J. Agr. Sci. Tech. (2020) Vol. 22(2): 579-593

Selecting Strategic Policy for Irrigation Water Management (Case Study: Qazvin Plain, Iran)

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ABSTRACT

Water is considered as the most important component, but a limiting input, for agricultural production in Iran. In the context of water resources management, due to the limited availability of water and high cost of supplying it to the users, improvement of water use productivity has been regarded as one of the most appropriate approaches to manage water demand. Various tools have been applied for water management policy in the context of preventing high levels of water deficit. In the present study, different policy scenarios related to water supply management are assessed. These include estimation of the impacts of each policy scenario on physical and economic productivity indices and employment, using positive mathematical programming methods and maximum entropy. This methodology was applied to water use in the Qazvin Plain, Iran. Results suggested that application of these policy scenarios not only decreased water consumption but also generated desirable social and economic effects. Results of the ranking showed that the policy of imposing tax on input generated the best results for the study area. However, it is admitted that selection of the best policy scenario is dependent on the weight that policy makers would select for various indicators.

Keywords: Positive Mathematical Programming, Maximum Entropy, ELECTRE, AHP, Water Productivity

INTRODUCTION

Water is a fundamental element for life as well as for important processes of all creatures and, therefore, is considered as the main basis for life permanence on the earth (Gomez-Limon and Martinez, 2006; Viala, 2008; Pimentel *et al.*, 1997). Studies in Iran show that a 10% decrease in water availability causes a 0.8% decrease in gross national product (Yousefi, 2010). Accordingly, an improvement of water consumption in Iran is regarded as one of the most important issues in the long-term development of the country. Current target for water consumption in agricultural uses for Iran is to reduce it from 92% to 87% in the next 20 years (Yousefi *et al.*, 2011).

In the light of the forthcoming shortage of water, some economists and policymakers around the world have proposed various approaches to solve such universal water resources problems (He *et al.*, 2005). One of the recommended solutions is implementation of a national water productivity system for agriculture (Bouman and Tuong, 2001). To achieve this goal, initial identification of effective factors in increasing the productivity of this scarce input is needed, which should be based on appropriate planning and research on the improvement of its productivity (Dinar, 2000). This is supported in Iran by Ehsani and Khaledi (2003). Fortunately, such a measure has been endorsed by policymakers and other specialists in Iran, as noted in section 4 of The General Policy, sections 19 and 37 of Development Plan, sections 6 and 10 of the

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[DOR: 20.1001.1.16807073.2020.22.2.17.5]

long-term strategies of water resources development in the country, plus article 18 of Development Plan. Therefore, increasing water productivity is emphasized as one of the main strategies for managing scarce water resources.

One of the solutions for increasing water resources productivity includes management of water demand and application of on-line management tools. Using these tools, the impact of different policies for agricultural water demand can be simulated. These policies may be related to pricing and water supply control, as well as various other complementary policies (e.g., the policy of imposing tax on input, tax on products or a mixture of these issues) (He *et al.*, 2005). Such policy evaluations have been carried out in Iran as well as in other parts of the world, which are reviewed below.

Tsur and Dinar (1997) found that water use is most efficient when pricing, such as Marginal Cost Pricing (MCP), is administered. However, the main drawback of MCP is the difficulty of including all marginal costs and benefits when determining the correct price to charge. Furthermore, as Perry (2001) indicates, a high marginal cost for water can reduce demand effectively; but is unlikely to be accepted politically. The limited acceptable range of pricing has weakened water pricing effectiveness as a policy option.

Molle (2002) summarized the reasons why water charges have been generally low for agriculture: 1) political sensitivity to increases in food prices, 2) competitiveness in international markets, 3) depressed level of most staple food prices as well as their fluctuating nature, and 4) the political risks associated with a significant increase in water charges. Numerous studies have suggested that maintaining low water tariffs will make this policy instrument ineffective in improving water allocation efficiency and increasing agricultural productivity (Molle and Center, 2001; Ogg and Gollehon, 1989; Johansson *et al.*, 2002). These studies have also concluded that transaction costs make the implementation of water pricing methods difficult. In response to high transaction costs, political economy concepts and new institutional approaches have been introduced into the analysis of water pricing reforms. He *et al.* (2006) responded to the question related to what policy alternatives to water pricing might improve irrigation water allocation efficiency. They provided a comparison of irrigation policies for allocating scarce water to agricultural production in Egypt and Morocco. Partial equilibrium agricultural sector models (specific to Egypt and Morocco) were employed for testing policy measures. Positive Mathematical Programming (PMP) was used to calibrate the models. Results suggest that effective policy depends on the social, economic, and environmental contexts of the specific regions. Cortignani and Severini (2009) applied the PMP model to investigate impacts of policies, such as water costs increase, reduction of water, and price change of products on the acceptance of the those systems that use lower volume of water in an area in Mediterranean countries. Results revealed that water cost had no effect on the acceptance of low-irrigation techniques. Latinopoulos (2008) examined the effects of pricing of irrigation water on the water demand in the north of Greece using multi-criteria decision- making (MCDM) approach. The main findings of the study showed that if water pricing is implemented as a political tool, it would face economic, social, and economic consequences, including 14% savings in water demand and 12% reduction in farmers' income, along with a decline in employment. Such changes can lead to serious economic impacts in the medium and long terms. Liu *et al.* (2008) investigated the physical productivity of water in 124 countries. He found that United States of America and China had the highest rate of water productivity in contrast with African countries, which had the lowest physical water productivity. Kahil *et al.* (2015) examined the impact of economic and environment on two water management policies (water markets and irrigation subsidies) on the irrigated agriculture in Southern Europe by using PMP. Results showed that water markets had higher private and social benefits than irrigation subsidies. Feike and Henseler (2017) employed PMP to investigate the impacts of multiple policy instruments on the rural development in China. Results indicated that combining the subsidies with multiple policy

[DOR: 20.1001.1.16807073.2020.22.2.17.5]

instruments could play a key role in promoting rural development. A number of previous studies have used the Elimination and Choice Translating Reality (ELECTRE) method in water research (Haider *et al.*, 2015; An *et al.*, 2017; Chhipi-Shrestha *et al.*, 2017; Punys *et al.*, 2019). In particular, Haider *et al.* (2015) used the ELECTRE method to select the performance indicators for small and medium sized water utilities. Based on the findings of this study, ELECTRE is a useful method for decision making when there exist small differences between various alternatives.

To sum up, previous studies have overlooked the importance of productivity indicators in selecting the best strategies for water management. Responding to this deficiency, in this study, we attempted to prove that making decisions based on productivity, economic, and social indicators can contribute to improving water management in Iran. Therefore, the objective of this study was to quantify the impact of four types of policy measures on productivity, economic, and social indicators, and then present the best strategies for water resources management. The contribution of this paper is two-fold. First, to the best of authors' knowledge, this is the first study that uses the combination of maximum entropy estimation and PMP to quantify the impact of policy measures on productivity, economic, and social indicators. Second, for the first time, it was attempted to use ELECTRE method to select the best strategies for irrigation water management.

MATERIALS AND METHODS

Study Area and Objectives

Figure 1 shows the location of study area (Qazvin Plain) in north of Iran. The needed water of Qazvin plain is provided by Taleghan dam. Water is released in no special order and is highly influenced by the urban demands of cities of Tehran and Karaj (high population concentration and extreme industrial activities) and climate-related extreme events (hydrological droughts). For the Qazvin region, urban population growth, low level of water productivity, inefficient allocation of water, and inappropriate cropping pattern are considered as major problems. In fact, the provision of adequate amount of water for urban consumption has been a challenging factor for the region. In order to solve this problem, various studies, based on technical and engineering approaches, have been conducted. However, due to the multifaceted and interdisciplinary nature of problems and issues regarding water resources (Serageldin, 1995), solution of problems in Qazvin plain requires consideration of economic, social, and

Figure 1. Study area: Qazvin Plain.

[DOR: 20.1001.1.16807073.2020.22.2.17.5]

political aspects aligned with technical solutions (Cai *et al.*, 2003).

In this study, data required for making the research model were obtained by collecting responses from 260 farmers for the crop year 2012–2013.

Design of Scenarios

In this study, four types of policy measures were simulated: 1) water pricing, 2) imposing input tax, 3) imposing output tax, and 4) water supply. With some variants, this resulted in six scenarios, as shown below:

Scenario S1: A 100% increase in price of irrigation water

Scenario S2: A 50% increase in price of irrigation water and 10% reduction in supply of irrigation water

Scenario S3: A 25% increase in price of irrigation water and 20% reduction in supply of irrigation water

Scenario S4: A 25% increase in input prices through tax (imposing input tax) (nitrogen and phosphate- fertilizer)

Scenario S5: A 50% increase in input prices through tax (imposing input tax) (nitrogen and phosphate- fertilizer)

Scenario S6: A 25% reduction in output prices through tax (imposing output tax) [(potato and tomato (These crops are higher water consumers.)]

Table 1 summarizes these scenarios. In scenarios S2 and S3, two policies, namely, water pricing policy and water supply policy, were included.

Analytical Framework: Positive Mathematical Programming (PMP)

Because farmers have many decision options in response to government policies, it is important to choose economic models that indicate farmers' behavior under novel strategic water policy and market conditions. In other words, these models must be able to show whether water policies can improve water saving objectives.

In the recent decade, PMP has turned into one of the famous models in farm level economic analyses. There are two main reasons for interest in this approach. First, the standard econometrics 'inability' to deal with incomplete and limited data and, second, linear programming models cannot correctly realize the farm production plan (Paris, 2010). Hence, PMP is widely used for policy analysis. In fact, PMP is perfectly calibrated to observed activity levels (Heckelei *et al.*, 2012).

The PMP methodology was introduced by Howitt (1995). This method is applied using a three-step program (Röhm and Dabbert, 2003):

Step One: Design a linear programming (LP) model to obtain the profit maximizing crop mix. The basic model can be stated as follows:

$$\max z = p' x - c' x \quad (1)$$

St

$$Ax \leq b \ [\lambda] \quad (2)$$

$$x \leq x_0 + \varepsilon \ [\rho] \quad (3)$$

$$x \geq 0 \quad (4)$$

Where, z is the objective function value, ρ is (n * 1) vector of product price, x is (n * 1) vector of production activity levels, c' is (n * 1) vector of accounting cost per unit of activity, A is (n*m) matrix of coefficients in resource constraints, b is (m*1) vector of available resource quantities , x_0 is (n * 1) vector of production activities of observed levels, ε is (n * 1) vector of small positive numbers to avoid linear dependence between structural constraints and calibration constraints, λ is (m*1) vector of dual variables related to resource constraints, and ρ is (n * 1) vector of dual variations related to calibration

Table 1. Description of policy scenarios.

Senario	Water Pricing Policy	Water Supply Policy	Input Tax Policy	Output Tax Policy
S1	✓			
S2	✓	✓		
S3	✓	✓		
S4			✓	
S5			✓	
S6				✓

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constraints.

Step two: In the second stage, dual values obtained in the first stage are used to calibrate yield function (Mittelhammer, 2000; Paris and Howitt, 1998). This production function can be expressed as follows (Jordan, 2012):

$$y_i = \sum_i x_{ij} \propto_{ij} - \frac{1}{2}\sum_{K=1} \beta_{ijk} x_{ij}\, x_{ij} \quad (5)$$

Where, i and k are crop type, j is production inputs, α and β are coefficients of production function, and y is yield of crop i. In calibration Eq. (5), it is needed to specify the number of parameters (n+n(n+1)/2) that is more than the number of observations. In other words, our model suffers as being "ill-posed". To avoid this problem, Maximum Entropy (ME) estimation was employed (Heckelei and Britz, 1999). ME estimation has several advantages. First, it allows flexibility in selecting the functional forms for objective function. Second, it has the potential of expanding the database for parameter specification. Third, ME estimation, as compared to the tradition econometrics model, has a lower dependence on the restrictions on parameters (Howitt and Britz, 1999). For further information about details of Maximum Entropy, see Howitt (2005).

Step Three: Vector and matrix in nonlinear production function are replaced by resource limitations of nonlinear programming pattern that are as follows:

$$MAX\ TGM = \Big(\Big\{\sum_j p_i \Big[\sum_i \propto_{ij} - \frac{1}{2}\sum_{K=1} \beta_{ijk} x_{ij}\Big] * x_{ij}\Big\} - \Big\{\sum_{Labour,land,machinery} \sum_i x_{ij} * c_{ij}\Big\} + t_{water} \sum_{water} \sum_i x_{ij} * q_{ij} + t_{Nitrogen\ \text{fertilizer}} \sum_{Nitrogen\ \text{fertilizer}} \sum_i x_{ij} * q_{ij} + t_{\text{Phosphate fertilizer}} \sum_{\text{Phosphate fertilizer}} \sum_i x_{ij} * q_{ij}\Big) \quad (6)$$

$$\sum_{j=land} \sum_i x_{ij} \le b_{land} \quad (7)$$

$$\sum_{j=land} \sum_i \frac{w_i}{ef_i} x_{ij} \le b_{water} \quad (8)$$

$$\sum_i a_{ij} x_{ij} \le b_j \quad (9)$$

$$x_{ij} \ge 0 \quad (10)$$

Where, sub-indices i, k and j are crop type and production inputs. Equation (6) is the objective function, which shows total gross margin (TGM), t_j are prices of inputs j (water, nitrogen and phosphate fertilizers), q_{ij} are the applied inputs j (water, nitrogen and phosphate fertilizers) to each crop i. The first constraint (Eq. 7) represents that sum of irrigated land cannot exceed total available land, and b_{land} is available land. The second constraint (Eq. 8) limits the water available for irrigation. Here, w_i , ef_i, and b_{water} are the water requirements of the i[th] crop, the technical efficiency, and total water available for irrigation, respectively. Equation (9) is a constraint for other input factors. Here, a_{ij} and b_j are Leontief coefficients and available resource quantities, respectively. The forth constraint (Eq. 10) imposes the non-negativity restrictions for the variable of x_{ij}.

Water Productivity Criteria

Generally, agricultural water productivity is estimated using different approaches. In this study, physical, economic and employment productivity criteria were employed following Molden *et al.* (2010) and Seckler (1996) , which are defined as follows:

- Physical productivity: Typically measured as production per unit of water;
- Economic productivity: Typically measured as producers' profit per unit of water;
- Employment productivity: Typically measured as the amount of employment created per unit of water.

Table 2 shows the equations used for calculating the above productivity criteria.

Selection and Weighting of Criteria using the ELECTRE Method

Once the analysis has more than one scenario (as noted above), there emerges a need for using a method of selecting the best scenario. In this study, this was accomplished using the ELECTRE method. This method benefits from a new concept known as 'outranking' instead of ranking the other options (Shanian and Savadogo, 2006; de Almeida, 2007; Roy and Vanderpooten, 1996; Belton and Stewart, 2002). In this procedure, all options are subjected to an evaluation through comparative outranking, leading to elimination of ineffective options (Shanian and

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Table 2. Formulas of productivity measures

	Formula [a]
Physical Productivity of Water	$\frac{\sum_{j=land}\sum_i y_i x.\, l_{ij}}{\sum_{j=land}\sum_i \frac{w_i}{ef_i} x.\, l_{ij}}$
Economic Productivity of Water	$\frac{\left(\left\{\sum_j p_i\left[\sum_i \propto_{ij} - \frac{1}{2}\sum_{K=1}\beta_{ijk} x.\, l_{ij}\right] * x.\, l_{ij}\right\} - \left\{\sum_j\sum_i x.\, l_{ij} * c_{ij}\right\}\right)}{\sum_{j=land}\sum_i \frac{w_i}{ef_i} x.\, l_{ij}}$
Employment Productivity of Water	$\frac{\sum_{j=land}\sum_i a_{i"labour"} x.\, l_{ij}}{\sum_{j=land}\sum_i \frac{w_i}{ef_i} x.\, l_{ij}}$

[a] $x.\, l_{ij}$ are the optimal level of inputs

Savadogo, 2006). ELECTRE has been introduced as one of the effective methods for ranking strategies when there is uncertainty and vagueness. Hence, ELECTRE has been used in many studies of economics, environmental factors, and water management (Velasquez and Hester, 2013).

The method consists of 9 steps:

Step 1: Calculate the normalized decision matrix using Eq. (11):

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \quad (11)$$

Where, r_{ij} is the rating of alternative $A_i$with respect to the criteria C_j , w_j is weight of the criteria C_j, i-1,…,m, m is number of alternatives, and j=1,…,n, n is number of criteria (Jahanshahloo *et al.*, 2006).

Step 2: Multiply the weighted and normalized decision matrices:

$$V_{ij} = n_{ij}.w_j \quad \text{j=1,2,...,n, i=1,2,...,m} \quad (12)$$

Where, w_j represents the weight of the j^{th} attribute.

Step 3: Determine the concordance S_{kl} and discordance D_{kl} sets:

$$S_{kl} = \{j | r_{kj} > r_{rj}\} \quad (13)$$

$$D_{kl} = \{j | r_{kj} < r_{rj}\} = J - S_{kl} \quad (14)$$

Step 4: Calculate the concordance matrix I_{kl}, on the basis of the concordance sets (Jahanshahloo *et al.*, 2006). The concordance matrix is calculated as:

$$I_{kl} = \sum_{j\in s_{k,l}} w_j \; ; \; \sum_{j=1}^{n} w_j = 1 \quad (15)$$

Step 5: Calculate the discordance matrixNI_{kl}. The discordance matrix is calculated as:

$$NI_{kl} = \frac{\max_{j\in D_{k,L}} |V_{ki} - V_{Ji}|}{\max_{j\in J} |V_{ki} - V_{Ji}|} \quad (16)$$

Step 6: Determine the concordance dominance matrix $\bar{I}$, on the basis of the average index of concordance. This matrix can be determined as:

$$\bar{I} = \frac{\sum_{K=1}^{m}\sum_{l=1}^{m} I_{k,I}}{m(m-1)} \quad (17)$$

$$f_{kl} = 1 \quad if \quad I_{kI} > \bar{I}$$

$$f_{kl} = 0 \quad if \quad I_{kI} < \bar{I}$$

Step 7: Determine the discordance dominance matrix $\overline{NI}$. $\overline{NI}$ is on the basis of the average index of discordance- $\overline{NI}$ as follows:

$$\overline{NI} = \frac{\sum_{K=1}^{m}\sum_{l=1}^{m} NI_{kl}}{m(m-1)} \quad (18)$$

$$g_{kl} = 1 \quad if \quad NI_{kI} \le \overline{NI}$$

$$g_{kl} = 0 \quad if \quad NI_{kI} > \overline{NI}$$

Step 8: Determine the aggregate dominance matrixh_{kl}.

$$h_{kl} = f_{kl}.g_{kl} \quad (19)$$

Step 9: Eliminate the less favorable alternatives:

$$h_{kl} = 1 \;\rightarrow \text{For at least one } l \rightarrow l = 1,2,\ldots.m \quad k \neq l \quad (20)$$

$$h_{kl} = 0 \;\rightarrow \text{For all i} \rightarrow i = 1,2,\ldots.m \quad i \neq k \quad i \neq l \quad (22)$$

Figure 2 shows the main steps involved in the study methodology for selecting the best policy scenario.

RESULTS AND DISCUSSION

As previously stated, some of the most important and effective policies that can affect water consumption include water pricing policy, and the policies of imposing tax on

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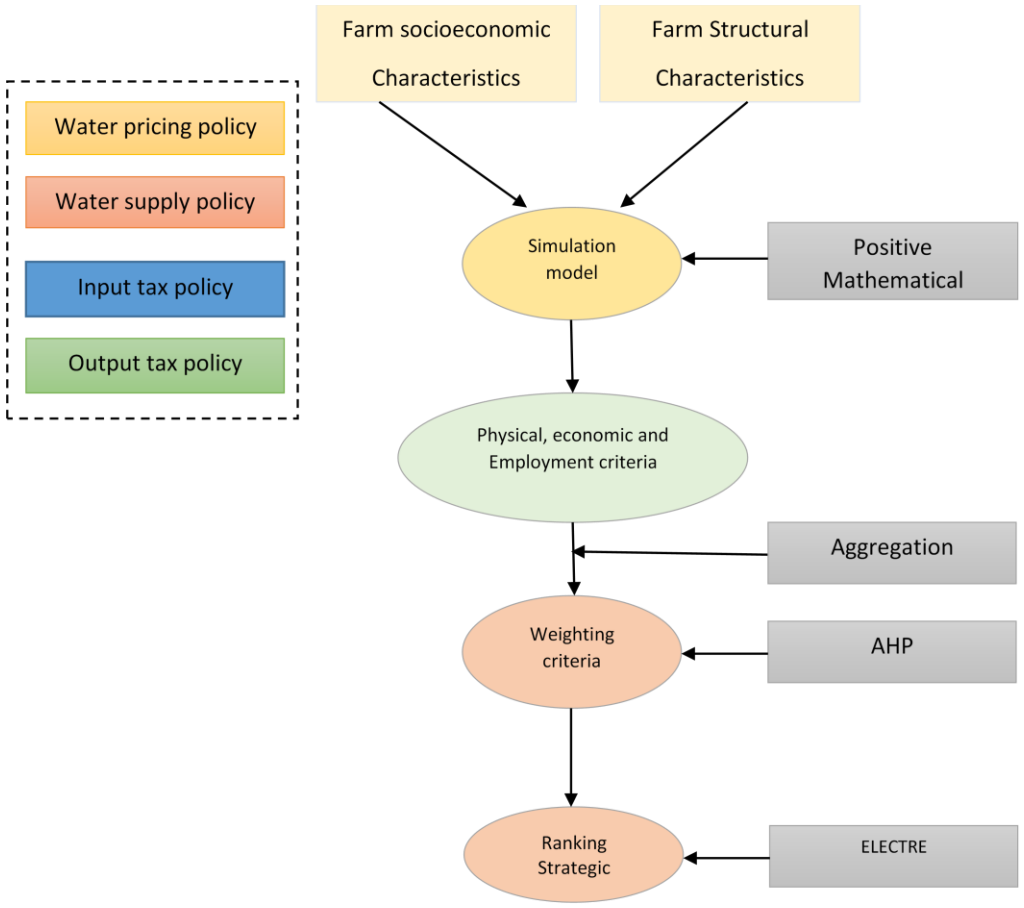

Figure 2. Main steps of the research methodology.

input and output. As an economic activity, agriculture generates profit for the owner of resources, which is a major motivation for decisions taken by the producers. Farmers usually react to the new water policies and market conditions that lead to a change in the level of their profit. The farmers' reactions to these policies can be measured through monitoring the changes in cropping pattern, profit, production, water saving, and inputs consumption. Table 3 shows the amount of inputs used in the current situation in Qazvin plain. Approximately, 75% of the total agricultural land is allocated to wheat production. Therefore, wheat has the highest share in inputs consumption (see Figure 3).

The reaction of producers in terms of change in cropping pattern as a result of each policy is shown in Table 4. The increased water price scenario (S1) led to a reduction in the area under crops with high irrigation requirements. This result is in line with the findings of Radmehr and Shayanmehr (2018), Gómez-Limón and Riesgo (2004), and Ghorbani and Hezareh (2017). For example, the share of crops such as corn was reduced by 29.98%, sugar beet by 25.07%, and potato by 33.99%. In contrast, crops such as tomato, due to higher profit per unit of water, faced the least amount of change (only 5.04% reduction in area) under this policy.

The increased water-price scenario associated with reduced water availability in the second (S2) and third (S3) scenarios had an even higher reduction in the area of crops needing a higher level of irrigation. The reaction of producers under higher input cost scenarios (S4 and S5) indicated a moderate reduction in the cultivation area of various crops. Facing such cost increases, producers in Qazvin plain reduced the area under wheat only by 4.47%, barley by 5.15%, corn by 5.68%, and sugar beets by 4.21%. To compensate for these losses, producers increased the area under crops like potato, tomato, and

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Table 3. Base input uses in current situation.

	Wheat	Barley	Corn	Sugar Beet	Potato	Tomato	Rapeseed	Beans
Land (ha)	20407.00	2055.30	226.00	612.30	50.00	1075.50	2202.30	267.00
Water (1000m3)	163256.00	12331.80	2486.00	10102.95	625.00	16920.00	15416.10	2670.00
Labor (h)	244884.00	29760.74	3333.50	37619.71	4350.00	129060.00	17177.94	10947.00
Nitrogen fertilizer(Ton)	5202.82	427.84	108.48	260.35	8.42	426.45	694.45	65.44
Phosphate fertilizers(Ton)	3919.67	338.15	54.46	125.77	10.06	237.13	252.51	32.28

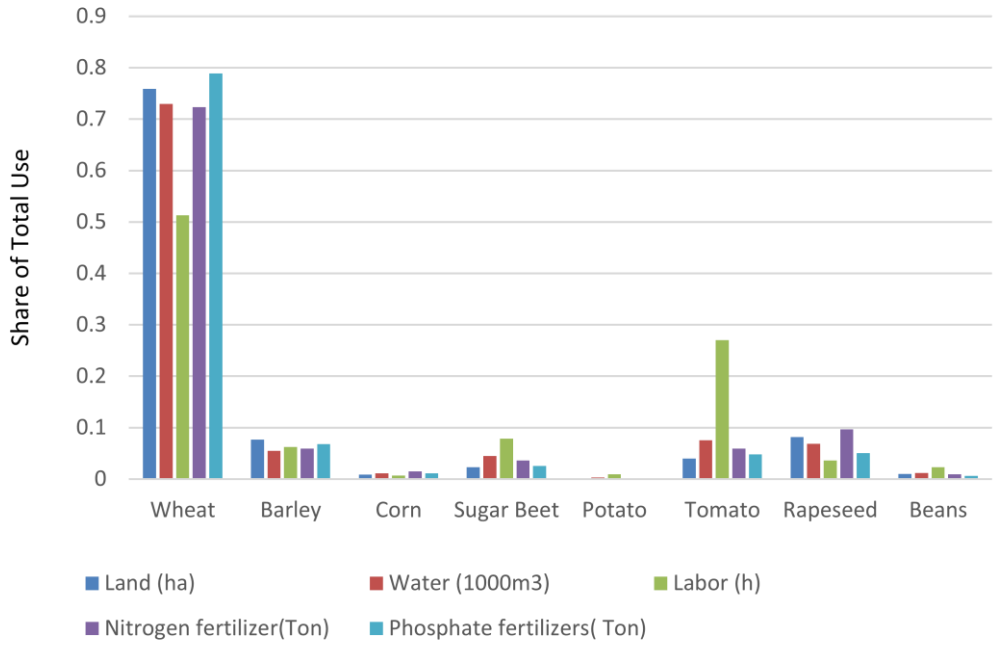

Figure 3. Inputs used by crops.

canola (8.90%, 0.03%, and 8.78%, respectively). Hence, water consumption decreased for barley, wheat, corn, and sugar beet, and to a lesser extent increased for potato, tomato, canola, and bean in comparison to S1, S2, and S3 scenarios. The policy scenario of tax on products (S6) reduced net prices by producers, and reduced area under wheat, sugar beet, potato, and tomato, while the area of other crops was increased.

Changes in water consumption (%) for each crop in different management scenarios are shown in Table 5. Increasing the irrigation water price by 25% and 20% decrease in available water (S3 scenario) led to 100% reduction in water requirement in relation to the current situation in the Qazvin plain. On the other hand, the policy of a tax on product and tax on input had no significant effect on water consumption in the region. However, these scenarios change the gross margin and employment. These results are consistent with the findings of He *et al.* (2009).

In addition to the change in cropping pattern and reduction in water consumption in the region (Tables 4 and 5), these policy scenarios also cause production reduction resulting in a change in physical productivity of water as well as in economic benefits and employment. The impact of various policy scenarios on physical productivity of water is shown in Table 6. Change in the physical productivity in the cultivation of wheat and rapeseed was not noticeable. However, the policy of a tax on potato and tomato crops had no significant effects on physical productivity of water for other crops. Comparing the policies showed that mixed policy of water pricing (25% increase in relation to the present price) and reduction of the available water (20%) provided the best result as measured by the physical productivity of water

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Table 4. Change in cropping pattern (%) as a result of each policy for Qazvin Plain, in 2013.

Senario	Wheat	Barley	Corn	Sugar beet	Potato	Tomato	Rapeseed	Beans
S1	-16.71	-23.03	-29.98	-25.07	-33.97	-5.04	-12.00	-24.29
S2	-9.90	-13.73	-17.97	-14.89	-20.44	-3.03	-7.18	-13.96
S3	-19.84	-27.28	-35.45	-29.74	-40.80	-5.96	-14.20	-29.04
S4	-2.23	-2.57	-2.84	-2.11	5.71	0.01	-1.12	5.00
S5	-4.47	-5.68	-5.68	-4.21	8.90	0.03	-2.25	8.78
S6	-0.19	0.93	2.78	-24.36	-60.11	-7.66	0.96	1.66

Table 5. Changes in water consumption (%) for each crop in different management scenarios,in 2013.

Senario	Wheat	Barley	Corn	Sugar beet	Potato	Tomato	Rapeseed	Beans
S1	-16.78	-23.62	-32.21	-25.20	-36.27	-5.35	-13.39	-32.57
S2	-9.94	-14.08	-19.29	-14.97	-21.77	-3.21	-8.00	-18.94
S3	-19.92	-27.99	-38.11	-29.74	-43.48	-6.33	-15.85	-38.83
S4	-2.23	-2.52	-2.59	-2.10	5.21	0.02	-1.07	4.30
S5	-4.46	-5.05	-5.17	-4.20	8.16	0.04	-2.13	7.59
S6	-0.19	0.93	2.67	-24.29	-50.32	-7.49	0.94	1.37

for various crops in the study area. On the other hand, despite the effect of the policy of tax on input leading to improvement of productivity indices (except bean), its effects were somewhat negligible.

Given that gross margin and employment are considered as important criteria in the evaluation of management policies, each of these issues was investigated further. It is expected that water policies contribute to a reduction in water consumption, and finally lead to less production in the study area. The impact of various policy scenarios on economic productivity of water is shown in Table 7. These results suggest that, except under S3 and S5 scenarios, no clear direction in the change was noted. Similar to the index of physical productivity, the mixed policy of water pricing (25% increase in relation to the present price) and reduction of the available water (20%) provided the best results in terms of economic productivity of water; while the policy of tax on input was less efficient than the other policies.

Results of investigation of the effect of policy measures on employment are presented in Table 8. According to these results, the employment productivity for most crops does not significantly change. However, similar to previous two indices, scenario S3 created the best condition for this index. The policy of tax on input had approximately neutral effect on the employment productivity criterion for all crops (except potato). In fact, implementation of this policy cannot lead to improvement of employment condition in this area, while the policy of tax on product caused reduction of employment productivity for potato and tomato. In fact, it can be concluded that imposing a tax on crops that have higher water consumption can lead to a reduction of employment productivity criterion in the study area due to production reduction and change in other activities as a result of the reduction in water consumption.

Aggregating model results provide a glimpse of values that can be used for making decision on the best policy measure. As shown in Table 9, all criteria (except employment productivity) are changed by water polices. These results are used for selecting a suitable policy for the study area.

The AHP(Analytic Hierarchy Process) method is used in the selection process of determining the degree of significance for each criterion. Hence, 15 experts and agricultural specialists were interviewed. The resulting weights assigned to each criterion are shown in Table 10. According to these experts, the economic productivity index received the highest weight (22%), while production criterion received the least (6%). Table 10 also indicates the polarity(Polarity: `+' = more is better, `-' = less is better) of criteria. It can be seen that water consumption criterion has the negative polarity of criterion among the other criteria. These weights were used to select the best water policy by ELECTRE method.

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Table 6. Results of physical productivity of each policy for Qazvin Plain (Ton/1000 m^3), in 2013.

	Crop	Baseline year	S1	S2	S3	S4	S5	S6
Physical Productivity criteria	Wheat	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	Barley	1.41	2.43	2.43	2.44	2.41	2.41	2.41
	Corn	1.34	1.41	1.37	1.42	1.34	1.34	1.34
	Sugar beet	3.72	3.73	3.73	3.73	3.72	3.72	3.72
	Potato	6.96	7.16	7.05	7.22	7.00	7.02	5.52
	Tomato	7.63	7.65	7.64	7.66	7.63	7.63	7.61
	Rapeseed	1.11	1.14	1.13	1.14	1.11	1.11	1.11
	Beans	4.10	4.55	4.33	4.68	4.15	4.18	4.12

Table 7. Results of economic productivity of each policy for Qazvin Plain (Million Rails/1000 m^3), in 2013.

	Crop	Baseline year	S1	S2	S3	S4	S5	S6
Economic Productivity criteria	Wheat	0.59	0.63	0.61	0.64	0.60	0.60	0.59
	Barley	0.75	0.82	0.79	0.84	0.76	0.76	0.75
	Corn	0.89	1.03	0.96	1.07	0.89	0.90	4.16
	Sugar Beet	3.82	4.18	4.02	4.27	3.85	3.87	3.72
	Potato	1.61	1.94	1.77	2.05	1.58	1.56	1.94
	Tomato	2.78	2.89	2.84	2.91	2.78	2.78	2.93
	Rapeseed	0.47	0.51	0.49	0.52	0.47	0.47	0.46
	Beans	0.19	0.24	0.21	0.25	0.18	0.18	0.18

Table 8. Results for employment productivity of each policy for Qazvin. Plain (10 h/m^3) (In 2013).

	Crops	Baseline year	S1	S2	S3	S4	S5	S6
Employment Productivity criteria	Wheat	122.11	111.46	118.53	139.69	120.21	118.33	122.34
	Barley	137.78	143.73	142.90	176.38	136.07	134.39	136.49
	Corn	107.16	118.99	114.66	154.23	104.30	101.49	104.26
	Sugar Beet	123.25	127.50	127.31	159.89	122.42	121.62	114.23
	Potato	169.44	224.03	197.80	276.22	159.08	153.18	350.44
	Tomato	779.11	790.39	788.70	822.63	775.65	772.19	717.59
	Rapeseed	278.86	287.62	286.34	319.97	275.98	273.11	276.23
	Beans	192.23	245.10	218.79	293.87	181.61	173.96	189.58

Table 9. Decision matrix for Qazvin Plain: models results for the selected attributes for each scenarios

Senario	Production Ton	Employment 10 h[a]	Water 1000 m^3	TGM Million Rials	Employment Productivity	Economic Productivity	Physical Productivity
S1	170095	406225.5	186843.8	181516.5	0.91	0.97	2.17
S2	183210	435041.4	201878.9	189620.1	0.91	0.94	2.15
S3	164070.7	392974.3	179937.7	177720.4	0.91	0.99	2.18
S4	199144.5	470634.9	219562.4	200874.5	0.91	0.91	2.14
S5	195798.3	463723.5	215189.2	197689.8	0.91	0.92	2.15
S6	188831.4	455718.7	219738.7	198433.3	0.86	0.90	2.07

[a] Ten Hour.

[DOR: 20.1001.1.16807073.2020.22.2.17.5]

The ELECTRE method was then applied to the results of Tables 9 and 10. Tables 11 and 12 indicate the normalized decision matrix and normalized weight decision matrix that were calculated by Eq. 11 and 12. Ranking of various policy scenarios is presented in Table 13. These results suggest that scenarios S1, S3, and S6 are not selected, while scenarios S4 and S5 were selected. In fact, scenario of tax on input (S5) appears to fulfill the purpose of improving water indices in the study area.

Sensitivity analysis about the weights of the criteria was done to comprehensively analyze the results. This involved changes in the weights. Two alternatives were used: (1) The first alternative assumed that all criteria have equal weights (14.28%), and for the second alternative (experiments 2-8), one criterion has a higher weight (50%) than the weight of the remaining criteria (8.33%). This approach was used by Gallego-Ayala (2012). Results are shown in Table 14. The main conclusion of this analysis is that selection of the most suitable policy measure depends on the significance of criteria (weights assigned). For example, if reducing water consumption is of

Table 10. Results of weights and polarity of criteria.

	Production	Employment	Water	TGM	Employment Productivity	Economic Productivity	Physical Productivity
Weight of Criteria (%)	0.06	0.08	0.12	0.14	0.20	0.22	0.18
Polarity of Criteria	+	+	-	+	+	+	+

Table 11. Normalized decision matrix for Qazvin Plain.

Senario	Production	Employment	Water	TGM	Employment Productivity	Economic Productivity	Physical Productivity
S1	0.02	0.03	0.04	0.05	0.08	0.09	0.07
S2	0.02	0.03	0.05	0.06	0.08	0.09	0.07
S3	0.02	0.03	0.04	0.05	0.08	0.09	0.07
S4	0.03	0.04	0.05	0.06	0.08	0.09	0.07
S5	0.03	0.03	0.05	0.06	0.08	0.09	0.07
S6	0.03	0.03	0.05	0.06	0.08	0.09	0.07

Table 12. Normalized weight decision matrix for Qazvin Plain

Senario	Production	Employment	Water	TGM	Employment Productivity	Economic Productivity	Physical Productivity
S1	0.38	0.38	0.37	0.39	0.41	0.42	0.41
S2	0.41	0.41	0.40	0.40	0.41	0.41	0.41
S3	0.36	0.37	0.36	0.38	0.41	0.43	0.42
S4	0.44	0.44	0.44	0.43	0.41	0.40	0.41
S5	0.43	0.43	0.43	0.42	0.41	0.40	0.41
S6	0.42	0.42	0.44	0.42	0.39	0.39	0.39

Table 13. Rank of scenario for selection of best policy measure, 0.

Senario	S1	S2	S3	S4	S5	S6
S1	0	0	0	0	0	0
S2	1	0	0	0	0	0
S3	0	0	0	0	0	0
S4	1	1	1	0	0	1
S5	1	1	1	0	0	1
S6	0	0	0	0	0	0

[DOR: 20.1001.1.16807073.2020.22.2.17.5]

higher significance, scenarios 1 and 2 are recommended.

CONCLUSIONS

Excessive water consumption in the agricultural sector of Iran is one of the main challenges facing planners and policy-makers. Water demand management is revealed as a new approach in this sector. This study was carried out in order to select the best policies to improve water productivity in Qazvin Plain, Iran. The PMP along with ELECTRE method was applied for achieving this aim. Results demonstrated that total crops cultivation acreage would decrease in each strategy. These results always will have a negative effect on farmers' income, total employment, and production. These strategies have a positive and significant impact on reduction of water demand that can have different effects on water productivity index. Therefore, any strategy that has the least impact on total gross margin (TGM), employment, and production has the highest impact on the reduction of water demand, and can be considered as the best policy.

Results of this study suggest that the input tax strategy is recommended as the best policy because, compared to other policies, it has minimal impact on farmers' income. However, this policy has an insignificant effect on water saving. This result confirms that the economic and social concerns of rural communities are much more serious than the water crisis in Iran. Elimination of farmers' economic and social problems is a requisite to select an appropriate policy consistent with reducing water consumption.

Water pricing and supply policies can be selected as the best policies when the importance of water saving is higher than the economic criteria. Therefore, in the current situation, to reduce water crisis, the government should perform complementary policies to support the farmers to be able to impose very strict water policies.

Results showed that the weight of criteria is very important in selecting an appropriate policy. Therefore, selecting a suitable policy for irrigation-water management needs an accurate cognition from the economic, social, and environmental factors in the study area.

Table 14. Results of the sensitivity analysis.

Experiment		The Best Scenario
1	All criteria dimensions same weight	S5
2	Weight of production criterion dimensions 50% Weight of the other criteria dimensions 8.33% [a]	S4 S5
3	Weight of employment criterion dimension 50% Weight of the other criteria dimensions 8.33%	S4 S5
4	Weight of Water criterion dimensions 50% Weight of the other criteria dimensions 8.33%	S3 S1
5	Weight of TGM criterion dimensions 50% Weight of the other criteria dimensions 8.33%	S4 S5 S6
6	Weight of physical productivity criterion dimensions 50% Weight of the other criteria dimensions 8.33%	S5
7	Weight of employment productivity criterion dimensions 50% Weight of the other criteria dimensions 8.33%	S3 S1
8	Weight of economic productivity criterion dimensions 50% Weight of the other criteria dimensions 8.33%	S5

[a] Weight of each criterion (Employment, Water, TGM, Physical productivity, Employment productivity, and Economic productivity) is equal to 8.33% ($\sum w = 50\%$), where w is the weight of the other criteria dimensions. This method is used for other experiments.

[DOR: 20.1001.1.16807073.2020.22.2.17.5]

The policy makers and planners should not use one common strategy for heterogeneous areas.

Climate change is one of the important factors that can affect water resources and crop production. Therefore, the decisions and planning for water management may be affected by climate change. Hence, we recommend that the impacts of climate change on the selection of the best policies for water management should be considered by future studies. In this study, it was assumed that Leontief coefficients and yield are fixed and exogenous. For this reason, our model may not be able to reflect the actual response in a real situation. Hence, the relationship between water policies and technology adoption needs also to be considered.

ACKNOWLEDGEMENT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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[DOR: 20.1001.1.16807073.2020.22.2.17.5]

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انتخاب سیاست استراتژیک برای مدیریت آب آبیاری (مطالعه موردی: دشت قزوین، ایران)

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چکیده

آب به عنوان یک جزء مهم اما یک نهاده محدود در تولید کشاورزی ایران محسوب می‌شود. در خصوص مدیریت منابع آب، با توجه به دسترسی محدود به آب و هزینه بالای عرضه آن برای مصرف‌کنندگان، بهبود بهره‌وری مصرف آب به عنوان یکی از مناسبترین رویکردها برای مدیریت تقاضای آب در نظرگرفته شده است. در زمینه جلوگیری از سطح بالای کمبود آب، ابزارهای مختلفی برای سیاست مدیریت منابع آب در نظر گرفته شده است. در مطالعه حاضر، سناریوهای سیاستی مختلفی برای مدیریت تقاضای آب ارزیابی شده اند. این شامل ارزیابی اثرات هر سناریوی سیاستی بر شاخص‌های بهره وری فیزیکی، اقتصادی و اشتغال، با استفاده از مدل های برنامه ریزی مثبت و حداکثر بی نظمی می‌باشند. این روش برای استفاده از آب در دشت قزوین ایران بکار گرفته شد. نتایج پیشنهاد می‌کند، استفاده از این سناریوهای سیاستی علیرغم کاهش مصرف آب دارای اثرات نامطلوب اقتصادی و اجتماعی هستند. نتایج رتبه بندی نشان می‌دهد که سیاست مالیات بر نهاده نتایج بهتری را برای منطقه مورد مطالعه ایجاد می‌کند. همچنین، نتایج تایید می‌کند که انتخاب بهترین سناریوی سیاستی وابسته به وزن است که سیاست گذاران برای شاخص های مختلف انتخاب می‌کنند.

[DOR: 20.1001.1.16807073.2020.22.2.17.5]