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The Effects of Agricultural Water Pricing Policies on the Sustainability of the Water Resources: A Case of Irrigation Network in Qazvin Plain

Parvaneh Nasiri, Saeed Yazdani[1]* and Reza Moghaddasi
College of Agriculture, Science and Research Branch, Islamic Azad University, Tehran, Iran
[1]Faculty of Agriculture, Tehran University, Tehran, Iran
✉ syazdani@ut.ac.ir

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Abstract: Qazvin plain in Iran is one of the most fertile regions for crop production, but it has been suffering from severe crises in water resources, inefficient water allocation, and improper cropping pattern due to low tariffs in recent years. One influential policy in the context of sustainable water resource management is suitable pricing. Given the legal potentials and technical conditions for the adoption of various pricing policies, the present paper addresses the effect of area, volumetric or two-part tariff pricing policies with the scenarios of pricing by water supply cost, economic value, or residual value of water on economic variables and water use rate. To this end, positive mathematical programming method was adopted and the data were collected through a questionnaire from the farmers served by the irrigation network of Qazvin plain. Also, experts' opinions were collected and a library study was conducted. The results show that area pricing policy has no impact on water use management in crops irrigated with sprinkler or flood systems and increased water use by as high as 72% in alfalfa farms irrigated by flood system. Volumetric policy and two-part tariff policy reduces water use by as high as 45% in most cropping systems with various irrigation technologies and encourages farmers to use sprinkler or tape irrigation technologies. However, given the negative economic impacts of these pricing policies on local farming, it is imperative to offset their adverse impacts by alternative policies that can improve water resource sustainability and at the same time, do not cause fluctuations in economic interests of users.

Key words: Sustainable water resource management, positive mathematical programming, water pricing policies.

Introduction

Water scarcity is becoming a central issue in agricultural activities around the world (Istiaque et al., 2016). Thus, policymakers have focused on the adverse environmental impacts of the economic activities – especially in developing countries located in arid and semi-arid regions (Wichelns et al., 2006). One of the critical aspects of sustainability considered by most academic and non-academic circles is agriculture sustainability. In this sense, the main question about water sector modification is related to the adoption of integrated water resource management whose final goals are economic efficiency, social equity, and environmental sustainability (Raghavendra et al., 2017). Researchers and policymakers have supported sustainable water resource management as the best approach to mitigate the current and future challenges of water resources and have emphasized that sustainable water management in agriculture should concurrently accomplish two goals: supporting agricultural water requirement to ensure food security, and preserving the natural environment

*Corresponding Author

associated with it (Cai et al., 2003). It is imperative to improve water productivity to maintain agricultural production to guarantee food security. Sustainability as a whole encompasses three dimensions: economic, social and environmental (Lynam and Herdt, 1989). An important policy for implementing integrated water resource management is the pricing policy that allows distributing water among users in proportion to the value of marginal product and motivates them to save water and avoid its waste (Easter, 1999).

Qazvin province in Iran is among the regions that have been suffering from the scarcity of surface water resources, low irrigation tariffs and efficiency, inefficient water allocation in the study areas, and improper cropping pattern (Water Research Institute, 2008). Extensive research in Iran and other parts of the world has focused on water resource operation management and different pricing policies by mathematical programming. Some studies have calculated sustainability indicators with different methods and have explored the effect of various scenarios of saving environmental inputs on each sustainability indicator. Some have used fractional mathematical programming to calculate sustainability indicator for different scenarios that influence water use (Borimnejad and Yazdani, 2004; Mousavi and Gharghani, 2009; Azimifard et al., 2013; Yazdani et al., 2016).

Some works have used positive mathematical programming and maximum entropy to study the effect of pricing policies and have mostly documented that unsustainability in different dimensions has existed in the respective studied areas (Bakhshi et al., 2011; Hezareh, 2013; Kavousi Akbaripour, 2013; Rahnama et al., 2013; Parhizkari et al., 2014; Vaziri et al., 2016; Bagheri et al., 2017). Among studies in other countries, we can list Gómez-Limón and Riesgo (2004), Iglesias and Blanco (2008), Berbel et al. (2009), Cortignani and Severini (2009), Gallego-Ayala and Gómez-Limón (2009), Speelman et al. (2009), and Gallego-Ayala (2012) that have tested the multidimensional impacts of water pricing separately.

According to what was mentioned, the need for considering water resource management and examining the regulations on water pricing shows that there are legal potentials to implement different methods of pricing. Therefore, with respect to severe crises faced by water resources in Qazvin plain, the present paper focuses on the effect of various pricing methods on cropping pattern and the factors underpinning sustainability dimensions (economic, social, and environmental) in lands covered by the irrigation network in a certain time period in order to provide the policymakers with some guidelines.

Materials and Methods

The present study aimed to evaluate the response of irrigation network users in Qazvin province, Iran to different water resource pricing scenarios. The study was composed of two phases: (1) the selection of water pricing scenarios, and (2) the simulation of farmer behaviour. Water resources were priced in terms of ha or area, volume, or by two-part tariff with respect to the facilities and technical conditions of the network, as well as the regulations of water tariffs. The scenarios were defined by the predetermined pricing techniques and three criteria, i.e. final cost, economic value, and ability to pay for water. They are described in Table 1. The results of the calculation of final cost, economic value, and residual value of the agricultural water as compared to the current local tariffs show that the cost to supply 1 m^3 water including the costs of the dam and network operation and maintenance amounts to 3,090 IRR[1] which rises to 13,960 IRR when capital costs are included.

The economic value of water is at least 7,730 and at most 11,010 IRR/m^3 whereas the average residual value of water is 3,610 IRR/m^3. It should be noted that the water tariff in 2015-2016 was 565 IRR/m^3 and extra ration from the integrated wells had the tariff of 1,130 IRR/m^3. It is evident that the water tariff is much lower than its supply cost. On the other hand, the current tariff is much lower than the economic value and the average residual value. Consequently, the demand has been increased for water, the growing of crops with low economic values has been rendered economical, and the farmers show low willingness to use water-saving irrigation technologies. So, the government has to provide facilities as an incentive to encourage farmers to participate in pressurized irrigation schemes.

Farmer behaviour is simulated with a positive mathematical programming model. The structure of the model is grounded on an integration of the models used in relevant literature (Gómez-Limón and Riesgo, 2004; Gallego-Ayala and Gómez-Limón, 2009; Gallego-Ayala, 2012; Medellin-Azuara et al., 2012; Jamali Moghaddam, 2016; Hosseinpour Talebi, 2016; Shankayi, 2016). Recent years have witnessed extensive attempts to

[2] 1000 IRR (Iranian Rial) = US$0.023

Table 1: The description of scenarios considered for water pricing policies

No.	*Scenarios (water pricing policies)*			*Crops*							
				Total average (IRR)	*Wheat*	*Barley*	*Canola*	*Sugar beet*	*Green maize*	*Tomato*	*Alfalfa*
1	Status quo (per m^3)	Dam		565							
		Well		1130							
2	Area (per ha)	Final cost	Maintenance and operation costs	9861400							
			Total costs	44609320							
		Economic value of water	Minimum	24791290							
			Maximum	35182570							
		Residual value of water (ability to pay)	Average	11520920							
			Crops		27730510	13718350	18412450	91895100	57098960	116732010	96256890
3	Volumetric (per m^3)	Final cost	Maintenance and operation costs	3090							
			Total costs	13960							
		Economic value of water	Minimum	7730							
			Maximum	11010							
		Residual value of water (ability to pay)	Average	3610							
			Crops		3466	2111	2630	6126	4758	8647	5666
4	Two-part tariff	Final cost	Capital costs (per ha)	34747920							
			Maintenance and operation costs (per m^3)	3090							

Source: Research findings.

integrate econometric and programming methods into a single appropriate technique which have yielded the introduction of positive mathematical programming (PMP) models with the technique of maximum entropy. The model can be summarized as below:

$$max\ TGM = \sum_i \sum_t x_{it} \left(p_{it} y_{it} - c_{it} \right) \quad (1)$$

subject to:

$$\sum_i \sum_t (x_{it}) \le \sum_i \sum_t \left(x_{it}^0 \right) \quad (2)$$

$$\sum_i \left(x_{it} \right) \le \sum_i \left(x_{it}^0 \right) \left(1 + \varepsilon_1 \right) \quad (3)$$

$$x_{it} \le x_{it}^0 \left(1 + \varepsilon_2 \right) \quad (4)$$

$$\varepsilon_2 > \varepsilon_1 \quad (5)$$

$$x_{it} \ge 0 \quad (6)$$

In objective function (1), p denotes the i^{th} activity with the t^{th} technology, y represents each i^{th} activity with the t^{th} technology, c shows the variable cost of the i^{th} activity with the t^{th} technology, x is the variable of production decision or activity. Also, i represents the crops commonly grown in the studied region including wheat, barley, alfalfa, green maize, sugar beet, tomato and canola, and t denotes the technologies applied in the region including flooding, sprinkler and tape irrigation technologies. It should be mentioned that tape irrigation is not used for alfalfa, sprinkler and tape irrigation are not used for sugar beet, and sprinkler is not used for tomato. So, decision variables are decreased from 21 to 17.

In constraints, Equation (2) is related to total irrigation land available in the studied region. In this equation, x_{it}^0 shows the production activities with the intended technologies in the region. Equation (3) in which ε_1 expresses a small positive value shows the constraints for the whole activities in the studied region. Equation (4) describes the constraints for each activity type. In this equation, ε_2 is another small positive value that should be held true in Equation (5). In calibration constraints, the dual values pertaining to these constraints that expressed the shadow price of the produced crops are calculated. Given that the basic goal of the present study is to calibrate yield function for different crops – in order to identify well-formed yield functions that can describe farmers' real behaviour and to explore the effect of different policies on cropping pattern and input use – different forms of yield function is estimated for each crop by POLS[2] method.

The rationale for the use of this method is that it overcomes the shortcoming of the OLS technique and also the drawback of mathematical programming and PMP techniques presented by Howitt with respect to the use of means. POLS method groups all farmers and identifies production and yield functions for each individual farmer by reconstructing all observations in the base year and their simulation, thereby providing policymakers with better results. POLS technique is the same as the OLS technique that is performed under maximum entropy approach with probabilistic distribution and expected value. In this method, to maximize the Shannon objective function by probabilities, support points are considered to provide the maximum information for estimating the parameters of the economic model. By substituting the function of the sum of squared error terms for each economic model (linear, quadratic, cubic, etc.) and consequently its minimization under the approach of maximum entropy in the Shannon objective function assuming the structural constraints, first-order conditions and probabilistic functions with support points, the POLS technique well estimates the parameters of various function in the following cases:

1. in ill-posed situations in which the parameters of a model outnumber the statistical observations,
2. when there are problems arising from incorrect signs of the parameters, and
3. when the parameters are inherently non-linear.

The general model of the POLS method is as below:

$$\begin{aligned} \max H\left(B_0,\ldots,B_k\right) = & -P_{B_{011}} \log\left(P_{B_{011}}\right) \\ & - \cdots - P_{B_{01m}} \log\left(P_{B_{01m}}\right) - \cdots \\ & - P_{B_{11}} \log\left(P_{B_{11}}\right) - \cdots - P_{B_{1m}} \log\left(P_{B_{1m}}\right) \\ & - \cdots - P_{B_{k1}} \log\left(P_{B_{k1}}\right) - \cdots \\ & - P_{B_{km}} \log\left(P_{B_{km}}\right) - \sum_{i=1}^{n} U_i^2 \end{aligned} \quad (7)$$

in which B's represent the model parameters and P shows the probability level. Equation (7) that is a concave function represents the general form of the probabilistic distribution of the coefficients with respect to the support points. The last term in Equation (7) is the sum of squared errors that can bear any function form. Given the number of statistical observations, the first-order conditions of this function with its specific form should be applied to the model as a constraint so

[2] Probabilistic OLS developed by Peykani.

that the parameters can be estimated around the signs of the parameters with the help of the support points. The production function that is subjected to this examination should be selected in accordance with the technological structure of the agricultural sector. The appropriate production function is selected from the flexible production functions[3] for a good model in terms of the following criteria as Judge suggests: (1) the number of descriptive variables; (2) good fit; (3) compatibility with theory and agreement of coefficient signs with theory; and (4) generalizability and prediction potential (comparison of prediction with reality and experiences) (Gujarati, 1995). So, the estimation function is in the form of a third-order production function in which the constraints are defined as below:

$$B_0 + \sum_{i=1}^{n}(B_i X_i + B_j X_j^2 + B_k X_k^3 + X_i X_j \pm u_i) = Y_i \quad i \neq j \neq k \tag{8}$$

$$B_{11}P_{B_{11}}\left(\frac{Y_i}{X_i}\right) + \ldots + B_{1m}P_{B_{1m}}\left(\frac{Y_i}{X_i}\right) = B_1$$

$$B_{21}P_{B_{21}}\left(\frac{Y_i}{X_i^2}\right) + \ldots + B_{2m}P_{B_{2m}}\left(\frac{Y_i}{X_i^2}\right) = B_2$$

$$\ldots \cdot \ldots$$

$$B_k P_{B_{k1}}\left(\frac{Y_i}{X_i^k}\right) + \ldots + B_k P_{B_{km}}\left(\frac{Y_i}{X_i^k}\right) = B_k$$

Finally, the sum of the probabilities for the support points of the parameters should be equal to 1. Thus, to have this condition, the following constraints should be applied to the model:

$$\begin{aligned} P_{B_{01}} + \ldots + P_{B_{0m}} &= 1 \\ P_{B_{11}} + \ldots + P_{B_{1m}} &= 1 \\ P_{B_{k1}} + \ldots + P_{B_{km}} &= 1 \end{aligned} \tag{9}$$

To study the farmers' behaviour, the statistical population was composed of all farmers who worked in the lands located at the lower part of the Grade 2 canals of the irrigation network in Qazvin plain. This population amounted to 87 villages and five counties (Abyek, Buin Zahra, Takestan, Qazvin and Alborz). The population was sampled by the two-stage cluster sampling technique. The main cluster was determined on the basis of the distance from the catchment location. Among the villages, 20 villages were sampled randomly according to Cochran's formula as below:

$$n = \frac{Nt^2S^2}{Nd^2 + t^2S^2}$$

A number of 120 questionnaires were collected in the 2015-2016 growing season.

Results and Discussions

The present study focused on the irrigation network of Qazvin plain as the study site. This is one of the oldest and most modern irrigation networks in Iran and possesses appropriate technical and institutional facilities for optimal allocation of water resource and implementation of water pricing policies including volumetric water delivery to local water authorities (called *Mirab* in Iran), proper infrastructure and measurement tools as the prerequisite for water allocation and pricing, and the existence of water user associations in the network (Water Research Institute, 2008). The network was constructed to transfer water from Ziyaran Dam to the agricultural lands of Qazvin and covers 80,000 ha gross area and 58,000 ha net area of the lands with grade 1 and grade 2 soil. Figure 1 displays the general scheme of the network.

The main crops in lands served by the network include wheat, barley, canola, green maize, sugar beet, tomato, and alfalfa. They were included in the model as the decision variables. The data on yield, price, income, production costs, and water requirements of these crops are summarized in Table 2.

It is evident in this table that sugar beet, green maize and tomato have high yields whereas canola, barley, and wheat produce low yields. The amount of water used by alfalfa, sugar beet, tomato and green maize is over 10,000 m^3/ha and the highest gross margin is related to tomato, sugar beet, alfalfa and green maize which generate a return of over 50,000,000 IRR/ha. The results show that the application of pressurized irrigation technologies (sprinkler and tape systems) will reduce water use considerably so that irrigation efficiency will be improved from 35% for flood irrigation to about 70% for sprinkler irrigation and 90% for pressurized irrigation. Thus, production costs will be decreased

[3] Flexible functions are functions that can show the third region of production and can consider the interactions between inputs for production. These functions included generalized quadratic functions, generalized Leontief function, Translog, and third-order.

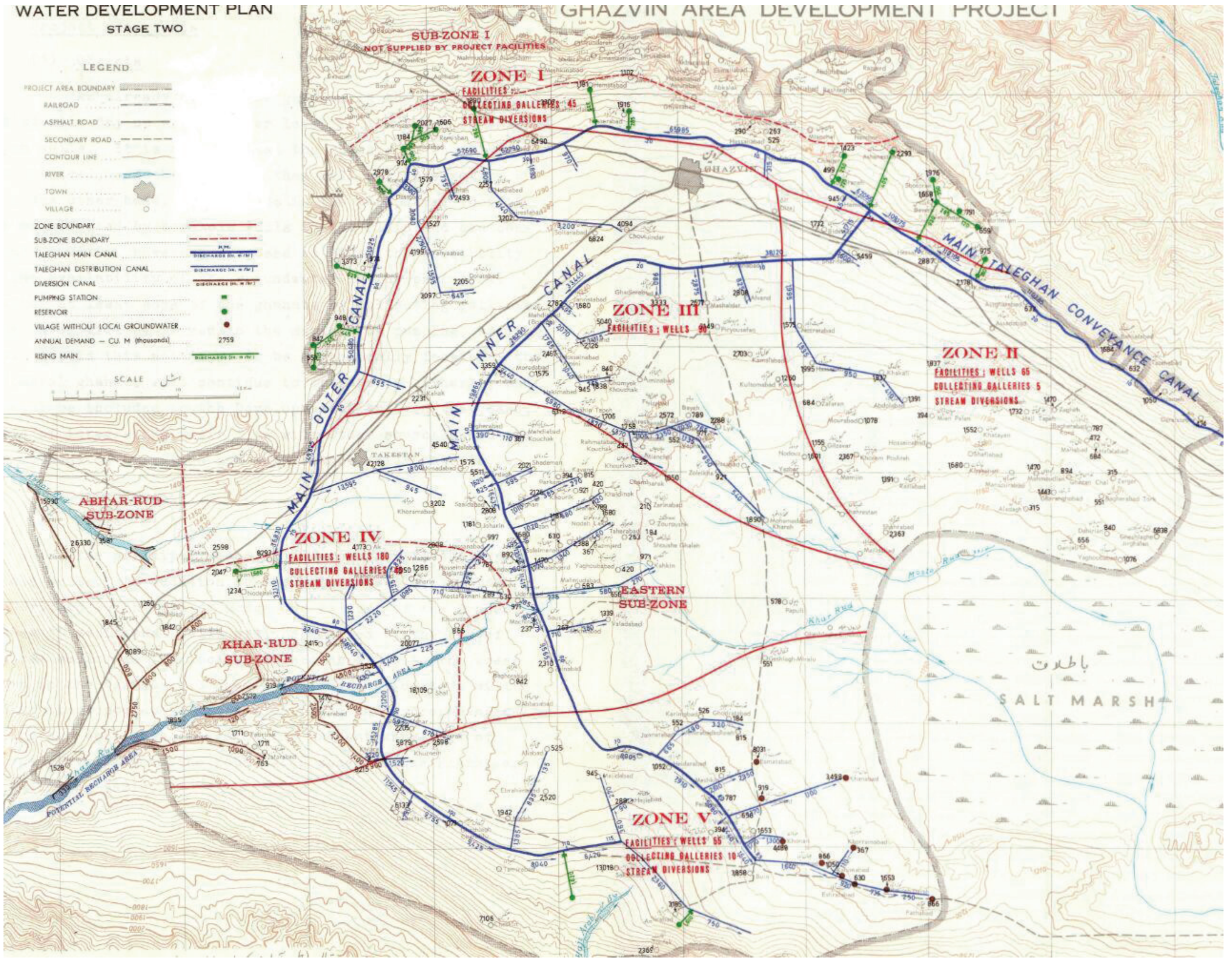

Figure 1: The general map of the irrigation network of Qazvin plain and the covered lands.

Table 2: Average quantities of production and consumption of inputs in current major crops

Crops	*Irrigation technology*	*Yield (kgha^{-1})*	*Gross margin (IRR ha^{-1})*	*Water (m^3 ha^{-1})*
Wheat	Flood	5133	2321051	8000
	Sprinkler	5082	2799306	4000
	Tape	6160	4110564	3111
Barley	Flood	4382	1004585	6500
	Sprinkler	4338	1406029	3250
	Tape	5258	2293012	2528
Canola	Flood	2400	1004585	7000
	Sprinkler	2376	1406029	3500
	Tape	2880	2293012	2722
Green maize	Flood	51443	5031896	12000
	Sprinkler	50414	5614630	6000
	Tape	61732	7983256	4667
Tomato	Flood	48317	10910451	13500
	Tape	57980	17636774	5250
Sugar beet	Flood	54109	8342010	15000
Alfalfa	Flood	17672	8665189	17000
	Sprinkler	21206	12410471	8500

Source: Research findings.

and the gross margin will be increased significantly. But, the implementation of these technologies requires substantial initial costs, a considerable of which is provided by the Jihad-e Agriculture Organization as a government grant.

As was noted, one of the main policies that influence water use in the agricultural sector is water pricing policy. The main goal of the agriculture as an economic activity is profitability. Thus, farmers show different behaviour patterns to policies that affect the relative income of their crops. So, responses vary with policies. This section used PMP method to examine the effect of higher water price as per the scenarios described in Table 1 on production rate, water use, cost and gross margin of each crop. To this end, the production functions of the main regional crops were estimated separately for irrigation technologies and available water resources. So, all options available in the studied region were considered in the production of the irrigated crops. Farmers' response is almost similar in production functions of the same crops irrigated with the same technologies given the fact that the studied region is homogeneous in terms of climatic conditions, water and soil, access to input market, and crops. The only difference is in the tariffs to use well or dam water resources (well water tariff is twice as great as that of dam water), but since the tariffs are much lower than the cost of water supply and its value, this difference can be ignored.

Table 3 presents the results of area pricing policy, in which the volume of the delivered water is not measured and the water is charged as per the hectares, under different scenarios. In all scenarios, the gross margin is mostly decreased due to the cost variations and, in some scenarios, the growing of the crops comes to a full stop because of the loss of return. It is observed that the growing of wheat, barley, canola, green maize and tomato with flood irrigation system is rendered uneconomical in the scenarios of pricing by total costs, minimum water value, and maximum water value. In the scenario of pricing by average ability to pay, farmers stop growing wheat and tomato under flood irrigation system and green maize under flood and sprinkler irrigation systems. It is surprising that in the scenario of pricing by operation and maintenance costs in which all crops have economical return, the water consumption does not change and only an increase is observed in water use in the systems that use sprinkler irrigation so that 22%, 31% and 71% more water is used in wheat, canola and alfalfa farms, respectively, and no reduction in water use is seen in farmers' behavior. In the scenario of pricing by maximum water value, the highest cost is incurred to the production. As a result, it experiences the greatest loss of gross margin among the crops so that the return of sugar beet irrigated by flood system is reduced by as high as 50%. The lowest loss of gross margin among the scenarios is related to the scenario of pricing by operation and maintenance costs in which the highest loss of gross margin is 32% related of alfalfa irrigated by flood system and the lowest loss is 2% related to canola and tomato irrigated by tape system.

In the context of the scenario of water pricing on the basis of the volume of the water delivered to the farmers, the results for the scenarios of pricing by water supply cost, by economic value, and by residual value of water show that in the scenarios of pricing by operation and maintenance cost and by average ability to pay, all studied crops are kept being grown but when water is priced in terms of the ability to pay for crops, farmers stop growing green maize irrigated by flood system because of its uneconomical return. In the scenarios of pricing by total costs, by minimum water value, and by maximum water value, some low-return crops (wheat, barley, canola, green maize and alfalfa) irrigated by flood system and, in some cases, by sprinkler system are eliminated from the cropping pattern. The flood irrigation system is upheld just for tomato and sugar beet because of their high return. An increase is predicted in the demand for labour with respect to wheat and alfalfa irrigated by sprinkler system.

In this pricing policy in all scenarios that have economic return, the simulation of farmers' response shows the decline of water use. The extent to which water use is reduced for crops is mostly greater in flood irrigation system than in other irrigation technology so that the maximum reduction is about 40% observed in wheat farms irrigated with flood system in the scenarios of pricing by operation and maintenance costs, by average ability to pay, and by the ability to pay for crops. The lowest loss of return among all studied scenarios is related to tomato irrigated by tape system whose return is decreased by 6% in the scenarios of pricing by operation and maintenance costs and by the ability to pay for crops. The highest loss is observed in canola irrigated by sprinkler system and in barley irrigated by tape system so that their return is reduced by 75% and 71% in the scenario of pricing by total costs, respectively (Table 4).

In two-part tariff policy that is a combination of both area and volumetric pricing policies and is required by Articles 33 and 34 of Fair Water Distribution Act enacted in 1982, it is observed that farmers stop

Table 3: The effects of area pricing policy

Pricing criteria		*Operation and maintenance costs*				*Total costs*				*Minimum water value*			
Crops	*Irrigation technology*	*Product*	*Cost*	*Gross margin*	*Water*	*Product*	*Cost*	*Gross margin*	*Water*	*Product*	*Cost*	*Gross margin*	*Water*
Wheat	Flood	0%	11%	-11%	22%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	9%	-9%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	10%	-10%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
Barley	Flood	0%	23%	-23%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	22%	-22%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	13%	-13%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
Canola	Flood	0%	10%	-10%	31%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	9%	-9%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	2%	-2%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
Green Maize	Flood	0%	22%	-22%	6%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	13%	-13%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	4%	-4%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
Tomato	Flood	0%	3%	-3%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	2%	-2%	0%	0%	27%	-27%	0%	0%	23%	-23%	0%
Sugar beet	Flood	0%	0%	0%	0%	-18%	0%	-18%	0%	0%	29%	-29%	0%
Alfalfa	Flood	0%	32%	-32%	72%	0%	30%	-30%	72%	0%	41%	-41%	72%
	Sprinkler	0%	10%	-10%	0%	0%	19%	-19%	0%	0%	47%	-47%	0%

(*Contd.*)

Pricing criteria		*Maximum water value*				*Average ability to pay*				*Ability to pay for crops*			
Crops	*Irrigation technology*	*Product*	*Cost*	*Gross margin*	*Water*	*Product*	*Cost*	*Gross margin*	*Water*	*Product*	*Cost*	*Gross margin*	*Water*
Wheat	Flood	Elimination from cropping pattern				Elimination from cropping pattern				0%	46%	-46%	39%
	Sprinkler	Elimination from cropping pattern				0%	43%	-43%	0%	0%	35%	-35%	0%
	Tape	Elimination from cropping pattern				0%	45%	-45%	0%	0%	36%	-36%	0%
Barley	Flood	Elimination from cropping pattern				Elimination from cropping pattern				0%	44%	-44%	0%
	Sprinkler	Elimination from cropping pattern				Elimination from cropping pattern				0%	34%	-34%	0%
	Tape	Elimination from cropping pattern				0%	73%	-73%	8%	0%	20%	-20%	8%
Canola	Flood	Elimination from cropping pattern				0%	65%	-65%	31%	0%	17%	-17%	31%
	Sprinkler	Elimination from cropping pattern				0%	72%	-72%	0%	0%	27%	-27%	0%
	Tape	Elimination from cropping pattern				0%	60%	-60%	0%	0%	24%	-24%	0%
Green maize	Flood	Elimination from cropping pattern				Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	Elimination from cropping pattern				Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	Elimination from cropping pattern				0%	47%	-47%	0%	0%	69%	-69%	0%
Tomato	Flood	Elimination from cropping pattern				Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	56%	-56%	0%	0%	26%	-26%	0%	0%	27%	-27%	0%
Sugar beet	Flood	0%	50%	-50%	0%	0%	18%	-18%	0%	0%	46%	-46%	0%
Alfalfa	Flood	0%	76%	-86%	72%	0%	32%	-32%	72%	0%	83%	-83%	72%
	Sprinkler	0%	91%	-91%	0%	0%	39%	-39%	0%	0%	88%	-88%	0%

Source: Research findings.

Table 4: The effects of volumetric pricing policy

Pricing criteria		*Operation and maintenance costs*				*Total costs*				*Minimum water value*			
Crops	*Irrigation technology*	*Product*	*Cost*	*Gross margin*	*Water*	*Product*	*Cost*	*Gross margin*	*Water*	*Product*	*Cost*	*Gross margin*	*Water*
Wheat	Flood	0%	15%	-15%	-42%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	16%	-16%	-12%	Elimination from cropping pattern				0%	42%	-42%	-24%
	Tape	0%	9%	-9%	0%	0%	54%	-54%	0%	0%	26%	-26%	-5%
Barley	Flood	0%	38%	-38%	-7%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	18%	-18%	-15%	Elimination from cropping pattern				0%	45%	-45%	-28%
	Tape	0%	10%	-10%	-6%	0%	71%	-71%	-7%	0%	23%	-23%	-17%
Canola	Flood	0%	20%	-29%	-35%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	13%	-13%	-12%	0%	75%	-75%	-26%	0%	34%	-34%	-24%
	Tape	0%	8%	-8%	-3%	0%	58%	-58%	-5%	0%	22%	-22%	-5%
Green maize	Flood	0%	46%	-46%	-45%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	34%	-34%	-9%	Elimination from cropping pattern				Elimination from cropping pattern			
	Tape	0%	10%	-10%	-19%	0%	48%	-48%	-20%	0%	27%	-27%	-23%
Tomato	Flood	0%	7%	-7%	-2%	0%	26%	-26%	-39%	0%	18%	-18%	-8%
	Tape	0%	6%	-6%	-4%	0%	18%	-18%	-5%	0%	14%	-14%	-7%
Sugar beet	Flood	0%	8%	-8%	-5%	0%	57%	-57%	-5%	0%	23%	-23%	-12%
Alfalfa	Flood	0%	29%	-29%	0%	Elimination from cropping pattern				Elimination from cropping pattern			
	Sprinkler	0%	19%	-19%	-8%	0%	57%	-57%	-33%	0%	31%	-31%	-17%

(*Contd.*)

Pricing criteria		*Maximum water value*				*Average ability to pay*				*Ability to pay for crops*			
Crops	*Irrigation technology*	*Production*	*Cost*	*Gross margin*	*Water*	*Production*	*Cost*	*Gross margin*	*Water*	*Production*	*Cost*	*Gross margin*	*Water*
Wheat	Flood	Elimination from cropping pattern				0%	15%	-15%	-42%	0%	23%	-23%	-44%
	Sprinkler	Elimination from cropping pattern				0%	16%	-16%	-12%	0%	22%	-22%	-5%
	Tape	0%	44%	-44%	-5%	0%	9%	-9%	0%	0%	11%	-11%	0%
Barley	Flood	Elimination from cropping pattern				0%	38%	-38%	-7%	0%	19%	-19%	-5%
	Sprinkler	Elimination from cropping pattern				0%	18%	-18%	-15%	0%	7%	-7%	-23%
	Tape	0%	39%	-39%	-26%	0%	10%	-10%	-6%	0%	4%	-4%	-10%
Canola	Flood	Elimination from cropping pattern				-9%	20%	-29%	-35%	-9%	15%	-24%	-36%
	Sprinkler	0%	40%	-40%	-36%	0%	13%	-13%	-12%	0%	10%	-10%	-14%
	Tape	0%	34%	-34%	-17%	0%	8%	-8%	-3%	0%	5%	-5%	-5%
Green maize	Flood	Elimination from cropping pattern				0%	46%	-46%	-45%	Elimination from cropping pattern			
	Sprinkler	Elimination from cropping pattern				0%	34%	-34%	-9%	0%	56%	-56%	-14%
	Tape	0%	56%	-56%	-27%	0%	10%	-10%	-19%	0%	18%	-18%	-20%
Tomato	Flood	0%	21%	-21%	-36%	0%	7%	-7%	-2%	0%	25%	-25%	-5%
	Tape	0%	14%	-14%	-7%	0%	6%	-6%	-4%	0%	14%	-14%	-2%
Sugar beet	Flood	0%	46%	-46%	-1%	0%	8%	-8%	-5%	0%	22%	-22%	-4%
Alfalfa	Flood	Elimination from cropping pattern				0%	29%	-29%	0%	0%	52%	-52%	-7%
	Sprinkler	0%	27%	-27%	-17%	0%	19%	-19%	-8%	0%	26%	-26%	-15%

Source: Research findings.

Table 5: The effects of two-part tariff pricing policy

Pricing criteria		*Total costs*			
Crops	*Irrigation technology*	*Production*	*Cost*	*Gross margin*	*Water*
Wheat	Flood		Elimination from cropping pattern		
	Sprinkler		Elimination from cropping pattern		
	Tape	0%	54%	-54%	0%
Barley	Flood		Elimination from cropping pattern		
	Sprinkler		Elimination from cropping pattern		
	Tape		Elimination from cropping pattern		
Canola	Flood		Elimination from cropping pattern		
	Sprinkler		Elimination from cropping pattern		
	Tape	0%	58%	-58%	-5%
Green maize	Flood		Elimination from cropping pattern		
	Sprinkler		Elimination from cropping pattern		
	Tape	0%	46%	-46%	-28%
Tomato	Flood	0%	38%	-38%	-3%
	Tape	0%	15%	-15%	-5%
Sugar beet	Flood	0%	26%	-26%	-4%
Alfalfa	Flood	0%	55%	-55%	-5%
	Sprinkler	0%	40%	-40%	0%

Source: Research findings.

growing some low-return crops and even the application of pressurized irrigation system does not render their growing economical (e.g. barley). But, growing some crops like wheat, canola and green maize irrigated with tape system is economical. Nonetheless, the loss of gross margin is observed in all crops and this can be attributed to the increased cost. The water use is decreased in almost all crops that are predicted to be included in cropping pattern. The highest decrease in water use is 28% related to green maize irrigated by tape system, but water use does not change for alfalfa irrigated by sprinkler system and wheat irrigated by tape system. The highest loss of return in the context of this pricing policy is 59% that is related to canola, 55% that is related to alfalfa irrigated by flood system, and 54% that is related to wheat irrigated by tape system.

Conclusions

The present paper simulated farmers' response to various scenarios of water pricing policy versus the status quo. According to the results, higher water price in the context of area pricing policy only influences farmers' profit and thereby affects the cropping pattern, but water use is not decreased and even in flood irrigation systems, it is increased remarkably. Also, in this scenario, most crops that are crossed out from the cropping pattern have a lower water requirement. But, in the scenarios of water price increase by volumetric pricing policy, the impacts extend to water use reduction in addition to its economic effects on profitability. Thus, these scenarios contribute to environmental sustainability. In two-part pricing policy, water use is reduced remarkably because of the volumetric delivery of water to farmers and their charging at a fixed rate. This policy renders the cropping systems that are based on flood irrigation technology uneconomical and enforces farmers to select high-return crops for their cropping system and concurrently adopt pressurized irrigation technologies to ensure the profitability. So, to enhance water use efficiency and alleviate the harmful environmental impacts of the unbalanced use of water in agricultural production, the government is recommended to adopt volumetric water supply policy and to stop water subsidization policy.

Nonetheless, it should be noted that the immediate abolishment of subsidization policy will entail a sharp increase in production costs and will severely impair smallholders who usually lack the financial reserves so that they may be eliminated from the production chain. Thus, it is recommended to implement price liberalization policy on water in the agricultural sector gradually and at the same time, to provide farmers with direct payment policy in order to help them adopt proper irrigation technology. Also, it is necessary to implement the policy of guaranteed trade of crops that have low water requirement so that farmers have enough chance to accommodate with the new conditions and the damages to the agricultural sector can be alleviated.

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