Water pricing impact on the economic valuation of water resources

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Abstract

This paper discusses the effect of an adjustment of the irrigation water pricing on encouraging users to save water. In this context, a basin model was developed according to the mode of access to irrigation water in order to help decision makers to guide their future choices. In a normal year, the increasing of the equilibrium water rate leads necessarily to a decrease in the irrigation water consumption. In case of the application of the tariff adjustment plan, this decrease is up to 22.14%. However, the decision of farmers in a dry year is not too influenced by an increase in the equilibrium rates of irrigation water. In case of drought, as well as a substantial reduction of rainfed areas, irrigated areas have also decreased up to 19.84%.Much more, the water shadow price, under drought conditions, is three times higher than the rate applied in the irrigated perimeter of Tadla.

Keywords: Irrigation water pricing; Water shadow price; Equilibrium water rate; Water resource; Agricultural income; Basin model; Morocco.

1. Introduction

In Mediterranean countries, water resources are limited and unevenly distributed in space and time. The countries of the Southern Shore, which includes Morocco, are endowed with only 10% of the total of this water resources (Blinda, 2012). In Morocco, the water resources management is currently subject of considerable problems that hinder its development in an integrated and efficient manner. Indeed, Morocco's commitment to the rational use of water resources is proving important in order to ensure quantitative and qualitative sustainability. The need to develop more flexible rules governing the irrigation water allocation can become significant measures to adapt the impacts of future climate variability to sustain food security and rural livelihoods in the developing world's dry regions (Ward, Amer, & Ziaee, 2013).

Water pricing is an important policy instrument in irrigated perimeter. In those areas, regional water managers face the challenge of managing ways of using water to increase the productivity of irrigated agriculture (Huang, Wang, Easter, & Rozelle, 2010). Irrigation water pricing can provide an important signal to guide water use patterns (Griffin, 2001).The importance of irrigation water pricing can be twofold. Firstly, farmers will be more aware of the economic importance of water and its scarcity. Secondly, it provides incentives to farmers to think about shifting towards a more productive cropping pattern.

Since the sixties, Morocco adopted the irrigation water pricing which was established by the agricultural investment plan (AIP) in 1969 by the Dahir 1-69-25 July 1969/Decree 2-69-37 concerning the conditions of water distribution and use in the irrigated areas (Belghiti, 2005). The tariff structure of water is based on the volume of water consumed, prompting the user to adopt a rational attitude towards water. Water pricing has been a subject of many discussions, firstly, in order to preserve the financial equilibrium of charges for water services. Secondly, to ensure the enhancement of productivity potential for farmers to have the ability to pay water at a tariff that ensures the sustainability of their system. Over the years, the tariff system has provided a progressive application of the charge of water, called the equilibrium rate, to reflect the progressive effects of irrigation on irrigated production system. The irrigated perimeter of Tadla was concerned by a decision to increase the water equilibrium rate. This joint decision between the Ministry of Agriculture and Marine Fisheries, the Ministry of Economy and Finance and the Ministry of Energy, Mines, Water and Environment (No. 2451.09 /17 September 2009) adjourned since its publication in the official journal No. 5781 October 26, 2009 has not emerged so far.

In a context where water resource is a limiting constraint in agricultural production, this paper discusses the possibility that any increase of the water equilibrium rate can encourage users to save water.

In the scientific literature, water economy was strongly present over the past decades. Early research has focused on a single source of water, surface water or groundwater. GISSER and SANCHEZ (1980) and FEINERMAN and KNAPP (1983) were the first to address the economic aspects of groundwater management. However, in most watersheds, there is a combined use of groundwater and surface water for irrigation. Therefore, increasing importance has been given to the joint management of the use of groundwater and surface water use, given that groundwater and surface water are two components of a single system and must be managed jointly (Gemma & Tsur, 2007). To react to the complexity of the conjunctive water management, an innovative approach was emerged by the research work of X. Cai (1999) for the watershed of the Syr Darya in Central Asia. In his work, he has developed an inter-annual dynamic model that integrates hydrological, economic, agricultural and institutional components in order to analyze sustainability issues related to water resources management.

The evaluation of the agricultural development policies was strongly present in research which has developed basin models (X. Cai, McKinney, & Lasdon, 2003; X. Cai & Wang, 2006; Pulido-Velázquez, Andreu, & Sahuquillo, 2006; Ward, Hurd, Rahmani, & Gollehon, 2006). The sensitivity of water allocation strategies was also present in other research like: (Draper, Jenkins, Kirby, Lund, & Howitt, 2003; Heidecke & Heckelei, 2010; Jakeman & Letcher, 2003; Jenkins et al., 2004; Letcher, Jakeman, & Croke, 2004).

Following this work, this paper proposes a hydrologic-economic optimization model for the Tadla sub-basin in Morocco to assess the irrigation water pricing as an agricultural development policy at the irrigated perimeter of Tadla level.

2. Methodology

2.1. Tadla sub-basin

Tadla sub-basin is located in central Morocco (Figure1). The agricultural area is about 300 000 ha, including 124 600 ha of irrigated areas. The rainfall, in the study area, is mainly characterized by an annual irregularity and interannual variability, with an average amount of 330 mm/ year (DRA, 2012).

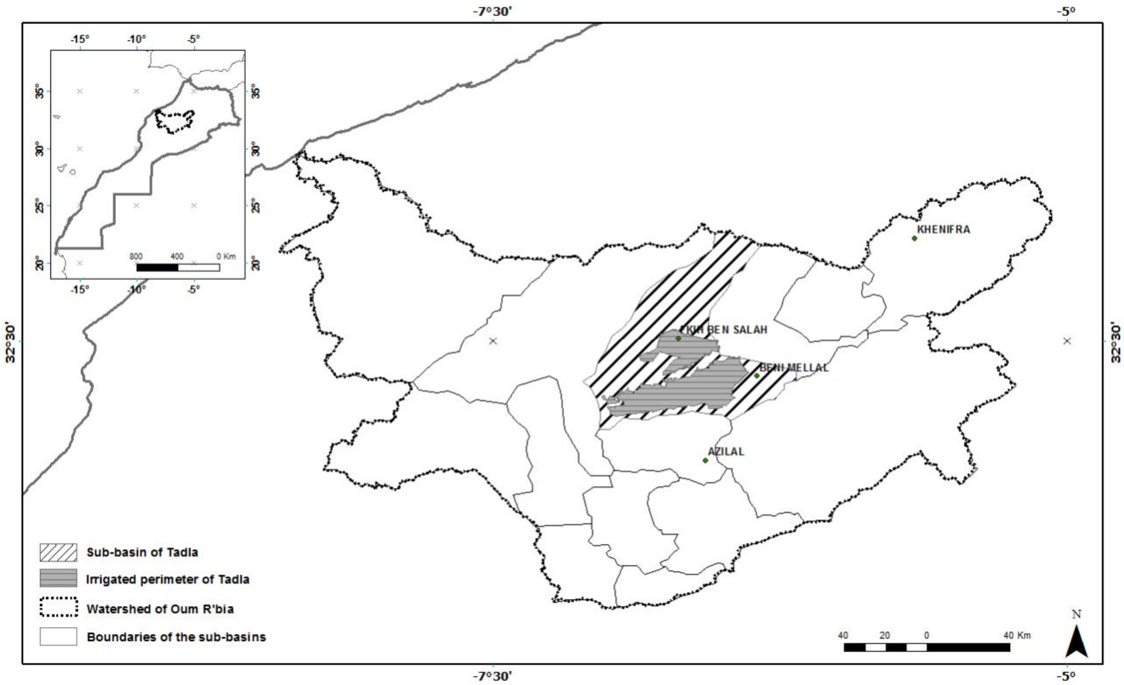

Figure 1: The sub-basin of Tadla in Morocco

The analysis of rainfall data in this sub-basin shows that water resources are experiencing a significant decline, a significant decrease in rainfall: 135 mm between 1963-1980 and 1981-2007 at Ouled Gnaou station. Also, a reduction of reservoirs inputs has been observed: 51% for Bin El Ouidane reservoir and 43% for Ahmed El Hansali reservoir (between 1941-1996 and 1997-2007) (ABHOER, 2012.).The water used for irrigation in the Tadla sub-basin comes mainly from surface water. However, the proportion of groundwater is becoming increasingly important in recent years with the overall decline in rainfall. The main river in the Tadla sub-basin is Oum ErRbia, one of the most important rivers of Morocco. Regarding groundwater, the Tadla sub-basin contains three groundwater (Beni Amir, Beni Moussa and Dir), and a deep groundwater of the Eocene. In this paper, we chose to concentrate the effort on the irrigated perimeter of Tadla. The choice of this perimeter is dictated by strategic and practical considerations. Indeed, the hydro agricultural equipment and the economic and environmental importance of this perimeter has led, over the years, to a large number of studies and research, which constitute an important knowledge base for the success of this research.

2.2. Structure of “TadMod” model

At the base, the model “TadMod”, developed for this study, is a nonlinear optimization model, where, given a number of constraints, we seek to maximize an objective function reflecting a social utility function. After the specification of the objective function , in our case : the overall value generated at the sub-basin, and constraint functions, the model is calibrated based on the positive mathematical programming approach (Howitt, 1995).

In order to better reflect the complexity of the exploitation and valuation of irrigation water requirements, the proposed model is sufficiently disaggregated in physical and functional units: agricultural demand sites, commune, speculation and source of irrigation water.

Thematically, the structure of the model considers three components: hydrological, economic and agronomic components. Each component is presented with a block of equations (Figure2).

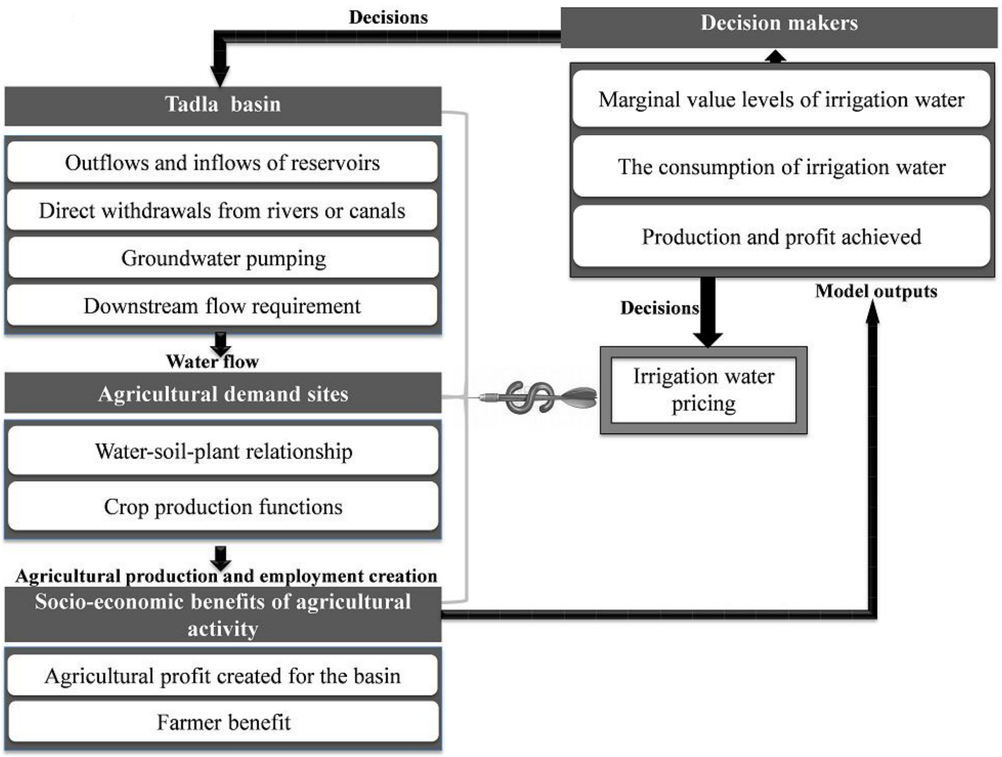

Figure 2: The structure of the "TADMOD" model of water management for the Tadla sub-basin.

For solving the model, we opted for the GAMS CONOPT solver. It is a nonlinear programming solver which performs an optimization under constraint for reservoir contents, pumping, water use patterns, crop mix, irrigation technologies, and mode to access to irrigation water for all basin nodes. TadMod model is based on the actual relationship between the different nodes of the hydrological network (Figure 3). These nodes represent physical entities which can be points of water delivery, reservoirs, groundwater, or agricultural sites. The codification of this model is written in GAMS (The General Algebraic Modelling System), where data, assumptions, constraints, and results are available from the authors upon request.

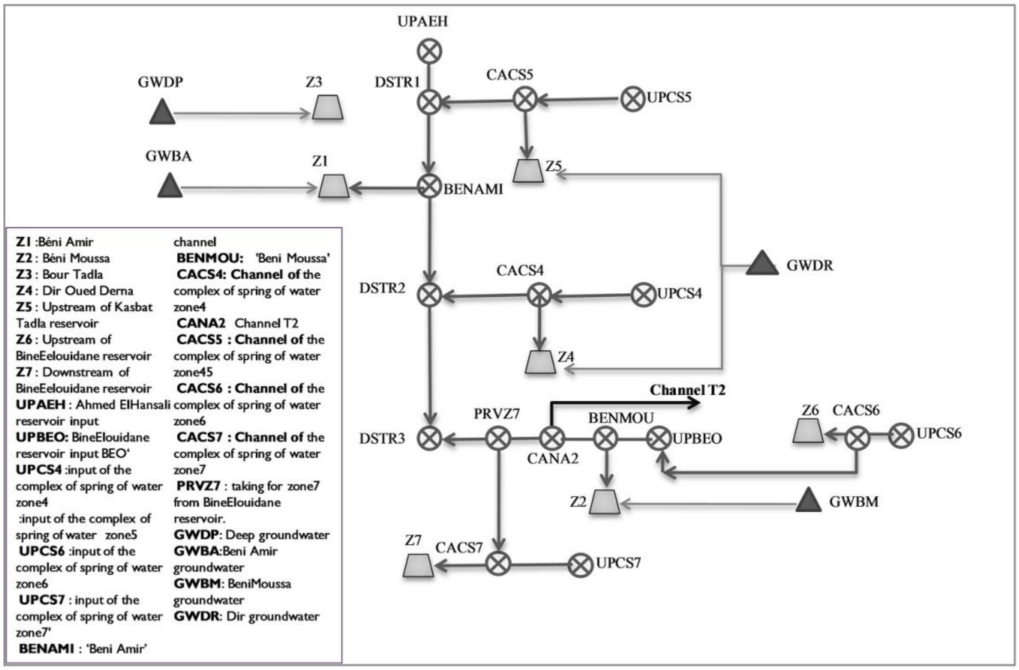

Figure 3: A schematic representation of the various components and relationships of the Tadla sub-basin

TadMod includes:

-Seven agricultural sites: Beni Amir, Beni Moussa, Bour Tadla, Dir Wadi Derna,Upstream of Kasbat Tadla reservoir, Upstream Bine Elouidane reservoir, Downstream of Bine Elouidane reservoir. For each site, we distinguish between modes of access to irrigation water.

-Nineteen groups of the most important crops for the region in terms of area and production.

- Differentiation between the sources of irrigation: large hydraulic, private pumping, large hydraulic combined with pumping private and drainfed areas.

- Twelve periods (September to August), allowing a monthly calculation of availability and demand of irrigation water.

- Four groundwater: Beni Moussa, Beni Amir, Dir and Deep groundwater.

- Two reservoirs: Bine Elouidane and Ahmed Elhansali.

- Fifteen nodes, each node corresponds to a distribution point of water which feeds one or more agricultural sites.

2.3. Database

The nonlinear optimization model adopted for this research requires technical data and needs additional studies in agricultural and hydrology science. It also requires a thorough knowledge of water management specificities in the Tadla sub-basin and its hydric resources potential. These data are collected from regional actors of the irrigation water management. Also an investigation was conducted with agricultural development centers regarding standards for factors of production use and the average yields per agricultural sites and modes of access to irrigation water.

To validate and complete the database, a "farm investigation" was conducted with farmers in the area of research. Also, to understand the diversity of production potential at the regional level, a farm typology was used. Previous work on farmer strategies in terms of water management and agricultural production in the irrigated perimeter of Tadla has been useful to choose the typology. To analyze the diversity observed in the farmers behaviour, especially towards water management, we used the typology generated by (Bacot, 2001), based on mode of access to irrigation water. This typology considers four types of farm types: a- farmlands with an easy access to groundwater and surface water (A_SGW); b- farmlands with an easy access to surface water and with limited access to groundwater (A_SW); c-farmlands with easy access to groundwater and not having access to surface water (A_GW); d- farmlands who don't have access to surface water and groundwater (R_A).

2.4. Scenarios simulated

This section discusses the exogenous shocks to simulate and justifies the choice of each simulation and how they are considered in the model.

2.4.1. Reference Scenario

The base year for this research is the crop year 2009-2010. This scenario will help to understand the use of irrigation water in the irrigated perimeter of Tadla and later will serve as a reference for comparing results of different simulated scenarios.

2.4.2. Simulation 1: the increase of the equilibrium rate of irrigation water

The adjustment of the equilibrium rate of irrigation water, especially to increase it, has been subject to discussion and debate within water management services. Some of them encourage this adjustment and others are reluctant. For the irrigated perimeter of Tadla, increases in equilibrium rate of irrigation water were determined by a joint decision between the Ministry of Agriculture and Marine Fisheries, the Ministry of Economy and Finance and the Ministry of energy, mining, water and the environment (No. 2451.09 / September 17, 2009) (Official Journal, 2009). This decision announced that the equilibrium rate of irrigation water must achieve 0.40 Moroccan Dirham (MAD) per cubic meter in 2011. This increase has not been applied until now for doubt that the new rate will not be supportable by the farmers of the region. Pricing is supposed to be an important tool to enhance economic valorisation of irrigation water, but it must be tolerable by farmers.

This simulation focuses on the increase of the equilibrium rate of irrigation water in the irrigated perimeter of Tadla. This scenario simulates, in the case of a normal year, the effect of an increase of 25% in the equilibrium rate of irrigation water applied to the surface water.

According to the tariff adjustment plan of surface water, the value of the equilibrium rate of irrigation water used for this simulation is 0.4 MAD/ m³.

The main objectives of this simulation are, firstly, to determine the behaviour of farmers facing a change in the equilibrium rate of irrigation water, and to assess their ability to pay charges before and after the increase of this rate.

2.4.3. Simulation 2: Drought conditions

Given that Morocco including the Tadla sub-basin was affected by periods of prolonged drought, it has been important to take into account the issue of water scarcity in the future, in policies and management strategies of water. For this, it is important to simulate a scenario which reflects the case of a dry year.This scenario allows understanding farmer behaviour in conditions of water scarcity. It simulates the impact of a change in the equilibrium rate of irrigation water and a reduction of 40% of the water supply, groundwater recharge and rainfall in the irrigated perimeter of Tadla.

3. Results and Discussion

3.1. Analysis of the reference situation (2009-2010)

3.1.1. Irrigation water shadow price

The water shadow price is one of the most significant results derived from this paper. It allows to assessing the economic value of agricultural water in each agricultural site according to the access mode to irrigation water. The water shadow price is defined as the marginal increase in the value of the objective function (the agricultural profit) if we increase water availability by one additional unit; in our case, it is an additional cubic meter. The following figure (Figure 4) shows the evolution of the irrigation water shadow price for the irrigated perimeter of Tadla.

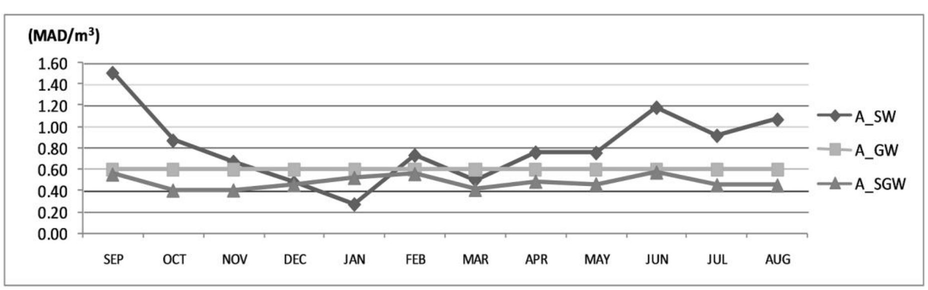

Figure 4: The evolution of the irrigation water shadow price according to the mode of access to irrigation water.

The water shadow price does not change through periods for farmlands with easy access to groundwater "A_GW", given that; there are no constraints on the use of groundwater resources by period. For the types of access to irrigation water "A_SW" and "A_SGW" the water shadow price increases from February to September, and then decreases with the first rains which usually coincide with the month of October. The average water shadow price calculated for irrigated perimeter of Tadla is about 0.78MAD for the cubic meter. It varies in a range from 0.47MAD/m³on average for farmlands conducted in "A_SGW" mode to 1.22MAD/ m³ for those conducted in "A_SW" as shown in the following table (Table 1).

Table 1. Value of the water shadow price by agricultural sites and types of access to irrigation water (MAD/m³)

		Modes of access to irrigation water		
		A_SW	A_GW	A_SGW
Agricultural sites	Beni Amir	1.66	0.6	0.51
	Beni Moussa	0.92	0.6	0.42
	Tadla perimeter	1.22	0.6	0.47

Analysis of the results shows significant differences in the water shadow price according to agricultural sites and the mode of access to irrigation water.

The effect of variations in irrigation water supply on the irrigation water shadow price is remarkable in different agricultural areas according to the mode of access to irrigation water.

Farmlands conducted in "A_SW" mode have the highest value of irrigation water shadow price, with an average of 1.22 MAD/m³. This value can be explained by the irregularity of surface water supplies through the canals of the irrigation network. Also, this group of farmland receiving irrigation water in non-appropriate times according to the decision of the farmers and the majority of these lands are using a traditional irrigation called flood irrigation. Then, the farmland conducted in "A_GW" mode with an average irrigation water shadow price of 0.60MAD/m³. This value can be explained by the fact that farmers keep a large area for crops valuing water better and they have also the possibility of choosing an irrigation technique in accordance to their context. Finally, farmlands conducted in A_SGW mode have an irrigation water shadow price low compared to other farmlands, on average 0.47MAD/m³. These farms can irrigate at the appropriate time and choose to irrigate either with surface or groundwater.

3.1.2. Irrigation water use

The total irrigation water demand of crops is about 807.94 million cubic meters in the irrigated perimeter of Tadla. From the beginning of the crop season until February, irrigation demand of crops is relatively low. From March until June, the agricultural demand becomes higher and reaches a peak in April with a value of 131.15 million m³ (Figure 5).

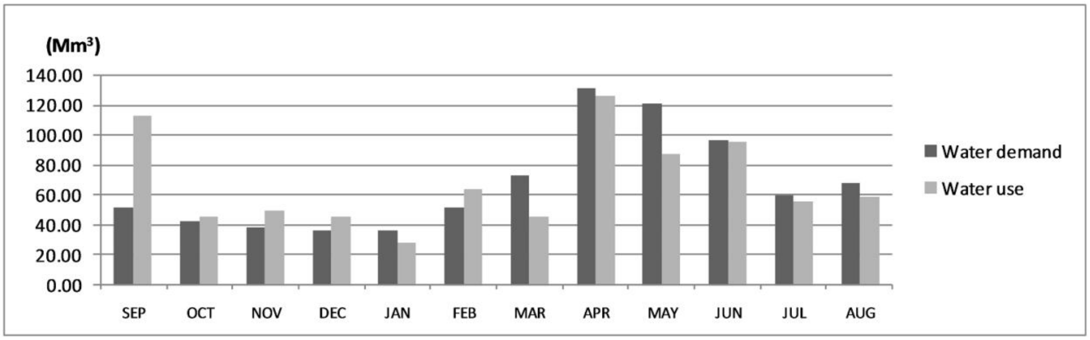

Figure 5: Evolution of irrigation water supply and demand in the irrigated perimeter of Tadla during the reference year (2009-2010).

By comparing the irrigation water use and demand in the irrigated perimeter of Tadla, the results of our calculations show that the supply and demand do not move in the same direction. Thus, from September to February, the supply is higher than demand, given that, this period is known by the heavy rainfall. After this period, and until August, the irrigation water demand increases in spite of the offer which can not satisfy the needs of farms in the region.

3.1.3. Net margin

For the base year, the total net margin in the irrigated perimeter of Tadla is estimated at 1880.94 million MAD, with an average per hectare of 13551.51 MAD. The net margin realized by each agricultural site according to mode of access to irrigation water is as follows:

Table 2. Net Margin by mode of access to irrigation water in the irrigated perimeter of Tadla

		Mode of access to irrigation water			
		A_SW	A_GW	A_SGW	R_A
Total Net Margin (Millions MAD)	The irrigated perimeter of Tadla	892.84	313.58	329.25	345.26
	Beni Amir	326.24	115.36	152.25	205.41
	Beni Moussa	566.6	198.23	177	139.85
Net Margin (MAD/Ha)	The irrigated perimeter of Tadla	12624.34	20975.8	20975.8	3027.79
	Beni Amir	12088.75	19525.97	21411.05	2993.86
	Beni Moussa	12981.39	22425.63	19992.56	3054.94

What appears from the above table (Table 2) is the existence of differences between farmlands considering their net margin per hectare within the same agricultural site in depending on the mode of access to irrigation water. Farmlands conducted in "A_GW" and "A_SGW" modes achieve a high net margin by hectare, so 20975.80 MAD/Ha. In these farmlands, farmers achieve high yields, seen that they are able to irrigate at the appropriate time with sufficient water quantity. Finally, the net margin in the farmlands conducted in “A_SW” mode reach 12624.34 MAD/Ha. Farmers of this type of farmlands, make the lowest yields compared to other, because they receive limited quantities of irrigation water according to rainfall years.

3.2. Results of the simulation (1): Increase in the equilibrium rate of irrigation water

3.2.1. Irrigation water shadow price

The analysis of the value of water for agriculture is a relevant indicator of water pricing. With the new value of water tariff (0.40 MAD/m³), the irrigation water shadow price has increased compared to the baseline situation to reach 0.86 MAD/m³ on average.

The value of the irrigation water shadow price in case of an increase in the equilibrium rate of irrigation water is expressed in the following table (Table 3) according to modes of irrigation water access.

Table 3. Value of the water shadow price by agricultural sites and modes of access to irrigation water (MAD/ m³)

	Modes of access to irrigation water					
	A_SW		A_GW		A_SGW	
	Value (MAD/ m³)	Variation/ reference year(%)	Value (MAD/ m³)	Variation / reference year(%)	Value (MAD/ m³)	Variation / reference year(%)
Beni Amir	1.67	+0.5	0.6	0	0.54	+4.68
Beni Moussa	1.26	+26.98	0.6	0	0.49	+14.28
The irrigated perimeter	1.43	+14.42	0.6	0	0.52	+9.31

Except for farmlands conducted in “A_GW” mode, which will not be affected by the increase in the equilibrium rate of irrigation water, the water shadow price at the farmlands conducted in “A_SW” and “A_SGW” modes will know a net increase. This variation of the irrigation water shadow price leads to fundamental questions about the choice of crops and the measures taken by farmers in order to balance between available resources and cropping system at the irrigated perimeter of Tadla.

Farmlands conducted in “A_SW” mode were affected by a significant increase in the irrigation water shadow price 14.42%. In the farmlands conducted in “A_SGW” mode, the irrigation water shadow price has increased by 9.31% compared to the reference year. The increase in the equilibrium rate of irrigation water may weaken farmlands conducted in “A_SW” mode. For this, the water pricing must be accompanied with other parallel policies in order to improve the technical efficiency of farmers making them able to pay higher water rates. This confirms the findings of some authors (J. A. Gómez-Limón & Berbel, 2000; Liao, Giordano, & Fraiture, 2007; Molle, Venot, & Hassan, 2008), who affirm that for water pricing to be successful, it is necessary to introduce a set of parallel policies to help improve the productivity of irrigation water to go in tandem with water pricing.Webber, Barnett, Finlayson, and Wang (2008), state that the weakness of most of the present proposals for pricing irrigation water is that they intend to charge farmers for use of water without providing them a compensatory income.

3.2.2. Irrigation water use

The tariff increase is reflected in a reduction of 22.14% in the use of surface water. Seen that, the price per cubic meter of water becomes more expensive, farmers will tend to reduce and rationalize the use of water by choosing the crops valuing water (Figure 6).

Also, the use of groundwater for irrigation will not be affected by this tariff increase. It is going to have, in fact, a small decrease of 0.32%.

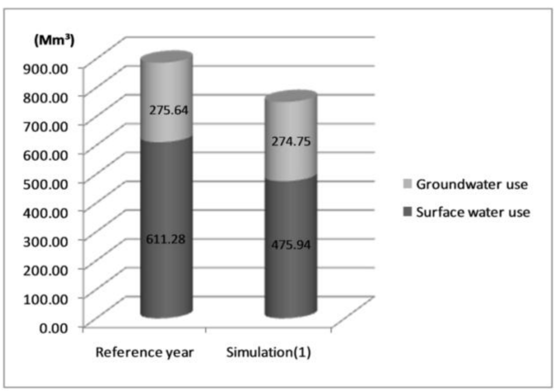

Figure 6: Irrigation water use.

Therefore, we can say that the increase in the equilibrium rate of irrigation water generates a rational use of irrigation water, but it shouldn’t forget that such decrease in water consumption is reflected by a reduction in water volumes marketed and therefore by an increase in the cost of a cubic meter of water, because the most part of the water cost is constituted by fixed operating costs and maintenance of equipment. This should lead to reflect well on the passage of the current rate at the equilibrium rate, decided for 2011, in order to avoid the negative effects of an increase in water tariffs as a shortfall for regional actors of the irrigation water management, in terms of income derived from the volumes of water not marketed.

3.2.3. Effect of the increase in the equilibrium rate of irrigation water on the cropping system

The increase in the equilibrium rate of irrigation water will not affect the total area allocated to irrigated crops. The main results obtained in response of the increase in equilibrium rates of irrigation water on cropping system are summarized in a table below (Table 4).

Table 4. Variation in the cropping system

Crops	Crops proportion in the reference year (%)	Crops proportion in the simulation1 (%)	Variation/Reference year(%)
Cereals	67.058	67.276	0.218
forages	15.393	15.217	-0.175
vegetables	1.512	1.519	0.006
Sugar beet	3.39	3.306	-0.084
Sesame	0.304	0.304	-4E-08
Legumes	0.413	0.407	-6E-03
Citrus	2.524	2.529	0.004
Olive	8.642	8.679	0.037
Almond	0.196	0.197	0.001
Pomegranate	0.414	0.414	-4E-09
Other tree crops	0.154	0.154	2E-04

The increase in the equilibrium rates of irrigation water didn’t have a significant effect on cropping system, unless the increase in the cereal crops area at the expense of the area allocated to forage. Therefore, forage crops that were affected in terms of allocated area, are considered the most vulnerable to an increase in the equilibrium rates of irrigation water.

3.2.4. Effect of the increase in the equilibrium rate of irrigation water on the net margin

Water pricing effect has been strongly present in many empirical studies of irrigation water demand function, especially in arid countries (e.g.,Jose A. Gómez-Limón and Riesgo (2004) and Varela-Ortega, M. Sumpsi, Garrido, Blanco, and Iglesias (1998)). In these studies, water pricing would not always stimulate the desired changes in water use due to the low elasticity of demand for irrigation water. A limited effect is also expected if the cost of water is small, relative to total production costs. Besides, the implementation of water pricing could also engender collateral effects such as a decrease in agricultural income and labor demand in rural areas.

The result of this simulation shows a decrease of around 6.52% of the average net margin in the irrigated perimeter of Tadla. It has decreased from 13551.51 million MAD made in the reference year to 12667.86 million MAD.

The following table (Table 5) shows the variation of the net margin per hectare due to the increase in the equilibrium rates of irrigation water.

Table 5. Net margin according to mode of access to irrigation water

	Mode of access to irrigation water							
	A_SW		A_GW		A_SGW		R_A	
	Value (MAD/Ha)	Variation/ Reference year (%)	Value (MAD/Ha)	Variation/ Reference year (%)	Value (MAD/Ha)	Variation/ Reference year (%)	Value (MAD/Ha)	Variation/ Reference year (%)
Net Margin	11231.16	-11.03	20975.8	0	18940.3	-8.01	3027.79	0

Referring to the table above, the effect of the price increase of surface water on the net margin per hectare is significantly felt in farmlands conducted in “A_SW” and “A_SGW” modes. However, farmlands conducted in “A_SW” mode are the most vulnerable to the effects of this price increase. Their net margin per hectare was significantly reduced by 11.03% on average, because they depend directly on the surface water. Then, farmlands conducted in “A_SGW” mode, with a decrease of 8.01% in their net margin per hectare. These farmlands are relatively less affected in case of an increasing in the equilibrium rate of irrigation water because they combine between surface water and groundwater. Finally, farmlands conducted in "A_GW" mode and rainfed farmlands will not be affected because they are not concerned by the use of surface water.

3.3. Results of the simulation 2: Increase in the equilibrium rate of irrigation water in a drought situation

3.3.1. Irrigation water shadow price

In this situation, the effect of drought is more important than the increase in the equilibrium rate of irrigation water. The results of this simulation show a significant increase in the irrigation water shadow price, relative to the reference situation, it increased from 0.78MAD/m³ observed in the reference year to 0.92MAD/m³. We can therefore conclude that the water resource is very constraining to production in the irrigated perimeter of Tadla during a drought year. This reflects the important role that represents water for crop yields and net farm income.

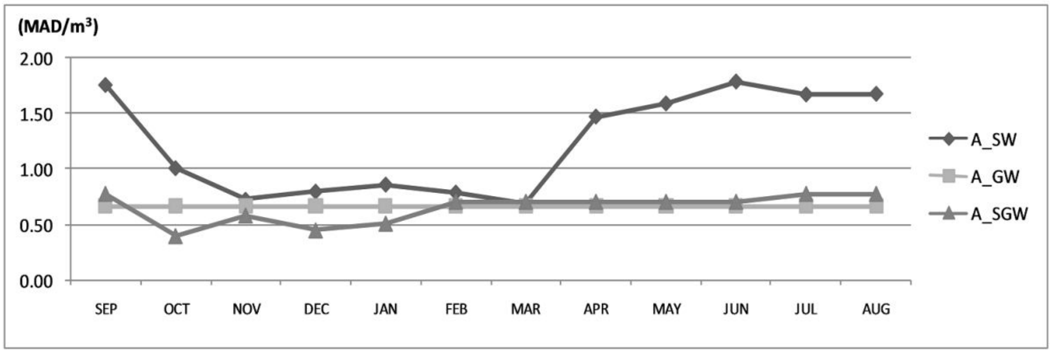

Figure 7: Effect of drought on the irrigation water shadow price in the irrigated perimeter of Tadla.

For farmlands conducted in "A_GW" mode, the irrigation water shadow price did not vary by period, given that there are not constraints on the use of groundwater per period. For the farmlands conducted in "A_SW" and "A_SGW" modes, the irrigation water shadow price increases from February to September, then decreases with the first rains which generally coincide with the month of October (Figure 7). Its value varies in the range of 0.6MAD/m³ on average for farmlands conducted in "A_SGW" mode to 1.24MAD/m³ for those conducted in "A_SW" mode as shown in the model results summarized in the following table (Table 6).

Table 6. The irrigation water shadow price in the irrigated perimeter of Tadla

	Modes of access to irrigation water					
	A_SW		A_GW		A_SGW	
	Value (MAD/ m³)	Variation/ reference year (%)	Value (MAD/ m³)	Variation/ reference year (%)	Value (MAD/ m³)	Variation/ reference year (%)
Beni Amir	1.33	+42.11	0.67	11.76	0.63	+18.72
Beni Moussa	1.17	+40.18	0.67	11.76	0.56	+25
The irrigated perimeter of Tadla	1.24	+41.13	0.67	11.76	0.6	+21.74

The water shadow price, at the Tadla Farmlands, will know a net jump by increasing the equilibrium rate of irrigation water in a drought situation. Farmlands conducted in “A_SW” mode were affected by a significant increase in the irrigation water shadow price 41.13%. This value can be explained by the irregularity of surface water supplies in a drought situation through the network canals of irrigation. The irrigation water shadow price has increased by 21.74%, in the farmlands conducted in “A_SGW” mode, and by 11.76% in those conducted in “A_GW” mode compared to the reference year. These values are lower compared to the previous because these farmlands have easy access to groundwater. However, the average level of the irrigation water shadow price is much higher than the equilibrium rate of irrigation water. So, in this case, this level isn't a limiting factor to increasing the equilibrium rate.

3.3.2. Irrigation water use

The irrigation water tariff increase in a drought situation is reflected in a reduction of 29.46.14% in the use of surface water (Figure 8). Having regard to the decrease in water availability and the water tariff increase, farmers will tend to reduce and rationalize the use of irrigation water.

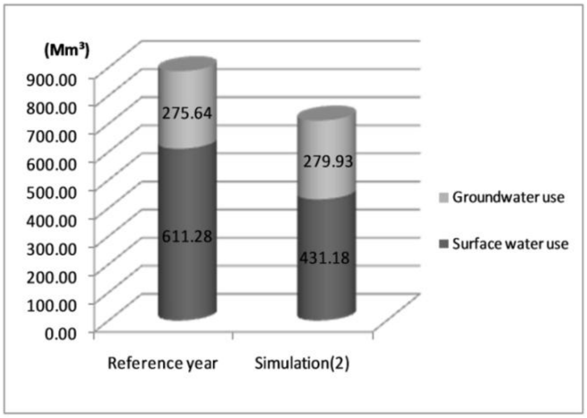

Figure 8: Effect of drought on the use of irrigation water Mm³.

Farms that use only surface water are the most affected because they don't have another alternative for irrigation. Farms that have access to groundwater are less affected because they have a direct access to groundwater. Therefore, to compensate for the scarcity of surface water during this period, the use of groundwater for irrigation will be slightly affected in this situation. This explains the small increase of 1.55% in the use of groundwater.

3.3.3. Effect of drought on the cropping system

Under drought conditions, the cultivated area in the irrigated perimeter of Tadla will decrease by about 19.84%, about 20265 hectares.

Table 7. Cultivated area in the irrigated perimeter of Tadla

		Reference year (ha)	Simulation 2 (ha)	variation/Reference year (%)
Total irrigated area	A_SW / A_SGW *	86384.45	66126.63	-23.45
	A_GW / A_SGW *	32341.9	32334.22	-0.02
Total area of irrigated crops (A_SW / A_SGW / A_GW)		102113.95	81848.458	-19.84
Total area of rainfed crops		117618.6	111607.6	-5.11

Note: *Agricultural areas conducted by A_SGW Mode are included in both groups: A_SW / A_SGW and A_GW / A_SGW *.

In the above table (Table 7), we chose to combine the "A_SGW" mode with each "A_GW" and "A_SW" modes, seeing that the farmlands conducted in this mode have areas conducted at the same time in the "A_GW" and "A_SW" modes. Indeed, the total areas allocated to irrigated crops have undergone a significant decline.

However, the results show a reduction of 23.45% for farmlands conducted in "A_SW/A_SGW" because they depend directly on surface water. For lands conducted in "A_GW/A_SGW" mode, the cultivated areas decreases lightly by 0.02%. Farmers are moving towards reducing the area allotted for irrigated crops, which is an adaptive response to drought. The effects of drought have also affected rainfed crops areas, resulting in a reduction of 5.11% of the areas that will be converted into fallow land.

3.3.4. Drought effect on the net margin

Generally, pricing policy, even if it is beneficial to the community by their positive effects on production and water economy, there is no chance to be adopted if farmers don't generate incomes. So in this context, the most important risk to analyze is the reduction in farmer income. In case of drought, the total net margin in the irrigated perimeter of Tadla decreases from 1880.94 million MAD estimated at the reference year to 1240.92 million MAD. The net margin realized per hectare according to each mode of access to irrigation water is as follows:

Table 8. Net margin according to mode of access to irrigation water

	Mode of access to irrigation water							
	A_SW		A_GW		A_SGW		R_A	
	Value (MAD/Ha)	Variation/ Reference year (%)	Value (MAD/Ha)	Variation/ Reference year (%)	Value (MAD/Ha)	Variation/ Reference year (%)	Value (MAD/Ha)	Variation/ Reference year (%)
Net Margin	9928.95	-24.02	20413.33	-2.68	17927.98	-12.93	852.35	-71.84

Referring to the table above (Table 8), the drought effect on the net margin per hectare is significantly felt by all modes of access to irrigation water. However, rainfed farmlands are most vulnerable to the drought effect, the net margin per hectare was significantly reduced, 71.84% on average, because they depend directly on rainwater. Therefore, the reaction of the farmer in this case would result the abandonment of land, which will be left fallow. Farmlands conducted in "A_SW" mode come in second place with a 24.02% of reduction in the net margin per hectare, given that, in drought situation: the volumes of water released from reservoirs are reduced consequently, thing that will induce a significant reduction of surface water quantities and loss of production.

Then, the farmlands conducted in “A_SGW” mode, with a decrease of 12.93% in the net margin per hectare. These lands are relatively less affected by drought because they combine with the use of surface water and groundwater, thing that allows them to find an alternative for irrigation in case of surface water scarcity.

Finally, farmlands conducted in "A_GW" mode, are less vulnerable during a dry year. The net margin per hectare will have a small decrease of 2.68%, compared to other types of farmland. This decrease is essentially a result of the pumping cost that will be higher in case of drought because farmers must pump more water to compensate for the scarcity of rainfall.

4. Conclusion

In order to help regional decision makers to guide their future choices, this paper discusses the effect of an adjustment of the irrigation water pricing on the water value in the irrigated perimeter of Tadla in Morocco. In a normal year, the increase in the equilibrium rate of irrigation water may weaken farmlands conducted in “A_SW” mode. Their net margin per hectare has decreased significantly by 11.03% on average, because they depend directly on surface water. For the farmlands conducted in “A_SGW” mode, the net margin per hectare has decreased by8.01%. Farmers in these farmlands are relatively less affected in case of the increase in the equilibrium rate of irrigation water, because, they combine between surface water and groundwater. For the irrigation water shadow price, it remains well above the equilibrium rate of irrigation water and therefore it doesn’t constitute a limiting factor to increase this rate. However, an increase in the equilibrium rate of irrigation water, in a normal year, leads necessarily to a decrease in irrigation water consumption. In the case of this study, it is around 22.14%. Thus, this situation should bring to reflect in order to avoid the negative effects of an increase in water tariffs as a shortfall for regional actors of the irrigation water management, in terms of income derived from the volumes of water not marketed.

The decision of farmers in a dry year is not too influenced by an increase in the equilibrium rates of irrigation water. The use of surface water is going to decline because of the constraint of water that hinders irrigated area expansion. This will induce farmers to choose crops that require less quantities of water and that achieve maximum yields to get maximum profit. Indeed, for irrigated crops, there has been an increase in the area allocated to cereal crops, particularly wheat, at the expense of forages and vegetables crops. The use of groundwater going to increase, because farmers tend to pumping more in order to cover their needs for irrigation by groundwater. The results of the increase in the equilibrium rate of irrigation water under drought conditions show that in addition to a substantial reduction in rainfed area, the total area of irrigated crops decrease also by 19.34 %. Much more, the irrigation water shadow price in a drought situation is three times higher than the rate applied in the irrigated perimeter of Tadla. This increase in the irrigation water shadow price hides the effect of an increase in the equilibrium rate of irrigation water in drought conditions. Therefore, an evaluation of an irrigation water pricing policy must take into account the interannual variability of the irrigation water shadow price.

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