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Economic Approach to the Sustainable Management of Water Demand at the Farm Level in Central-Eastern Tunisia: Compromise and Economic Instruments

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Abstract

In Tunisia, the scarcity of water resources is accentuated in recent years with a permanent climate irregularity threatening the sustainability of irrigated agriculture as well as the economic equity of the rural population. In response to this problem, public policy makers are still seeking to consider regulatory instruments to address these climatic effects on agriculture and on water resources in general. The purpose of this study is to reach a compromise between the economic and environmental objective and the appropriate political instruments to maintain economic equity. To answer this question, a multi-objective programming model was applied at level of the farm type in Central-East Tunisia, in the case study of Kalâa Kebira. The results show that the multiobjective modeling approach has proven that the possibility of compromise between two conflicting objectives is possible. The use of integrated regulatory instruments to restore this trade-off such as pricing or subsidy must be synchronized. Indeed, public decision-makers may consider an increase in the pricing of irrigation water of 0.080 DT/m^3 (0.240 DT/m^3), but provided that they grant subsidies in the order of 20% on the cost of production of the strategic agricultural activity in the region. These results prove that the compromise that is the solid support of agricultural sustainability and we cannot be maintained between conflicting objectives that through conflicting and synchronized public instruments if we want the promotion of Tunisian agriculture in the future years.

Keywords

Water Resources, Agricultural Farm, Multiobjective Modeling, Policy Instruments Of Regulation

1. Introduction

During the last 30 years, irrigated agriculture in Tunisia has increased from 250 to 450 thousand ha in 2010. The irrigated areas represent 8% of the total agricultural surface; irrigation contributes with 35% of total agricultural production and 20% of agricultural exports. The growth of the agricultural production in the recent years is mainly due to the expansion of irrigated areas. However, the increase of irrigated areas has clear consequences on the country's water resources [1]. Considerable efforts have been devoted over the time to introduce policies tools aiming to reach a sustainable irrigation water management [2-12].

Therefore, the new strategy introduced in the nineties has turned to the management and regulation of demand, while continuing the effort of water mobilization [3]. The main objective for this strategy is to conserve water resources and encourage demand management in the irrigation sector. Indeed, water pricing is considered one of the most important economic tools in the water demand management strategy; it has remained for long time largely subsidized and not reflects the reality of the resource production costs [4-11]. The pricing policy remains the most appropriate instrument to allocate this water resource, but the search for the right price of water that does not affect the other environmental, social and economic aspects is the most difficult.

According to the economic theory, the farmers would respond to the rising of water prices by reducing their consumption, according the negative slope curve demand. However, in the case of irrigation water, this reaction is not always true. Several studies showed the elasticity of water demand one beyond a certain threshold will become responsive to increase water pricing [5-8]. The same issue and recommendations have been raised in several research papers in irrigated agriculture in Tunisia [9-12].

The most important question is to find a compromise between the economic objective “the income of the farmer” and the environmental objective “the saving of water” in order to maintain the sustainability of irrigated agriculture in Tunisia.

This article aims to show how the synchronized use of regulatory instruments such as water pricing policy and subsidy policy can contribute to a compromise between two conflicting environmental economic objectives in order to ensure the sustainability of irrigated agriculture in Tunisia?

The document is organized as follows: The next section is the methodology adopted for this work. It is based on Multi-Objective Programming model (MOP) accompanied by a brief description of the case study. The section three presents and discusses the empirical results. Finally, the concluding comments are presented in Section 4.

2. Research Methodology

Before assessment impact of water pricing in this paper, a Multi-Objective Programming model (MOP) is developed to determine the ideal price. The key of idea is to maximize profit and minimize water consumption, so as to preserve the water resources. The Non-Inferior Set Estimation (NISE) technique is used to generate the trade-off curves between these two objectives [13]. These trade-off curves will help to determine a kind of water saving by reducing consumption. Finally, the compromise technique is used as a tool to determine the set of Pareto optimal solutions nearest to the ideal point which corresponds to the ideal price of irrigation water. The multiobjective programming model applied is given by following expressions:

$$Max_l \boldsymbol{\pi} = gm' l - \frac{1}{2} l' Q l \qquad (1)$$

$$Min_l \mathrm{w} = w_{use}' l \qquad (2)$$

s.t $Al \leq b, l \geq 0$

Where w is the total of water consumption by farm; *gm*, w_{use} and *l* are $n\times 1$ vectors of unitary gross margins, water use per activity and non-negative variable of land allocation to crops, respectively; *A* is the $m\times 1$ vector of unitary resources requirements, *b* is the $m\times 1$ vector oh the availability of resources of resources, such as fixed resources (land) and variable resources (chemicals and labor).

2.1 Case study and data

The data used in this study were collected from farmers in the region of Kalâa Kebira located in the governorate of Sousse in Center-East of Tunisia (Figure 1). The main water source of this irrigated area is transferred from Nebhana dam, but the water scarcity is an important problem especially in recent years with the context of climate change. Volumetric water pricing is applied in the irrigated perimeter of Kalâa Kebira. Irrigation water prices are almost the highest in the governorate. The price is approximately 0.16 TD[1] (Tunisia Dinar)/m^3. The scarcity of water resources is a limiting factor for irrigated agriculture in this region of Kalâa Kebira. The farmers are obliged to look for other alternative sources of water in adverse weather conditions to irrigate their crops so that their economic losses are not very high after a large investment made at the beginning of the season.

The Kalâa Kebira perimeter was created in 2003; it is mainly occupied by the potato on large surfaces in rotation with other vegetable crops such as pepper and tomato. These crops are intercropped with the olive feet. This perimeter occupies an area of 540 ha and is managed by the Agricultural Development Group (GDA). The survey was carried out on a sample of 65 randomly selected farms. The questionnaire is composed of two main parts: (i) a farmer’s identification about socio-economic and demographic characteristic and (ii) a farm’ identification about a management practice crops, amounts and costs of inputs; quantities and value of outputs [14].

[1] 1TD= 0.34 EUR (Euro) = 0.4 USD (American Dollar)

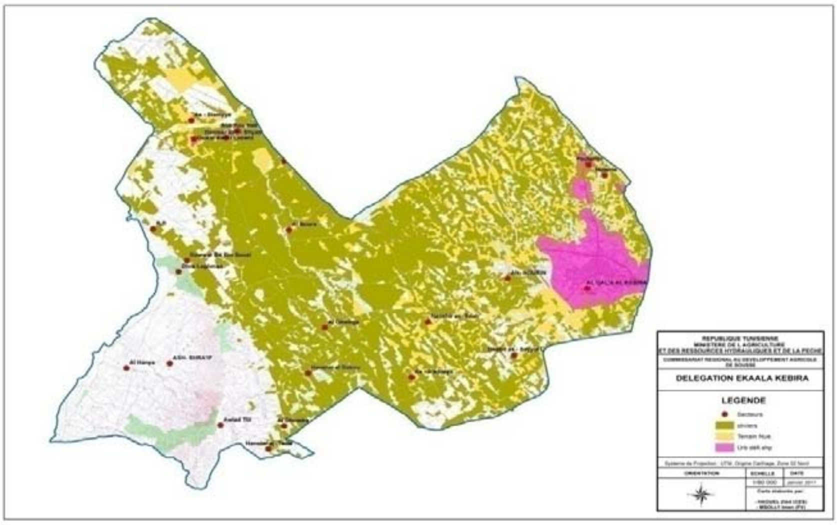

Figure 1. Case study: Location of Kalâa Kebira.

The data collected on socio-economic variables indicated that farmers had average age of 42 years with average number of experience in farming of 15 years. Formal education was average with almost 66% of the farmers having up to only 10 years of schooling. About 31% had less than primary education. Agriculture is the main activity for over 77% of farmers surveyed. Agriculture is the main activity for more than 77% of farmers surveyed but 57% of them are full owners of cropland, the rest are tenants or both (Table 1).

The average size on the farm for the sample was 8.83 ha. This 'average farm' is only a representative farm type of the studied perimeter of Kalâa Kebira. The main crops are vegetables and arboriculture. 43% of the average total area is occupied by potato crops with an area of 3.83 ha. This crop is grown in rotation with tomato crops which has 26% with an average area of about 2.26 ha, or with pepper crops which has 17% with an average area of about 1.5 ha. These crops are found in intercropping with arboriculture, particularly the olive tree. The area of the latter is of the order of 1.24 ha representing 14% of the average total area of the sample (Table 1).

Table 1. Sample characteristics

Variables	values (in percentage)
Age of farmers	42 years (60% between 30-60 years)
Schooling	10 years (31% primary schooling)
Experience (average of years)	15 years
Main activity (agricultural) (%)	77%
Land status (owner) (%)	57%
Average size on the farm (ha)	8.83 ha
Crops (ha)	
Potatoes	3.83 (43%)
Pepper	1.5 (17%)
Tomatoes	2.26 (26%)
Olives	1.24 (14%)

Source: Farm survey data.

3. ngs and discussion

3.1 Results of the Multi-Objective Programming model (MOP)

The multiobjective programming model was applied. First, each of two objectives was been optimized separately subject to the same constraints sets. The obtained values of each objective in the extreme optimal solutions are shown in Table 2. The pay-off matrix obtained in Table 3 indicates that the gross margin can vary between 55,093.96 (DT) and

64,558.22 (DT). Water consumption decreases from 38.400 (1,000 m^3) m^3 to 34.850 (1,000m^3), the highest value corresponding to the maximization of the gross margin. When the objective function is the minimization of the consumption of water, we notice that the possibility of saving water is possible with an economic loss of gross margin. This economic loss may be important, it is around 14.66% against the economy of water is 9.24% (Table 2).

Table 2. Pay-off matrix

Objectives	*Maximizing gross margin*	*Minimizing consumption water*	*Deviation (%)*
Gross margin (TD)	64,558.22	55,093.96	-14.66
Consumption water (1,000m^3)	38.400	34.850	-9.24%

Source: Multi-objective programming model results.

Figure 2 shows the trade-off curve between gross margin and consumption water. Using the NISE method, a set of optimal solutions has been identified between the extreme points (A and B) [15]. To reduce the set solutions, the compromise technique was applied with the weight for the gross margin maximization objective function is equal to the unit ($w_1 = 1$) and the weight of the objective function of minimizing water consumption is equal to the inverse of the slope coefficient of the trade-off curve ($w_2 = \frac{(38400-34850)}{(64558.22-55093.96)} = 0.375$). The $L1$ and $L\infty$ solutions constitute the boundaries of the compromise set. This compromise solution C is nearest solution to ideal solution (Figure 2).

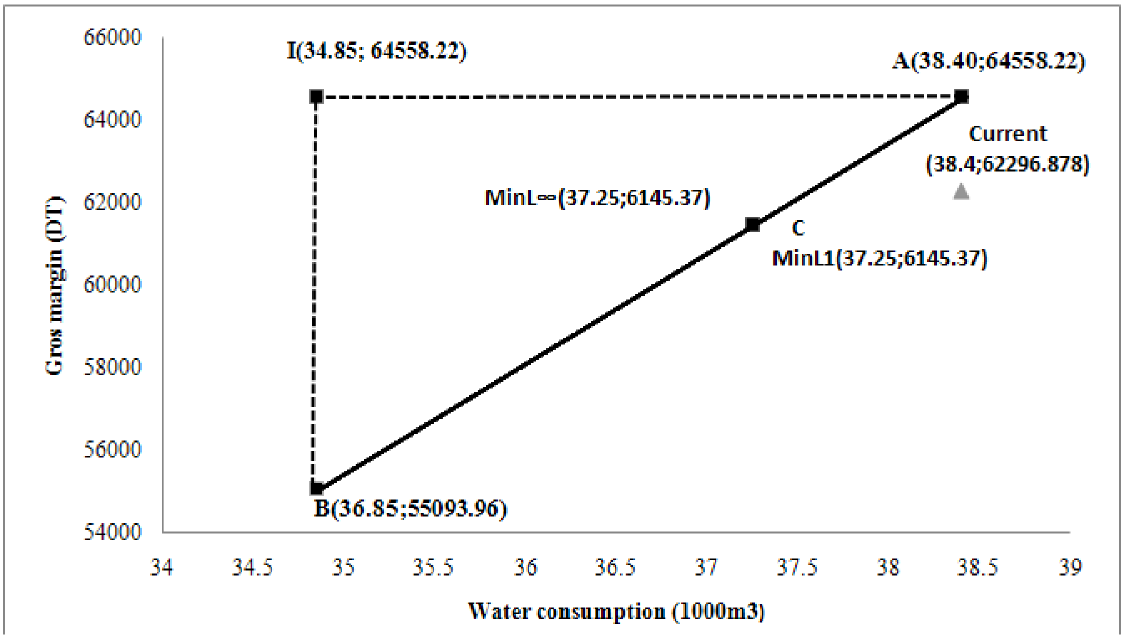

Figure 2. Trade-off curve between gross margin and water consumption.

Water consumption is decreased from 38.4 (1,000 m3) to 37.2 (1,000 m^3). This implies a saving of water of about 3.12% compared to the current situation. The reduction of water consumption implies economic losses about 1.35% compared to gross margin of the current situation (Table 3).

Table 3. Compromise solution: gross margin versus water consumption

	Gross margin	*water consumption (1000m^3)*
Current situation	62,296.88	38.40
$L1$ and $L\infty$ for ($w_1 = 1; w_2 = 0.375$)	61,453.37	37.25
Deviation (%)	-1.35%	-3.12

Source: Compromise model results.

To maintain this compromise which is characterized by a gross margin of the order of 61,453.37 and a consumption of the order 37.25 (1,000 m^3), regulatory instruments were tested through sensitivity tests. This test is based on the water pricing policy and the subsidy.

Table 4. Regulatory instruments (policy & Subsidy)

Increase Policy water(DT/m^3)	*Gross margin (DT)*	*Consumption water (1,000m^3)*	*Subsidy (%)*	*Gross margin (DT)*	*Consumption water (1,000m^3)*
0.160	62,296.88	38.40	25%	623,458	38.4
0.180	61,528.87	38.40	**20%**	**61,452.07**	**37.25**
0.200	60,762.14	38.16	15%	59,066.23	37.23
0.220	60,003.07	37.74	10%	58,880.472	37.1
0.240	**59,252.53**	**37.25**	**5%**	58,695.24	36.99
0.260	**58,510.54**	**36.88**	0%	58,510.54	36.88

Source: model results.

It can be seen from Table 4 that the application of an increase in water pricing can lead to the point of compromise for the case of water consumption [37.25 (1,000 m^3)] but with an economic loss at the margin level gross margin of 4.88% (gross margin equals 59,252.53 TND). To remedy this economic loss, a test based on the subsidy rate of the cost of production of main crop (potato) can be very close to the point of compromise with a rate of about 20% (gross margin equal to 61,452.07 and water consumption of [37.25 (1,000m3)]. These results show that the existence of compromises remains possible, but how to reach and maintain this compromise is the most important issue for ensuring the sustainability of water resources and irrigated agricultural activity in Tunisia. Price policy is a necessary instrument for saving water but it is insufficient to maintain a compromise between two conflicting objectives, economic (agricultural gross margin) and environmental (saving water). The combination of regulatory instruments such as pricing and subsidy remains an appropriate strategy to ensure the sustainability of agriculture and water resources in Tunisia. These results are consistent with the results of other authors; [16] and [17] show that economic regulation instruments remain important tools for preserving water resources provided that they must be well implemented. The application of these tools requires a deep reading of the context of study and preverbal these tools are diversified and integrated to maintain this compromise between the environment and the economy.

4. Conclusion

The application of the multi-objective model has helped to build the trade-off between economic gross margin maximization and the environmental objective of reducing water consumption. To maintain the point of compromise, tools of economic regulation tools such as water pricing and subsidies have been tested. These results show that the possibility of finding a compromise between conflicting objectives exists but the problem how to maintain it to ensure the sustainability of resources and agriculture?

The answer is that regulatory instruments need to be diversified and synchronized to aim for all goals to be achieved with an acceptable degree of trade-off. Today, a deep contextual drive will require a multi-instrumented strategy for sound and adequate sustainable development.

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