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Irrigation water pricing between governmental policies and farmers' perception: Implications for green-houses horticultural production in Teboulba (Tunisia)

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Abstract

A positive mathematical programming model was constructed in this study to assess the effect of three water pricing scenarios on Teboulba's agricultural production systems. The effects of these scenarios were estimated for three groups of farmers from three irrigated districts. Results show that water demand in group 1 remains inelastic until achieving the price of 0.20 TND. A price above this level decreases water consumption, farmer's incomes as well as seasonal labor demand. For groups 2 and 3, the water demand curves remain highly inelastic even with a full cost recovery price. However, once reaching this last price, the model shows important income reductions reaching 20% of the current observed income. Moreover, a pricing policy aiming to recover operational and maintenance costs and which will be implemented independently from other economic, social and environmental measures can threaten the sustainability of the production systems in the region.

Key Words: *Water pricing, positive mathematical programming, greenhouses, economic impact, Teboulba*

JEL Classification: Q15, Q18

Introduction

In Tunisia, water pricing is considered as a significant economic tool in the reform process of water demand management. Indeed, the irrigation water prices were for long time largely subsidized and do not reflect the reality of the resource production costs. Following the recommendations of the Agricultural Structural Adjustment Program started in 1986, a new water pricing system has been settled up in order to find a compromise between the government aiming to cover investment costs, the service manager looking to adjust financial costs and the farmers whose objective remain to have water at lower prices (Bachta et al., 2004). Simultaneously, an institutional reform has been

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implemented with the objective of transferring water management from the State to Water Users' Associations (WUA)¹. WUA becomes the gatekeeper of the water resource at the local level. They also determine the irrigation water price, in the irrigation districts under their authorities, according to the operation and maintenance (O&M) they spend for supplying water to the farm level. Currently, an average significant reduction of the irrigation water subsidies is observed following the increase in irrigation water tariffs all over the country. However, those prices still only recover a part of the full water production and distribution costs.

On the other hand, the irrigated areas in Tunisia are still annually growing during the last three decades and no water savings were recorded in the agricultural sector. The total water demand at the national level is also growing despite the fact that water prices are increasing in average. In addition, the intensification rates in these areas as well as yields of irrigated crops are still under their full potential (MARH, 2006).

According to the economic theory, the farmers would respond to the rising of water prices by reducing their consumption, according to a negative slope curve demand. However, in the case of water, this reaction is not always true. Several studies showed that the water pricing does not cause necessarily the expected effects on water demand because of the low elasticity of demand for this resource (Varela-Ortega *et al.*, 1998; Gomez limon and Berbel, 2000; Feijoo *et al.*, 2000). Only beyond a certain threshold does irrigation water demand become responsive to increased water charges (De Fauture and Perry, 2002). Despite the importance of this issue on water pricing policy, there are few studies have been done in Tunisia (Thabet, 2003; Sghaier, 1995; Chebil *et al.*, 2008).

This paper is a contribution to the study of the impact of the Tunisian irrigation pricing policy on water demand at the farm level. We examine the effects of water pricing on economic, social and environmental indicators of the greenhouses production systems in the irrigated schemes of Teboulba (Tunisia). A Positive Mathematical programming (PMP) model considering the risk on output prices was used for this purpose. This kind of PMP models is used for the first time in Tunisia for the estimation of irrigation water demand functions.

The remainder of the paper is organized as follows: In section 2, the methodological framework, the adopted mathematical model and the study region are described. The next section presents and discusses the empirical results. Finally, the concluding comments are presented in section 4.

Methodology

PMP is a methodology developed to calibrate linear programming models using information contained in dual variables of calibration constraints to specify appropriate non-linear objective functions (Howitt, 1995; Heckeley and Britz, 2000). The non linearity can be introduced into the objective function at the receipts level (Howitt, 1995a) or at the cost production function (Arfini and Paris, 1995). The PMP model has been widely used in irrigation water pricing analysis (Ariaaza and Gomez, 2003). However, this paper is a first attempt to apply this model in the case of Tunisian irrigated agricul-

¹ Known in Tunisia as GDA (Groupement de développement Agricole).

ture. The following explains the main steps of this method:

➤ *Step 1* is formally described in the following model:

$$\text{Max}_x Z = p'y - c'x \quad (1)$$

Subject to:

$$AX \leq B$$

$$X \leq X_0(1 + \varepsilon)$$

$$X \geq 0$$

Where Z denotes the objective function value, p and y are $(k \times 1)$ vectors of output prices and sales activity levels, respectively. c and x are $(n \times 1)$ vectors of variable cost per unit of activity and production activity level. A represents a matrix of coefficients in resource constraints, B is a vector of available resource quantities. X_0 is $(n \times 1)$ vector of observed production activity levels and ε denotes a vector of small positive numbers.

– In this first step, the *model (1)* is solved in order to obtain values of the dual variables associated to the calibration constraints.

➤ *Step 2* consists of employing the vector of dual variables to specify a non-linear objective function in such a way that the marginal cost of the preferable activities are equal to their respective revenues at the base year activity level (X_0) (Heckelei and Britz, 2000). The variable cost function has the following form:

$$c'x = \alpha + \beta x \quad (2)$$

Where c' denotes variable costs, α and β are parameters calculated from the dual variables and used to calibrate the variable costs (see Gohin and Chantreuil, 2000).

➤ *Step 3*: After integrating the new variable costs equation (3), the resulting model fit in exactly the base year solution and the original constraints structure. The model (1) becomes non-linear as follows:

$$\text{Max}_x Z = p'y - (\alpha + \beta x)x \quad (3)$$

Subject to:

$$AX \leq B$$

$$X \geq 0$$

Model specification

The aim of this study is to integrate the risk on prices in the retained PMP model. For this purpose, we use the “mean-variance” approach which has been introduced firstly by Markowitz (1952). We consider ten states of nature relative to the observations on prices during the last ten years. The model of expected value (E)-variance (V) maximizes the expected return by minimizing its variability. Hence, an objective function is developed taking into account simultaneously the average income maximisation and the income fluctuations minimization. According to this method, we maximise the expected income rather than the average income:

$$RE = E(R) - \varphi\sigma(R) \quad (4)$$

$E(R)$: Expected income for each farmer’s group according to the observed prices per

environmental state.

φ : Coefficient of risk aversion (generally assumed equal to 1 when crop mix in the sample is homogeneous (Louhichi et al., 1999; Abbes et al., 2005)).

$\sigma(R)$: Standard deviation of the income;

The mean and the standard deviation relative to the expected income can be written for a given group of farmers as follows:

$$E(R) = \frac{1}{K} \sum_{k=1}^K \sum_{i=1}^n \frac{P_{ik} RDT_i - CV_i}{\xi} x_i \quad (4.1)$$

$$\sigma(R) = \sqrt{\frac{\sum_{k=1}^K [R_k - E(R)]^2}{K}} \quad (4.2)$$

P_{ik} : price per crop and environmental state;

RDT_i : yield per crop and per zone;

CV_i : variable cost per crop and per zone;

K : environmental state ($k = 1, \dots, 10$ years of observation);

R_k : income in the k^{th} environmental state

i : crop ($i = 1, 2, 3$);

x_i : surface per crop;

By calibrating model (4) using PMP approach, the increasing variable production cost per crop is assumed to be a non linear function of the crop allocated surface (Gohin and Chantreuil, 2000). Model (4) becomes as follows:

$$\text{Max } RE = E(R) - \varphi \sigma(R) \quad (5)$$

$$R = \sum_i^n [P_i \times RDT_i x_i - (\alpha_i + \beta_i \times x_i) x_i - (be_i \times x_i) \times pe_i] - ws \times pw$$

Subject to:

$$\sum_i^n x_i \leq T$$

$$\sum_i^n be_i x_i \leq de$$

$$\sum_i^n bw_i x_i = wd + ws$$

$$x_i \geq 0$$

Variables:

R : farm income

x_i : surface of the crop i

ws : temporary labour employed

Parameters:

p_i : market price of the crop i

- pe_i : irrigation water price
 pw : temporary labour wage
 α_i et β_i : parameters of the cost function estimated using the PMP
 be_i : water requirement of the crop i , and $(be_i \cdot x_i) \cdot pe_i$ constitutes the irrigation cost
 bw_i : labour requirement of the crop i
 T : exploited total agricultural surface
 de : availability of the irrigation water
 wd : availability of permanent and family labour

Study region and data

The data used in this study were collected from small-scale greenhouse farmers in the region of Teboulba (Center-East of Tunisia/Governorate of Monastir). This region belongs to Nebhana' irrigated district, where water scarcity is an important problem. The main water source of this irrigated area is transferred from Nebhana dam situated around 80 Km. Irrigation water prices in Teboulba are some of the highest in Tunisia. The price is approximately 0.15 TND m⁻³, whilst supplies in some other regions of Tunisia are priced at a minimum rate of 0.04 TND m⁻³. Volumetric water pricing is applied in the region. A water meter is installed at each farm and individual consumption is measured and charged by the WUA. Given the intensive-water character of greenhouses horticultural production, this resource is not negligible in the variable production cost for farmers in the area examined (between 14 and 41%, 31.4% in average, according to our survey).

The total agricultural area of Teboulba is around 1914 ha, of which 600 ha are irrigated. Horticultural production in non-warmed greenhouses is important, providing nearly the third of the production of the governorate of Monastir (Commisariat Régional au Développement Agricole, Monastir, 2004). The survey was carried out in 2005 on a sample of 62 randomly selected farms producing tomato, melon and pepper in non-warmed greenhouses. The questionnaire is composed of two main sequences: (i) a farmer's identification sequence (socio-economic and demographic characteristics) and (ii) a farm's identification sequence (practiced crops, amounts and costs of inputs; quantities and value of outputs, etc.). The irrigated perimeter of Teboulba is divided into three schemes (Zone 1: Bir Amach; Zone 2: Nakharia; Zone 3: Aitha-boudriss). The

Table 1. Main socio-economic characteristics of the sample

	Zone 1	Zone 2	Zone 3
age of farmers (Average)	45.7	42	43.7
"age" of the irrigated district (number of years in functioning)	31.4	25.6	22.4
Main activity (agriculture) (%)	50	70	100
Schooling (average number of years in education for farmers of the each district)	2.3	4.2	7.4
Average size of the farm (ha)	1.6	3.2	2.6

Average greenhouses number	5.5	6.8	5.8
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three schemes are different by their location, date of creation, average size of the farms and by some socioeconomic characteristics of the farmers (Table 1).

Water pricing scenarios

In Tunisia, it has been observed that cost estimation of water produced and delivered is not transparent (Thabet and Chebil, 2006). Thus any increase in water price is not well understood by farmers and can lead to dissatisfaction. Data is not consistent, making the establishment of a water pricing scheme difficult. Moreover, the water authority lacks accurate information on water productivity at farm level leading to asymmetric information on the side of the authorities as well as on the side of the farmers. Based on this qualification of water "market" in Tunisia, and on the trend of irrigation pricing policies, we choose, in this study, to test scenarios reflecting farmers' attitude as well as government preferences:

- *Governmental scenario "GS" (1)*: Full cost recovery. Public authorities' aims first to a variable cost recovery related to the O&M of the hydraulic infrastructure and second to recover the full costs in the long run. Indeed, currently the O&M costs (0.135 TND²/m³) are covered by the actual rates of water charged in the studied region. According to this, only the full cost scenario will be tested in this paper. Last studies' carried out by the Ministry of Agriculture and Hydraulic Resources at the end of the Nineties, estimated this price to be around 0.450 TND.
- *Farmers' scenario "FS" (2)*: Willingness to pay the irrigation water. In fact, a study conducted by Chebil *et al.* (2007), using Contingent Valuation Method (CVM) on the same farmers' sample used for this study, has revealed an average WTP of 0.22 TND. The latter is used in the second scenario.
- *Intermediary scenario "IS" (3)*: An arbitrary intermediate price between the two above values is taken: 0.35 TND.

Empirical results

Water demand functions

PMP models were simulated for each scenario and each of the three irrigated schemes mentioned above. When water demand schedules are calculated we can observe that differences in water demand in the three irrigated schemes become apparent as shown by figure 1. In fact, farmers in the scheme (1), opposed to those of the schemes (2) and (3), are sensitive for changes from Status Quo (SQ) to FS. This can be explained by the higher average of water consumption per ha in this area where soil quality and nematode diseases are frequent. However, the change in water consumption is small, and farmers continue to consume, in average, more than what farmers of districts (2) and (3) do in the *statue quo*. For water rates ranging from the IS to the GS price level, water demand by farmers of the district (1) becomes inelastic and quite stable around 1400 m³/ha, which remains very low with regards to crop requirements.

² Currently : 1 TND equals approximately 0.8 USD

In the irrigated schemes (2) and (3), water demand is inelastic for price rates ranging

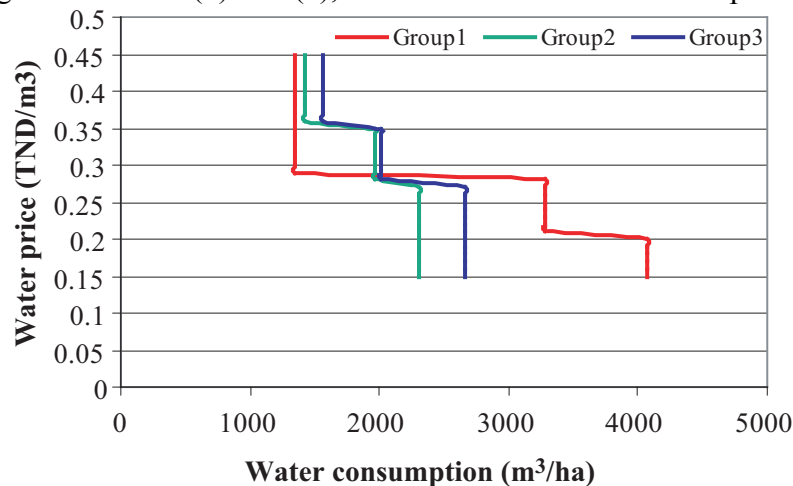


Figure 1. Water demand by group for each scenario

from current price charged in the region to 0.27 TND. Farmers are price unresponsive until achieving their willingness to pay. From this price and upward, water demand in the schemes (2) and (3) becomes elastic and farmers reply to the increase of water rates in scenarios IS and GS by decreasing their consumption of water. Due to the fact that water consumption per crop is almost the same for all crops practiced in the region (around 300 m³/green-house/crop cycle), the decrease of the average water consumption per farm results in a fall in the number of their owned green-houses.

Economic impact

Increases of water prices reduce substantially farmers' income as shown by Figure 2. This reduction is a consequence of two major factors that operate in the same direction:

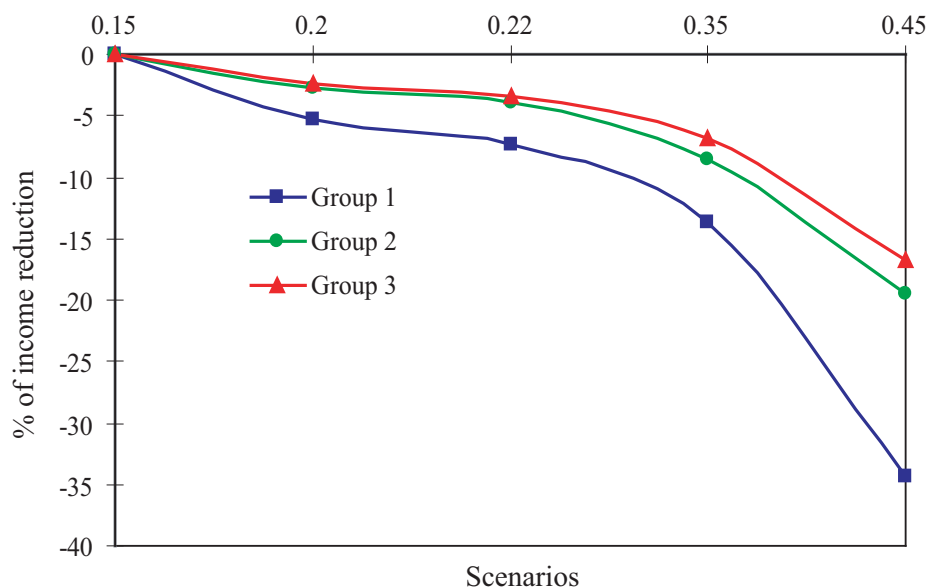


Figure 2. Income reduction for each scenario and for each group of farmers

- (i) public-sector water income means a transfer of income from the farming sector to the public sector. In the first instance it is a burden to be borne by the farmers (Gomez Limon *et al*, 2000);
- (ii) In addition, farmers respond to higher prices by reducing their water consumption through changes in their crop plans. However, alternative cropping systems are limited in the case of green-houses production at the studied region. Indeed, limited crops alternatives with almost similar water consumption per green-house are practiced in the Teboulba region. Then, our model indicates a reduction in the cropped area per farm which is presented in table 2.

Table 2. Average cropped area (ha) (green-houses) by farm in each scheme and by scenario

	<i>Scheme 1</i>	<i>Scheme 2</i>	<i>Scheme 3</i>
SQ	0.27	0.35	0.29
FS	0.25	0.35	0.29
IS	0.21	0.31	0.24
GS	0.21	0.23	0.24

Farmers in district (1) reduce water consumption in FS without reducing significantly their cropped area, which means that they start to use less water, in average, per ha. This can lead in a first step to an improvement in water productivity. The same remark cannot be drawn for farmers in schemes (2) and (3) who irrigate with doses close to the theoretical need advised by the agricultural extension services in the region.

Tables 2 shows that a full cost recovery price of water (GS) is critical for the horticultural production activity in the area. An exogenous shock such as an increase in input prices, a fall in the output prices or a climate risk can seriously threaten the incomes of the farmers (who already become vulnerable due to the implemented pricing policies) and consequently threaten the sustainability of the horticultural systems in the region.

Social impact

Farm labour demand, particularly the temporary labour, is slightly affected in all the tested scenarios. In fact, in the scheme (1), farmers respond to increased water rates by reducing their water consumption per ha or by decreasing the cropped area. No change in the temporary labour demand is observed. This is because of the part-time aspect of farmers', where 50 % of them have another main activity than agriculture (table 1). However, in schemes (2) and (3), farms are larger than those of scheme (1), by the same, the average number of green-houses in these districts is also larger compared to the first scheme. When water prices shift from 0.15 to 0.24 TND/m³, farmers reduce their temporary labour demand in the short run by around 10%. A higher water price would have small effects on the temporary labour demand which becomes inelastic.

Figure 3 reveals that a gradual water price increase will have small social effects on the green-houses production systems of Teboulba region. This is mainly due to the familial character of the agriculture in these schemes, where most of farmers are perma-

ment worker on their farms.

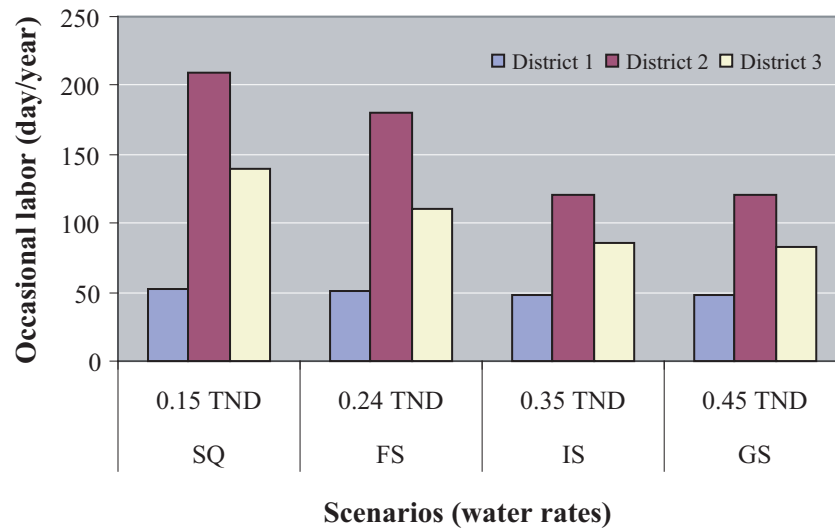


Figure 3. Temporary labour employment by district for the three scenarios

Conclusion

In this paper we used a positive mathematical model to simulate the effects of Tunisian irrigation water pricing policies in three irrigated schemes located in the coastal-central part of Tunisia (Teboulba). The study area is known by its horticultural production under non-warmed green-houses technique. The three schemes are different by their location, date of creation, average size of the farms and by some socioeconomic characteristics of the farmers. Three scenarios of irrigation water pricing were simulated (farmers' scenario reflected by their willingness to pay, Governmental scenario aiming to a full cost recovery of produced and delivered irrigation water, and an arbitrary intermediate price between these two extremes).

Results show that water demand in group 1 remains inelastic until achieving the price of 0.2 TND m⁻³. A higher price would affect negatively, water consumption, farmer's incomes as well as the occasional labor demand. Farmers of this first group belong to the oldest irrigated area in Teboulba, they are thus more experienced, but their land is also the less productive. Also, only 50% of farmers of this group consider agriculture as a main income activity. They are the less educated (compared to groups 2 and 3) and their average land size/farm is also the smallest in the region (1.6 ha compared to 3.2 ha in zone 2 and 2.6 ha in zone 3).

For groups 2 and 3, the water demand curves remain highly inelastic even with a full cost recovery price. However, the reductions in incomes reach almost 20%. Moreover, 0.45 TND m⁻³ is a critical price and can threaten the sustainability of the production systems of the region.

These results show that the local water rates implementation by WUA according to the specific socioeconomic and production conditions of the regions is a good and necessary strategy adopted by the Tunisian government in the framework of water management transfer. However, as seen in our case, three different regions, even though located in the same area, can be different regarding many of their socioeconomic and

productivity attributes. In our case, farmers from all of these regions belong to the same WUA and pay the same water rates. Thus, the implementation of the same pricing scheme for all of them will provide different results and can threaten the financial sustainability of a wide range of irrigated farmers.

The most farmers will be efficient in their irrigation water use, the most they will resist to higher irrigation prices. However, the improvement of the water use efficiency needs a set of actions and policies that have to be adopted and encouraged by the government. Thus, it is also necessary to accompany the implementation of new water prices by a bundle of agricultural policies designated to improve the productivity of water uses. Incentives for an adoption of water saving technologies, use of crops which highly valorize the irrigation water, adequate solutions for the problem of nematodes, etc. could be among agricultural policies which lead to a reduction of the negative effect of increasing water tariffs on farmers' income and help achieving a total recovery cost of irrigation water production in the region of Teboulba.

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