUAs disappear in many cases after the end of donor's financing programs (Vermillion, 1997). In other cases, they are not able to achieve full cost recovery of irrigation water delivery nor to cover their operational costs. This can be caused by many factors such as the bundle of transferred property right[1] system and the internal organisation of the associations. These factors are incentives for farmer's participation and determine the long term sustainability.

For the example of Tunisia, in 2003, only 27% of WUAs[2] succeeded to cover their entire operation and maintenance costs while 28% of them covered even less than 50% of those costs and were still

[1] In some cases, only the responsibility of irrigation water management is transferred. However, a bundle of property rights should be also transferred to WUAs to succeed the decentralization process.
[2] Total WUAs number in Tunisia is currently around 1150.

subsidized by the government (Al Atiri, 2003). It is also clear that WUAs in Tunisia still face a lot of challenges related to technical, financial and social aspects. Problems are however different from one WUA to another, with only some associations that can be considered efficient. In response to this observation, and taking into account that the initial judicial and administrative basis of all WUAs is the same, this study aims to undertake a comparison between WUAs performances. Many methodologies can be used for this purpose, ranging from a simple visual comparison of performance figures to relatively sophisticate mathematical methods (Malano et al., 2004). In our case, the relative efficiency for a sample of Tunisian WUAs is analyzed using Data Envelopment Analysis (DEA). In fact, many studies have used DEA methodology to analyze organization's efficiency. The applications range from banks, health and educational institutions and forest organizations to airlines and railway companies (Luo, 2001; Kirigia et al, 2004; Siddharthan et al, 1999; Kao et al, 1993; Viitala, 1998; Joro and Viitala, 1999; Balaguer-Coll et al, 2007). To our knowledge though, the application undertaken in this paper to assess the efficiency of organizations specialized in water management is quite unique. Only Umetsu et al (2005) have applied a similar DEA analysis of Turkish WUAs. One of the shortcomings in their paper was however, that notwithstanding the fact that they encountered significant effects of the WUAs size on the efficiency score, they did not consider a variable returns to scale specification. In irrigation and drainage sectors, DEA was furthermore often applied for estimating production efficiency of large irrigated systems and districts at regional level (Malana and Malano, 2006; Diaz Rodriguez et al., 2005; Malano et al., 2004; Diaz Rodriguez et al., 2004). In our study, we estimate that DEA is also suitable to apply in the case of water management associations. Moreover, the methodology used, allows calculating not only overall, but also sub-vectors efficiencies. Management and engineering efficiencies were assessed in order to appreciate their relative effect on the overall WUAs efficiency. In a second step, a *tobit* model was estimated to provide ideas about local inefficiencies and thus determining potential factors affecting the functioning of WUAs.

The paper is divided into six separate sections. After the introduction, the second section presents an institutional and organizational overview regarding Tunisian WUAs. The third section describes the DEA technique as well as the Tobit model used in this study and the fourth section describes the empirical application. Results and discussions are presented in the two last sections after which the most important conclusions are bundled.

2. Water user associations in Tunisia

In Tunisia, nearly 385,000 ha (7% of the arable lands) are presently irrigated (Ministère de l'Agriculture et des Ressources Hydrauliques: MARH, 2004). The irrigation sector consumes about 80% of available water resources, provides 35% of the value of agricultural production, and 26% of labor recruitment in agriculture. Moreover it produces 95% of horticulture crops, 30% of dairy production, and around 22% of agricultural sector exports (MARH, 2004).

WUAs have been created by government financing but they are responsible to ensure the collection of the water fees as well as service related fees (infrastructure maintenance, etc.). The number of WUAs has risen strongly from about 100 in 1987 to 1050 in 2003 (MARH, 2004) managing around 150 000 hectares of irrigated lands. In 2004, they were responsible for the management of 20% of the irrigated land in Tunisia. On the other hand, 48% of irrigated land was managed by private farmers, who mainly use private wells, and the rest (32%) is publicly managed by Regional Agricultural Development Commissions (Commisariat Régional de Développement Agricole: CRDA), which are regional public administrations with financial independency.

Each year, each WUA is responsible for the elaboration of its own budget. The WUAs also have the right to determine the water price and to decide whether the payment is on the basis of water volumes to produce or to distribute. Furthermore, they establish the amount of projected investments, and the operation and maintenance charges. Financially, the WUAs perform following tasks: operation and maintenance of canals, repairing of various infrastructures, functioning of the association and investments (Table1). The water charge established by the WUAs comprises water buying charges, energy fees, labor force charges and maintenance and management fees.

WUAs are managed by an administrative council composed of 3 to 9 members belonging to the adherents and elected by the general assembly for a total period of three years. The president of this administrative council is chosen among these elected members. His main mission is to represent the interests of the WUA in its relationships with the public administration and with other tiers. He can also choose a technical director (according to the needs and the financial situation of the WUA) to ensure a closer follow-up of various exploitation and maintenance tasks. Financial aspects of the WUAs are arranged by a treasurer, appointed on the recommendation of the administrative council and approved by the governor. The accounts of the WUAs are generally controlled by a regional financial agent belonging to the Ministry of Finance.

Table1. Principal financial revenues and expenditures of the WUAs

Financial Revenues	Financial expenditures
1- Contribution of users for adherence to the association; 2- Water selling; 3- Revenues from other activities that the WUA are allowed to undertake; 4- Conceivable subventions; 5- Various incomes.	1- Maintenance, reparations and functioning expenditures; 2- WUA management expenditures; 3-Refunding of loans; 4- Eventual investments; 5- Unexpected expenditures.

Source: MARH, 2004

3. Methodology of the study: Efficiency assessment by DEA technique

3.1. DEA models

The DEA method which is used in this study, defines efficiency as the ratio of weighted sum of outputs for a given Decision Making Unit (DMU), to its weighted sum of inputs. For each DMU_k, a nonnegative input vector $x^k = (x_{k1},...,x_{kN}) \in R_+^N$ is transformed to a nonnegative output vector $y^k = (y_{k1},..., y_{kM}) \in R_+^M$. In an input-oriented model of technical efficiency, the production possibility set (P), which describe also the technology, represent the set of all feasible input-output vectors: $P = \{(x, y) / x \ can \ produce \ y\}$

The measures of technical efficiencies by DEA techniques are relative. The bests performing DMUs have a score of 100%, and the inefficiencies of other DMUs will be measured relatively to a group's observed best practices. DEA technique does not require the development of standards against which efficiency is measured. Derived ratings are estimated within a set of analyzed units. DEA has also the ability to analyze several inputs and outputs simultaneously and in addition.

One of the analysis options in DEA is a choice between Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). CRS assumes that there is no significant relationship between the efficiency and the scale of operation. Thus assuming that large WUAs are just as efficient as small ones in converting inputs to outputs. However, we expect that the scale of activity (size of the organization) of the WUAs has an important effect on its efficiency (Umetsu et al, 2005). Furthermore we assume that changes in the organization's inputs can lead to disproportionate changes in its outputs. Therefore the option of VRS will be chosen in this study. A second option is the choice between input-oriented and output-oriented DEA models. If the focus is to use different resources more efficiently (instead of increasing production), then the suitable model to use is an input-oriented one (Rodríguez Diaz et al., 2004). In our case, it is necessary, as a national objective of the decentralization process, that WUA reach a cover rate of their expenditures ensuring their sustainability. In addition, the volume of water that a given WUA purchases from the regional water management administration is planned and fixed at the beginning of the year. This fixation is necessary for the determination of water rates in the WUA. Therefore, during the agricultural year, the WUA will focus mainly on the minimization of their expenditure. For those reasons, it is estimated that an input-oriented model will be more suitable for our problem. Recapulating, we chose to estimate Variable Return to Scale (VRS) efficiencies through BCC a (Banker, Charnes and Cooper, 1984) input-oriented model[3].

Following the BCC model, if we consider *K* DMU (*k=1,…,K*), each of them uses *N* inputs variables x_{nk} (*n=1,…,N*), for producing M outputs y_{mk} (*m=1,…,M*). Each DMU_0 becomes the reference unit and then we have to resolve the following linear program *k* times (one time for each DMU):

$$Min_{\theta,\lambda}\theta \qquad (1.1)$$

$$\text{s.t.} \quad \sum_{k=1}^{K}\lambda_k y_{m,k} \geq y_{m,o} \qquad (1.2)$$

$$\sum_{k=1}^{K}\lambda_k x_{n,k} \leq \theta.x_{n,o} \qquad (1.3)$$

$$\sum_{k=1}^{K}\lambda_k = 1 \qquad (1.4)$$

$$\lambda_k \geq 0 \qquad (1.5)$$

Where θ is a variable representing the efficiency of the reference DMU_0, and hence the percentage of reduction that each input must be subjected to reach the production frontier. λ_k is a vector of k

[3] Banker, Charnes and Cooper (1984) suggested an extension of the CRS DEA model to account for variable returns to scale (VRS) situations. The use of the CRS specification when not all DMU's are operating at the optimal scale will result in measures of TE which are confounded by scale efficiencies (SE). The use of the VRS specification will permit the calculation of TE devoid of these SE effects (in Coelli. Tim., 1996).

elements representing the influence of each DMU in determining the efficiency of the DMU_0. The term $\sum_{k=1}^{K} \lambda_k y_{m,k}$ indicates the weighted sum of outputs of all DMU which must be superior or equal to the output of DMU_0 (constraint 2). In constraint 3, θ is the measure of technical efficiency and represents, at the same time, the minimized objective. Thus, constraint 3 indicates that the value of θ to be assessed must shifts the production factors on (toward) the production frontier (for a given output level). Equation 4 consists of the convexity constraint which specifies a variable returns to scale option. The DMUs whose λ values are positive will be the reference set for DMU_0 under study. In fact, it is the linear combination of those units which will formulate the situation objective needed to become efficient.

To calculate the efficiency of use of an individual input or subset of inputs, the "sub-vector efficiency" concept can be introduced. This measure generates a technical efficiency for a subset of inputs while remaining inputs are held constant (Speelman et al., 2007). The sub-vector efficiency measure looks at the possible reduction in the selected subset of inputs holding all other inputs and outputs constant (Oude Lansink and Silva, 2004; Oude Lansink and Silva, 2003; Oude Lansink et al., 2002; Färe et al., 1994). Following Färe et al. (1994) technical sub-vector efficiency for the variable input (*t*) can be determined for each farm i by solving the following transformed model (2):

$$Min_{\theta^t,\lambda} \theta^t \qquad (2.1)$$

$$\text{s.t.} \sum_{k=1}^{K} \lambda_k y_{m,k} \geq y_{m,o} \qquad (2.2)$$

$$\sum_{k=1}^{K} \lambda_k x_{n-t,k} \leq x_{n,o} \qquad (2.3)$$

$$\sum_{k=1}^{K} \lambda_k x_{t,k} \leq \theta^t . x_{t,o} \qquad (2.4)$$

$$\sum_{k=1}^{K} \lambda_k = 1 \qquad (2.5)$$

$$\lambda_k \geq 0 \qquad (2.6)$$

Where θ^t is the input *t* sub-vector technical efficiency score for the DMU_0 under study. The measure θ^t represents the maximum reduction of variable input *t* holding outputs and all remaining inputs (*n-t*) constant. All other variables are defined as in program (1). Therefore, the input *t* sub-vector technical efficiency model involves finding a frontier that minimises the quantity of input *t* (Oude Lansink et al., 2002).

3.2. Tobit model

The technical structure in addition to the administrative and organizational characteristics of WUAs can be potential sources of their inefficiency. Several variables are selected as potential determinants of the calculated technical efficiency. The efficiency scores obtained in the first stage of the work are regressed on these WUAs attributes.

In this second stage, ordinary least squares estimations are inconsistent as the values of the dependent variable (efficiency scores) lie in the interval [0, 1]. A censored regression or tobit model can be used to get a consistent estimation. The model is defined in terms of an index function:

$$\theta^{t*} = \sum_{r=1}^{R} \beta_r z_r + u_r$$

$$\theta^{t} = \begin{cases} \theta^{t*} if \ 0 \ \pi \ \theta^{t*} \ \pi \ 1; \\ 0 \ \ if \ \theta^{t*} \ \pi \ 0; \\ 1 \ \ if \ \theta^{t*} \ \phi \ 1 \end{cases}$$

Where θ^t are the DEA overall, scale, management, and engineering efficiencies used as a dependent variables and Z is a (*R*1*) vector of independent variables related to attributes and characteristics of WUAs in the sample. For *Tobit* estimates to be consistent it is necessary that residuals (u_r) are normal distributed (Holden, 2004). The estimation is carried out by minimising a log likelihood function with a part corresponding to not censored observations and other for the values equal to one.

4. Empirical application

4.1. Case study and data sample characteristics

The database used for this analysis was collected by the Agricultural and Hydraulic Resources Ministry of Tunisia. This central data concerns 45 WUAs which represents all the WUAs operating in the Cap Bon region (governorate of Nabeul). The Cap Bon is located in northern Tunisia and is bounded in the East by the Mediterranean Sea. In 2004 around 22% of total population in the Cap Bon region are employed in the agricultural sector. According to the CRDA Nabeul (2006), main crops produced in the region are fruits (60,500 ha), cereals (53,000 ha), and vegetables (35,000 ha). Total agricultural production of Cap Bon contributes with nearly 15% to the total national agricultural production. The number of farms in the region is about of 32,000 (6.6% of total Tunisian farms). Total agricultural area of the region is 256,500 ha, of which 183,000 ha are arable land and 41,000 ha are irrigable lands. Only 25,500 ha (92% of total irrigated area) are equipped by a public irrigation network and the remaining area is irrigated from dams and other private sources. Currently, irrigated areas in Cap Bon are about 13.3% of the total Tunisian irrigated lands. 71% of the irrigated areas are belonging to small and average-sized farms.

4.2. Overall, management, and engineering efficiencies

Concerning the selection of outputs and inputs, as a general rule of thumb there should be at least three DMUs for each input and output variable used in the model since with less than three DMUs per input and output too many DMUs will turn out to be efficient (Alfonso and Santos, 2005). According to the database, the WUA' expenditures can mainly be divided into management expenditures, maintenance costs, water purchasing costs, labor costs, investments, reimbursements of debts and other expenditures. Given that in our empirical application, we try to focus on the relationship between inputs-outputs of the WUAs within a general framework of minimization of irrigation water prices, we choose to aggregate main financial inputs of the water users associations into management expenditure, maintenance expenditure, and purchasing water expenditure. The maintenance expenditure vector integrates the labor and energy fees in addition to the classic maintenance costs. In fact, expenditure vectors were always used as inputs for DEA models to analyze the efficiency of organizations (Kirigia et al, 2004; Alfonso and Santos, 2005; Luo, 2003). However, given multiple objectives of WUAs (renewing equipment, price minimization for socioeconomic considerations, good maintenance and operation cover rates etc.), some expenditures, like investments would in the short run have negative effects on the results of the WUAs. In the long run, this input can have an inverse positive effect by decreasing the amount of annual maintenance cost and increasing the total amount of the WUAs return. To be able to consider the investment vector as an input, more detailed panel data would be needed. Therefore, in this study, the choice is made to calculate the efficiency scores in a static framework and thus the investment variable is not considered.

The chosen outputs considered are the annual irrigated area (ha), and the total annual irrigation water delivery per unit irrigated area (m^3 $ha^{-1}yr^{-1}$).The annual irrigated area is considered as key descriptor for irrigation and drainage scheme performance in the literature (Malano et al, 2004) and the total annual irrigation water delivery per unit irrigated area is also one of the most relevant service delivery performance indicators (Malano et al, 2004). It is used as benchmarking indicator in many International Water Management Institute (IWMI) studies. These two outputs are the only constant and stable WUA outputs in the short run. The financial revenue of the WUA, which could be a relevant output to consider, can always change from a year to another according to the objective of the association. For example, in some cases of high investments in modernization, the revenue will be quickly fall down during the studied year and can not be consequently taken as an efficient parameter to integrate it in such DEA models. Other data related to some productive performance indicators (total gross annual agricultural production in the area managed by the WUA; total annual value of agricultural production; output per unit service area, etc.) was not available. According to this input-output choice, an efficient WUA will be the one that had a lower Input/Output ratio (Expenditures/M3 and Expenditure/ha) and consequently which reflects more performance in minimizing water rates for farmers.

In the management sub-vector efficiency only the efficiency of the individual management expenditure input is considered, while holding the rest of inputs and outputs constant. Generally, the management expenditures are stable over the time (Terraux, 2002). The engineering sub-vector efficiency considers the inputs related to the total expenditure in maintenance (labor, energy and other maintenance expenditures). In the short term, this input gives an idea on the efficiency of the maintenance tasks and on the technical network situation of the WUA. Only the efficiency of this latter individual input will be considered in the calculation of the engineering sub-vector, while holding the rest of input vectors constant.

The 45 WUAs in Cap Bon are managing around 16,000 ha of lands (9% of total arable land in the governorate) owned by 8206 adherent farmers. The total volume of water distributed by those associations is around 87.5 Million cubic meters and the average irrigated surface per WUA is nearly 3090 ha. Basic statistics regarding the selected WUAs are shown in Table 2.

Table2. Basic statistics for the data used in the DEA Model

	Outputs		Inputs		
	Nbr of irrigated ha/year	Vol of water Distributed/ha (m3)	Management expenditure (TDN)	Maintenance expenditure (TDN)	Purchasing water cost (TDN)
Average	3090.7	346.9	3940.2	35214.5	49302
Standard Deviation	1595.9	286.2	3363.7	24416.3	56618.8
Minimum	491	15	103	2873	0*
Maximum	9427.1	1342	13539	106185	228252

** Water from drillings*

Several variables are hypothesized to affect the efficiency scores. Technical, administrative, and organizational characteristics of WUAs used in the Tobit Analysis came from the national survey of the structure and functioning of the WUAs made by the Tunisian Ministry of Agriculture and Hydraulic Resources.

Technical characteristics include the number of years of experience operating a WUA (age of the association), the number of pumping stations managed by the WUA, the irrigated area under control of WUA and that equipped with water saving technologies, the ratio of exploited area, and the ratio of water losses in water distribution operation. Organizational and administrative characteristics are also hypothesized to have an important effect on resources management inside a given WUA. In fact, the most organized WUAs are expected to be more efficient. Used variables are: ratio of adherent farmers to the WUA, number of technical salaried staff, number of members in the administrative council, and the existence (or not) of a technical director for the WUA.

5. Results

5.1. Efficiencies analysis

Using the General Algebraic Modelling System (GAMS) to solve the linear programming problems outlined above, the efficiency measures of the WUAs were estimated. Model (1) was solved 45 times to provide efficiencies for each farm under VRS specification. Management and engineering sub-vectors efficiencies were also calculated for each farm solving the second model (2). Table 3 gives the frequency distribution of the overall efficiency estimates obtained for the WUAs under study.

Table3. Frequency distribution of overall technical efficiency for the studied sample.

	Overall VRS Efficiency	
Technical Efficiency level (%)	N° of WUAs	%
0<Eff<=25	0	0
25<Eff<=50	4	8.89
50<Eff<=75	12	26.67
75<Eff<=100	29	64.44
Average Eff	81.34	
Scale Efficiency	0.7166	

The average efficiency provides information about the potential resource saving that could be achieved while maintaining the same output level. In our case, results show that overall efficiency of the WUAs in the Cap Bon region is around 81.3%. This implies that the same level of output can be reached by only using 81.3% of the used inputs. Average scale efficiency, which can be calculated as the ratio between CRS and VRS efficiencies, is around 71%. This measure indicates that many WUAs are not operating at an efficient scale.

Results show also that inefficiencies of the management and maintenance are larger than the overall inefficiency. The average management efficiency is around 65.7% while average engineering efficiency is 74.5%. Scale efficiencies of both sub-vectors are very low indicating that near 40% of management and of maintenance expenditures can be saved if WUAs would operate at an efficient scale. The frequency distribution of the two efficiencies is reported in Figure 1.

Figure 1 shows that nearly 6.7% of WUAs belong to the group of weak management efficiency (between [0; 25%]) while 33.3% of them belong to the second group (between [25%; 50%]) regarding the same criterion. In both groups we remark that WUAs inefficient in management are more frequent than WUAs inefficient regarding maintenance tasks. In fact, 40% of WUAs are inefficient (between [0; 50%]) in management while only 22% of them are inefficient (between [0; 50%]) in maintenance. In the same perspective, 77.7% of WUAs belong to the groups of good efficiency [50%; 100%] regarding the maintenance efficiency criterion while only 60% of them belong to the same group if we consider management efficiency. It is then clear that WUAs perform better in maintenance activities than management.

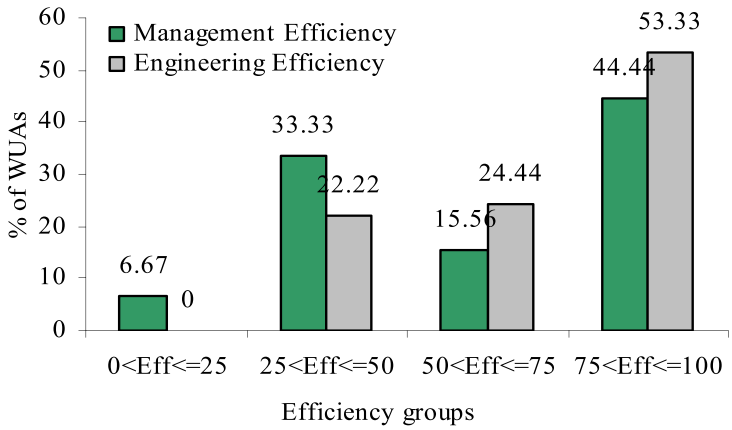

Figure1. Frequency distribution of the Management and Engineering efficiencies

5.3. Factors affecting efficiency of WUAs: follow-up Tobit analysis

Regressions in Table 4 present the estimation results of factors affecting scale and overall WUAs efficiencies scores respectively.

Table4. Factors associated with total and scale efficiencies: results of Tobit models.

Explanatory variable	Explained variable			
	Scale Efficiency		**Overall WUAs efficiency**	
	Estimate	*P*-Value	Estimate	*P*-Value
Technical characteristics of the irrigated district				
- N of years in function	0.011	0.627	-0.125***	0.005
- N of water pumping stations	0.0003	0.303	-0.0006**	0.076
- Areas equipped by water saving technologies	-0.0002	0.461	-0.0003	0.323
- Ratio of the exploited area	0.001	0.964	-0.008***	0.02
- Ratio of water losses	0.75	0.189	0.504	0.44
Administrative and organizational characteristics of the WUA				
- Ratio of adherents farmers to the WUA	0.004*	0.116	0.002	0.498
- N of technical salaried staff	-0.026	0.367	0.054*	0.108
- N of members in the administration council	-0.11***	0.010	-0.048	0.313
- Existence of a technical director	-0.146	0.242	-0.101	0.52
- Constant	0.955	0.014	2.695	0
σ	0.261	0.035[a]	0.258	0.046
Pseudo R2	0.501		0.396	
Log-Likelihood	-13.077		-14.906	
Number of observations	44		44	

*, **, *** = significant at 10%, 5%, and 1% level respectively.

[a] For σ the standard error is reported instead of the *P*-value.

As shown in Table 4, the regressions explain little of the variations in the calculated efficiency scores with the pseudo R-square value ranging from 0.39 to 0.5. Most of the independent variables have no significant effect on efficiencies. Of the five "technical" characteristics used in this study, none has a significant effect on the scale efficiency. However, two organizational and administrative characteristics can be of interest for explaining it. In fact, the WUAs scale efficiency is positively affected by the ratio of adherent farmers, suggesting that higher ratios result in higher scale efficiencies. In addition, the number of members in the administration council has a statistically significant negative impact on the scale efficiency (1% level). The other administrative characteristics (existence of technical director and number of technical salaried staff) have a negative but non-significant effect on the scale efficiencies.

For the overall WUAs efficiency scores, mainly technical variables are statistically significant. In fact, we found that the number of years in function, the number of the managed pumping stations as well as the ratio of exploited area have a significant negative effect on the efficiency of the Cap Bon WAUs. Only the number of technical salaried staff has a positive effect (10% level) on this efficiency.

Table 5 presents the results for the two Tobit estimates when the dependent variables are management and engineering efficiency scores respectively. For both regressions, the age of the WUAs has a negative and statistically significant (1% level) effect on the regressed scores. In addition, management efficiency was found to be also negatively affected by the number of members in the administrative council. Remaining independent variables had no significant effect on both dependent vectors.

Table5. Factors affecting the management and engineering efficiencies of the Tunisian WUAs: Tobit model results

Explanatory variable	Explained variable			
	Management Efficiency		**Engineering efficiency**	
	Estimate	*P*-Value	Estimate	*P*-Value
Technical characteristics of the irrigated district				
- N of years in function	-0.102***	0.024	-0.113***	0.003
- N of water pumping stations	-0.0002	0.620	-0.0003	0.304
- Areas equipped by water saving technologies	0.0004	0.354	0.0002	0.555
- Ratio of the exploited area	0.0004	0.912	-0.003	0.257
- Ratio of water losses	0.454	0.607	0.338	0.608
Administrative and organizational characteristics of the WUA				
- Ratio of adherents farmers to the WUA	0.001	0.817	0.002	0.534
- N of technical salaried staff	0.002	0.952	0.007	0.813
- N of members in the administration council	-0.1*	0.100	-0.063	0.172
- Existence of a technical director	-0.162	0.409	-0.040	0.785
- Constant	2.072	0.002	2.176	0
σ	0.385	0.057 [a]	0.289	0.042
Pseudo R2	0.202		0.343	
Log-Likelihood	-26.065		-17.329	
Number of observations	44		44	

*, **, *** = significant at 10%, 5%, and 1% level respectively.
[a] For σ the standard error is reported instead of the *P*-value.

6. Discussion

Results of DEA analysis show that the overall efficiencies among water users associations of the Cap Bon region (Tunisia) are relatively high and acceptable. However, efficiencies could reach a minimum of 45% for some WUAs indicating that nearly 60% of financial inputs of the association could be saved maintaining the output level. About 9% of the studied WUAs have an efficiency level under 50%. Additional resources allocated from the government to support those less efficient WUAs can then be saved or reallocated for other more productive activities in the irrigated districts.

The average scale efficiency obtained shows that WUAs are not operating at an optimal scale. This finding confirms inefficiencies due to the WUAs size reported by Umetsu et al. (2005). The latter authors have grouped 18 WUA into 6 artificially created WUA to see the effect of merger. Their results show that the average efficiency score improved slightly. In our case, we can just conclude that an adjustment of the scale could improve the global efficiency and the financial resources use into Tunisian WUAs.

Thirdly, the results regarding some specific tasks inside WUA indicate that the studied sample of Cap Bon' WUAs have a poor performance in term of management and maintenance efficiencies. In fact, management and maintenance are among main WUAs expenditures. However, despite the objective fixed by the government of fully covering rates of maintenance and operation costs, important losses in those financial tasks were assessed. A better accountability, in addition to an improvement of the maintenance market (by encouraging a private maintenance firms sector which is currently in its first development) could be among solutions leading to better performances regarding those two important tasks. A definition of optimal scale efficiency for the WUAs could be also an important source of maintenance and management resources savings.

The Tobit regression analyses result in some interesting findings. In fact, from the factors included in the scale efficiency regression that are significant, only the ratio of adherent' farmers in a given WUA has a positive impact. This suggests that an improvement of this rate could lead to a more efficient scale of operation. However, farmer's decision about their membership in a given WUA depends on many social and economic factors. Conflicts within the association are among the negative social factors affecting this decision. In addition, the studied region contains some superficial aquifers exploited by a major part of farmers, using wells for irrigation. Most of the time, those latter have no additional incentive to become members of a WUA. However, only if water rates in addition to transaction costs of purchasing water from the association are less than the costs of extracting water from their own wells, the farmer will takes decision to become a member of the association. Those considerations should be taken into account if we like to improve the ratio of adherent farmers and then improving the efficiency of WUAs. On the other hand, the number of members in the administrative council of the WUAs had a negative and statistically significant impact on the scale efficiency. This suggests that a reduction of this number would to improve the scale efficiency. This is opposite to the logical expectation that a higher number of administrative staff could improve the accountability and the governance of the WUA. We remark also that this variable has a negative impact even on the global, management, and maintenance efficiencies. Although only it effect on management efficiency was statistically significant. A positive factor on WUAs overall efficiency is the number of technical staff employed. This may indicate that WUAs who have invested in technical staff do benefit form this expertise.

The number of year in function for a given WUA also has a negative and highly significant effect on overall and sub-vector efficiencies. In fact, this can be interpreted in two ways. With time, the irrigation networks managed by the association will be older and then needs more expenses for their maintenance or renewing. For this reason older WUAs spend more money especially on maintenance and management tasks. This can influence their global efficiency and leads to resource losses. Good network management and renewing strategies could be a solution for this kind of problems. However, in most cases the WUAs administration members or even the technical director aren't well instructed persons. For them, elaborating a global optimal management plan is a difficult task. The help and guidance of the government will be needed in such cases. The second explication of the negative impact of WUAs' "age" can be reported to a non social sustainability between the members of the association. In fact, some specific studies (Makkaoui, 2006; Ben Salem et al, 2005; Chraga *et* Chemakh, 2003) report that social conflicts affect the individual perception and then participation in WUAs. If social conflict grows in time into a given WUA, it will be clear that its functioning and then its efficiency will be effected.

Another important factor which has a negative impact, but only significant on overall WUAs efficiency, is the number of pumping stations managed. In fact, each pump is used by a group of farmers. According to our first field inspections, the timing of the pump use is always source of conflict between farmers which likes to irrigate at the same time. An increase in the pumps' number and the creation of sub-councils from farmers which are managing the same pump could be good factors of improving the global WUAs efficiency.

7. Conclusion

The two stage analysis, using DEA and tobit models, applied to data collected on water users association of the Cap Bon region (Tunisia), has enabled the identification of factors that determine overall, management and maintenance efficiencies as well as scale efficiency of the Tunisian WUAs. The organizations studied were particularly complex for many reasons. In fact, objectives are multiple and different targets can be pursued leading to bias in some annual stated inputs which can be used in the DEA models.

The DEA analysis highlights the fact that management and maintenance tasks are important criterion in determining the overall WUAs' performance and efficiency.

The main findings regarding the determinants of WUAs efficiency concern the negative effect of the association age on its performance. This induces some questions about the sustainability of those organizations, which should be investigated. Globally, technical characteristics of the irrigated district and network are the most important determinants of the overall WUAs' efficiency in Cap Bon region. However, administrative and organisational variables are the most determinants of the scale and management inefficiencies.

Deeper analysis of the Tunisian WUAs should be undertaken in order to clarify some additional aspects of the structure and the functioning of WUA. Tests focusing on the scale efficiency are among advances that can be done in order to see if it concerns increasing or decreasing returns to scale. Social qualities of the members of administrative council are also important factors that should be more investigated in order to understand the negative effect of this variable on efficiencies. It will be necessary also to test the effect of the age of the irrigation network on the efficiency of the WAU. In fact, in some cases, the irrigation network exists before the creation of the WUA. A WUA charged to manage an old network will not be so efficient than another one which is charged to manage a new irrigation network.

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