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Impacts of Iranian Agricultural Water Resources Conservation Policies (Case of Baft County in Dashtab Plain)

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Abstract

Water scarcity has made water management one of the top priorities in the world because of climate change and population growth on the one hand and increasing demand for food on the other. The present study aimed to simulate the effects of conservation policies on water resources in the Dashtab plain, Iran, using the positive mathematical programming (PMP) method. Data were collected by a questionnaire for which 136 questionnaires were filled by randomly sampled experts of Agricultural Jihad Organization. The results showed that out of the three policies adopted in this study including limiting irrigation inputs, reducing irrigation input subsidies, and reducing crop prices, reducing subsidies on irrigation inputs were the best policy to protect irrigation resources and farmers' incomes.

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INTRODUCTION

Water scarcity and human inability to produce water have widened the gap between water supply and demand, especially in recent decades, with a shortage of supply in most parts of the world (Bakhshi et al., 2011; Rahnama et al., 2012). Water scarcity is one of the most important global problems in the present century, and the crises resulting from this scarcity pose a serious threat to sustainable development, the environment, human health, and welfare (Shahroudi & Chizari, 2009). Agricultural activities will be rendered impossible in Iran without resorting to irrigation due to the amount and type of rainfall in this country. However, the water use efficiency of Iran's agricultural sector is not comparable to other countries, not only in drylands but also in the modern waterways and modern networks that receive sufficient water. As agriculture is heavily dependent on irrigation in Iran, if the role of water in the development of the country is not taken into account, the country's food security will certainly face serious problems (Yousefi et al., 2012).

The widening gap between future supply and demand for water will require adequate attention to the basics of economic planning and optimal allocation of water resources and make water management imperative. There are many policy efforts today to reduce water use in the agricultural sector and improve its allocation. To improve water allocation efficiency, economists propose price increases for water inputs, but policymakers reject the proposal for economic, cultural, and political reasons (He et al., 2006). Briscoe (1996), Perry (2001), and Hellegers (2002) argue that considering water an economic commodity does not mean determining the right price for it, but rather that the right choice is made for water allocation. Also, the outcome of a policy and its effects largely depend on how the beneficiaries will respond to it. Today, this is predicted by Positive Mathematical Programming (PMP). In other words, before a decision can be made for policymaking, simulating the potential response of farmers through PMP can be an effective aid in making more correct decisions. The conventional way to simulate producers' decisions is to create a model that reflects constraints, opportunities, and goals, and then resolve them under changing assumptions about producers affected by the policy environment. In this method, known as Normative Mathematical Programming (NMP), the optimal condition is investigated and the effect of the desired policies on the optimal condition is investigated. However, in the PMP method used in the present study, the current situation and the current cropping pattern of the farmers are taken into account and the effect of the policies in question on the current (rather than optimal) situation is investigated (Bakhshi et al., 2011).

Sabouhi et al. (2007) used the PMP model to examine the response of farmers in Khorasan province, Iran, to policies of price change and water availability. The results showed that under the conditions of deviant policies (subsidy payments) and market failures (side effects) with an increase in water irrigation prices, social benefits would increase and private benefits would decrease. Bakhshi et al. (2011) used the PMP approach to study the effects of alternative pricing policies for irrigation water in the Mashhad plain, Iran. They found that the effect of alternative policies varied depending on the representative operating group and that water pricing and product taxation policies were more effective than complementary taxation policies. Sabouhi and Azadegan (2014) used a PMP model to estimate the dynamic supply functions of major agricultural products and analyzed the effects of irrigation pricing policy in a case study on the Mashhad-Chenaran plain, Iran. The results revealed that the policy of increasing the price of irrigation water would reduce the total cultivated area compared to the base year and farmers would shift towards cultivating and supplying higher-income crops in the region. In a study using multi-attribute utility function and linear mathematical programming, Gomez-Limon and Riesgo (2004) estimated the demand for irrigation water and examined the effects of irrigation pricing policy in the Spanish area of Duero. The results showed that water pricing had a significant effect on reducing farmers' income, but it reduced water use on agricultural land by about 10 percent. In a study using PMP, Azuara et al. (2009) examined the economic value of water under different conditions and reported that the economic value of water at the field and interconnected levels was relatively similar, but the variability and the effect of the distribution of each scenario were affected by aggregation. Gallego-Ayala (2012) used the PMP model and a hierarchical analysis to determine the price of irrigation water and analyze the effects of different water pricing policies on cropping patterns and inputs. In this study, the policies evaluated included volume pricing, area of cultivation, and the two-part tariff system. The PMP model of water price optimization was calculated for each pricing method and then the economic, social, and environmental criteria were prioritized using hierarchical analysis. The results showed slight changes in determining the optimal price for water and the values of inputs consumed in the cropping pattern obtained by the considered methods. Hellegers and Davidson (2010) examined the economic value of non-accumulated irrigation water in the Musa sub-basin in India. The results showed that the value of irrigation water was not equal among different crops, regions, and seasons. Howitt et al. (2012) used the positive planning model and Constant Elasticity of Substitution (CES) to calibrate economic models and analyze applied policies in California water resources management. The results showed that greater flexibility in the water market can reduce income losses from drought by up to 30 percent in implementing irrigation pricing policies. Aidam (2015) examined the effects of water pricing policy on Ghanaian water resources demand. The results showed that water pricing policy had a negative effect on demand for water resources in Ghana, yet it was only when water prices significantly increased. Nonetheless, if the water price is high, it will have a negative effect on farming activities, farmer income, employment, and crop variety. Thus, to minimize and reduce losses in the sector, farmers were suggested to be provided with information on water scarcity in order to persuade them to use the existing technologies for better water conservation. Zhou et al. (2015) performed a study in the Hiehe River basin in northwest China on whether irrigation water prices are effective leverage for water management. The results showed that the impact of the agricultural irrigation water price was statistically significant, but its elasticity had a slight effect at low water prices. In addition, farmers' reaction to the price increase was actually low. The price mechanism must be coupled with applicable water rights, water rationing, water authority improvements, and water user associations to motivate water conservation and improve irrigation efficiency. Additionally, increasing surface irrigation water price might end in the extraction and overuse of groundwater. Thus, the reduction of the permit for exploitation and the taxation of groundwater can prevent further aquatic decline. Shirzadi et al. (2018) investigated the effect of irrigation water pricing policy on the level of groundwater in the Neyshabur plain, Iran, using a PMP model. The results showed that increasing the price of irrigation water had a significant effect on changing the crop pattern, reducing the profits, and reducing the irrigation water consumption, so it had a positive effect on improving groundwater level.

In recent decades, over-harvesting underground aquifers has reached its climax. This disproportionate use of the aquifers has depleted some of the deep and semi-deep wells in the region, and other wells in the region have been hit by water scarcity. As the government heavily subsidizes agricultural water, delivering it to the local farmers almost free of charge, farmers do not value this vital agricultural input. The excessive harvest of this vital input has led to some land subsidence in the region, which could have devastating environmental consequences for the region in the future. Hence, the present study attempted to apply the effects of water resources limitation policies, irrigation water subsidy policies, and reduced crop prices for a development and conservation program using the PMP model and analyze and provide suitable solutions for the Dashtab Baft plain.

METHODOLOGY

In recent decades, mathematical programming models have widely been used in agricultural policy analysis and simulation of the effects of these policies on different parts of the agricultural system, such as possible changes in the inputs consumed, with a pattern of cultivation and welfare of farmers (Bakhshi et al., 2011; He et al., 2006). The most significant benefit of these models is their capability of evaluating the effect of policies at the farm level (Paris and Howitt, 1998). In NMP models, an optimal solution is selected from the possible ones. However, in such models, the results often do not reproduce the current allocation of inputs between production activities, and due to the difference between the optimal response of the model and the current cropping pattern, the farmers' responses to the policies adopted are practically not shown properly. Thus, the policy analysis of these models is not generally valid (Heckelei, 2002). Policymakers tend to compare current policy (base status) and alternative policy choices to predict outcomes. Hence, the model must reproduce the baseline as much as possible to validate the results, but the NMP method does not gain such validity because of the lack of a proper calibration mechanism (Howitt, 2005). Due to the disadvantages of constrained calibration methods, methods have been introduced to derive nonlinear supply functions based on the observed behavior of decision-makers and calibrate the model as a whole.

Nowadays, PMP models have been developed to overcome the disadvantages of the NMP method. The PMP models not only calibrate mathematical programming models (MPMs) to the observed values precisely but also provide realistic and flexible simulation behavior of the model (Howitt, 2005). The main idea of PMP is that the opportunity cost information of each activity in an initial NMP model is used to specify a model with a nonlinear objective function without infinite or additional constraints to be included in the model (Bakhshi et al., 2011; Howitt, 1995). By considering regional production functions, the PMP model eliminates the disadvantages it had in its previous models and analyzes policies using a quadratic function. After considering the functions of regional crop production, the PMP model includes CES. This capability helps the PMP model constrain the succession of inputs. The presence of spatial integration effects enhances the PMP model and enables the model to predict the impact of agricultural policies by collecting data or information at the minor or partial level of the study areas (Howitt et al., 2012).

The PMP method was first introduced by Howitt in 1995 and is the most commonly used method for calibrating an MPM in three stages:

Step 1: Defining the linear programming model with calibration constraints

Step 2: Applying dual values of the first stage model to determine the nonlinear objective function parameters

Step 3: Using the calibrated objective function in a nonlinear programming model to analyze policies

In the first step, the calibration constraints are added to the resource constraints of a linear programming model. These constraints limit the activity level to the levels observed in the base period. Assuming the maximization of program output, the initial model is stated as follows (Howitt, 1995; Paris & Howitt, 1998).

Maximize $\quad Z = px - cx \quad$ (1)

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

$$X \leq x0 + \varepsilon \ [\rho] \quad (3)$$

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

where Z is the value of the objective function, p is an (n * 1) vector of product prices, x is a non-negative (n * 1) vector of production activity levels, c is an (n * 1) vector of cost per activity unit, A is an (m * n) matrix of technical coefficients on resource constraints, b is an (m * 1) vector of available resource values, x_0 is a non-negative (n * 1) vector of observed levels of manufacturing activities, ε is an (n * 1) vector of small positive numbers to avoid linear dependence between structural constraints (2) and calibration constraints (3), λ is an (m * 1) vector of dual variables related to resource constraints, and ρ is a (n * 1) vector of dual variables of calibration constraints.

The difference between the above model and the linear programming model is that the calibration constraints are added to the model at this stage. By solving the above model, the double values corresponding to the above constraints, which represent the shadow price of the products produced, are calculated. Howitt (1995) and Heckelei (2002) interpreted the vector of ρ values associated with the calibration constraints as representations of any model correction error, data error, aggregation error, risk behavior, and price expectations. In the calibration of a decreasing nonlinear performance function, the ρ dual vector represents the difference between the value of the final and the average output (Howitt, 1995). Together with the cost vector (c), it shows the final and actual cost of producing the observed activity x_0. In step two, the dual values obtained from step one are used to estimate the nonlinear objective function parameters. In other words, dual values are used at this stage to calibrate the parameters of the nonlinear objective function. In this case, the activity levels observed in the base period are reproduced by a nonlinear model without the calibration constraints (Howitt, 1995). In the PMP method, the formation of a nonlinear objective function can be conducted by supply (cost) or demand (price) or a combination of the two (Howitt, 2005). Supply-based methods assume that nonlinear cost functions and constant performance are used for model calibration. Demand-based methods are useful when the model has been sufficiently large-scale defined to allow changes in the quantity of the product to change the price. The third method assumes that both supply and demand are nonlinear or risk components are added to the model. However, the general principle is to add nonlinear elements to the model to reflect the actual behavior of the users.

At this step, any nonlinear function having the desired conditions can be used for calibration (Heckelei, 2002). According to Howitt, in the PMP method, most of the cost functions are used as nonlinear best models by econometric data. Heckelei believes that because of the simplicity of calculations and the lack of robust reasons for other types of functions, a quadratic cost function (except for Paris and Howitt, 1998) is usually used in the objective function. The simplest function form used in most studies (He et al., 2006; Shirzadi et al., 2018) is the quadratic function. Given the desirable characteristics of the quadratic cost function such as the ascending ultimate cost function for each activity and the ease of working with these functions, this form of function is preferred over the other forms (Cortignani & Severini, 2009). In this study, a quadratic cost function econometric model was selected as the best form and specified in the PMP model as follows:

$$Cv(x) = d'x + \frac{x'Qx}{2} \quad (5)$$

where d represents the vector (n * 1) of a linear component of the cost function and Q represents the positive, definite, and symmetric matrix (n * n) of the quadratic component of the cost function.

As was already stated, the final cost vector (MCV) of the above cost function is equal to the sum of the cost vector c and the differential cost vector ρ:

$$MC^V = \nabla C^V (x')x0 = C + \rho \quad (6)$$

where C^V (x) is the gradient vector of the first-order derivatives of $C^V(x')_{x0}$ for $X=X_0$. To solve the above system of equations, which contains *n* equations with [n+n(n+1)/2] parameters, various solutions like the initial stiffness rule, the average cost approach, the use of exogenous elasticity of supply, and the production-based and maximum entropy refinements are used. In this study, the initial refinement rule was used. In the third step of the PMP method, the nonlinear cost function fulfilled in the previous step is examined in the objective function and in a nonlinear programming problem like the initial problem except for calibration constraints but with other system constraints:

$$\text{Maximize} \quad Z = p'x - \hat{d} - \frac{x'\hat{Q}x}{2} \quad (7)$$

$$\text{Subject to:} \; Ax \leq b \qquad [\lambda] \quad (8)$$

$$X \geq 0 \quad (9)$$

where vector $\hat{d}$ and matrix $\hat{Q}$ show the calibrated nonlinear objective function. Now, the above calibrated nonlinear model correctly reproduces the levels of activity observed in the status quo and the dual values of the resource constraints and is ready to simulate changes in the target parameters. Compared to the first-stage model, the third-stage model has no calibration constraints and its objective function is nonlinear. It has been attempted to incorporate the model used to include existing constraints in the studied area to examine the effect of the policies in question on the pattern of cultivation and consumption and the estimation of the economic value of water. Accordingly, model constraints include land, irrigation, and capital constraints.

The data were collected using the random sampling method by completing 136 questionnaires from the Dashtab plain's farmers and Dashtab Agricultural Jihad Organization. GAMS (General Algebraic Modeling System) software was used to solve the proposed model. This software was also used to solve Linear Problems (LP), Nonlinear Programming (NLP), Mixed Integer Programming (MIP), Mixed Integer Linear Programming (MINLP), and Mixed Complementary Problems (MCP).

RESULTS AND DISCUSSION

Dashtab Plain is located in the southwest of Baft (Lat. 28°57'57″ North, Long. 56°35'35″ East), 36 and 196 km away from Baft and Kerman counties, respectively. This area is the main part of Baft's agricultural enterprise that includes crops such as wheat, barley, and millet. The agricultural water of this area is supplied from deep and semi-deep wells.

This section first uses the statistical data in Table 1 and then, examines the model outputs for changes in the cultivated area, the shadow price, the amount of water consumed by farmers, and the gross farm income by using different scenarios.

Capitals includes seed, fertilizer, poison, and cost of machinery

Table 1 shows the amount of cultivated area, yield, capital, labor, and net water demand for the selected crops for the year 2017. Wheat and watermelon had the highest and lowest crop yields, respectively, and alfalfa and millet had the highest and lowest water requirement, respectively.

Water resource constraint scenarios

In this section, changes in crop area, the economic value of water, and gross income of farmers in the region are examined by using different reduction scenarios of 25 percent, 50 percent, and 75 percent of water resource limitation.

According to Table 2, in the scenario of a 25 percent reduction in water resources, the highest change in the cultivated area is related to barley whose cultivation is suspended by decreasing 100 percent of this crop in the cultivation pattern. The lowest changes are 1.38 percent and 1.25 percent for millet and watermelon, respectively.

Table 1
Selected Crops for the Base Year 2017

Selected crops	Cultivated area (ha)	Yield (t/ha)	Water requirement (m^3/ha)	Capital (000 IRR/ha)	Labor force (person-days)
Wheat	1350	3.5	3744	10500	22
Barley	1000	2.1	3168	7110	20
Alfalfa	600	10	6480	8000	28
Millet Sorghum Watermelon	65020080	1.95528.5	216859405184	3460109409600	122530

Table 2
The Results Obtained by the Dashtab Plain Water Resource Constraint Scenarios

Selected crops	Cultivated area (ha)	Water resource constraint scenarios (%)			Changes (%)		
		25%	50%	75%	25%	50%	75%
Wheat	1350	1266	750	204	-6.22	-44.44	-84.88
Barley	1000	0	0	0	-100	-100	-100
Alfalfa	600	573	408	233	-4.5	-32	-61
Millet	650	641	583	522	-1.38	-10	-19.69
Sorghum	200	182	75	0	-9	-62.5	-100
Watermelon	80	78	75	71	-1.25	-6.25	-11.25
The economic value of water	-	2360	6270	11900	-	-	-
Gross income (Million IRR)	303080	261870	187840	113970	-13.59	-38	-62.39
Water consumption (000 m^3)	15117	11338	7558	3779	-25	-50	-75

Moreover, the gross income in this scenario is decreased compared to the base year by 13.59 percent and the amount of water consumed by the farmers is decreased by 25 percent. The economic value of water in this scenario is 2360 IRR/m^3, meaning that the farmers have to spend a maximum of 236 IRR/m^3 to have an extra unit of water.

In the scenario of 50% reduction in water resources, the highest changes in the cultivated area are related to barley and sorghum, which exhibit 100 percent and 62.5 percent declines, respectively, and the lowest changes are related to watermelon and millet, -10 percent and -6.25 percent , respectively. The highest cultivated area is related to wheat. Moreover, the gross income in this scenario is decreased by 38 percent versus the base year reaching 187,840 million IRR, and the water consumed by farmers is decreased by 50 percent. The economic value of water in this scenario is increased to 6,270 IRR/m^3.

The scenario of 75 percent reduction in water resources shows that the highest percentage of changes are related to barley and sorghum so that both will be eliminated from the cultivation pattern, and the highest cultivated area is related to millet. Gross income in this scenario decreases by 62.39 percent and reaches 11, 3970 million IRR, and the economic value of water in this scenario is 11,900 IRR/m^3.

Scenarios for subsidizing irrigation water inputs

By applying various scenarios in this section, the cultivated area of the selected crops is examined. It also shows the effect of various scenarios on the gross income and water consumption of farmers.

We examine various scenarios according to the results of Table 3. In the scenario of a 25 percent reduction, the cultivated area of barley drastically reduces to 86 ha, but watermelon and millet experience the lowest declines of 1.25 percent and 1.69 percent, respectively, and the wheat has the highest cultivated area. Under the first scenario, gross income decreases by 17.84 percent from the base year and reaches 249,010 million IRR, and the water used by the farmers is preserved up to 28.55 percent.

By applying the scenario of 50 percent reduction, barley is removed from the cropping pattern and the other crops have a decreasing trend, with the two crops having the least variations and wheat showing the highest cultivated area. Under the scenario of a 50 percent reduction in irrigation water subsidy, the gross income of the farmers in the region is reduced by 28 percent and the water consumption is saved by up to 38.80 percent.

Table 3

Results Obtained by Applying Water Subsidy Reduction Scenarios of Dashtab Plain Irrigation

Selected crops	Cultivated area(ha)	Water subsidy reduction scenarios			Changes (%)		
		25%	50%	75%	25%	50%	75%
Wheat	1350	1236	1122	1008	-8.44	-16.88	-25.33
Barley	1000	86	0	0	-91	-100	-100
Alfalfa	600	513	426	338	-14.5	-29	-43.66
Millet	650	639	628	617	-1.96	-3.38	-5
Sorghum	200	144	88	31	-28	-56	-84.5
Watermelon	80	79	77	74	-1.25	-3.75	-7.5
The economic value of water		0	0	0	-	-	-
Gross income (million IRR)	303080	249010	218260	190200	-17.84	-28	-37.24
Consumed water (000 m^3)	15117	10800	9250	7895	-28.55	-38.80	-47.77

Table 4

Results Obtained by Applying the Price-Reduction Scenarios for Selected crops in the Dashtab Plain

Selected crops	Area under cultivation (ha)	Product price reduction scenarios				Changes (percent)			
		10%	25%	50%	75%	10%	25%	50%	75%
Wheat	1350	1258	1071	511	0	-6.81	-20.74	-75.55	-100
Barley	1000	770	330	0	0	-23	-67	-100	-100
Alfalfa	600	553	460	179	0	-7.83	-23.33	-70	-100
Millet	650	637	609	527	282	-2	-6.30	-18.92	-56.61
Sorghum	200	169	109	0	0	-15.5	-45.5	-100	-100
Watermelon	80	79	78	74	64	-1.25	-2.5	-7.5	-20
Gross income (million Rials)	303080	241210	231400	125510	44170	-20.41	-23.65	-58.58	-85.42
Consumed water (thousand cubic meters)	15117	13535	10411	4604	942	10.64	-31.13	-69.54	-93.76

Under the 75 percent reduction scenario, barley and sorghum undergo the greatest decline in their cultivated area by 100 percent and 84.5 percent, respectively. Barley is removed from the cropping pattern, sorghum is removed in scenarios above the cropping pattern, other crops follow a decreasing trend, and watermelon and millet show the lowest reduction. Under the third scenario, the gross income of farmers in the region is reduced to 37.24 percent and the water consumed by farmers is reduced to 47.77 percent adding 7,221,000 m^3 to underground aquifers.

The scenario of decreasing crop prices

In this section, the gross income and water consumption of farmers are examined with the assumption of various scenarios for reducing crop prices and their effect on the cultivated area.

The results of the four scenarios of 10, 25, 50, and 75 percent reduction in crop prices are presented in Table 4. In the first scenario, the cultivated area of barley and sorghum yields have the highest decrease of 23 percent and 15.5 percent , respectively, and watermelon and millet have the lowest reduction of 1.25 and 2 percent, respectively. By applying this scenario, gross income and water consumption decrease by 20.41 and 10.46 percent, respectively.

In the second scenario, as in the first scenario, barley and sorghum have the highest reduction in crop area, and the highest crop area is related to wheat. Under this scenario, the gross income and water consumed by farmers decrease by 23.65 and 31.13 percent, respectively.

In the third scenario, barley and sorghum disappear from the cropping pattern, and the cultivated areas of wheat and alfalfa decrease by 75.55 and 70 percent, respectively. Millet and sorghum exhibit the lowest decline in the cultivated area. Moreover, gross income and amount of water consumed by farmers decrease by 58.58 and 69.54 percent, respectively.

In the fourth scenario, by lowering the prices of the four crops - barley, wheat, alfalfa, and sorghum - the cropping pattern is eliminated, and the cultivated areas of millet and watermelon reduce by 56.61 and 20 percent, respectively. Moreover, gross income decreases by 85.42 percent compared to the base year and reaches 44,170 million IRR, and the water consumed by farmers decreases by 93.76 percent reaching 942,000 m^3, implying that 14,175,000 m^3 of water is added to groundwater.

Figure 1 shows, comparatively, the water consumed by farmers in the study area after adopting various policies compared to the base year.

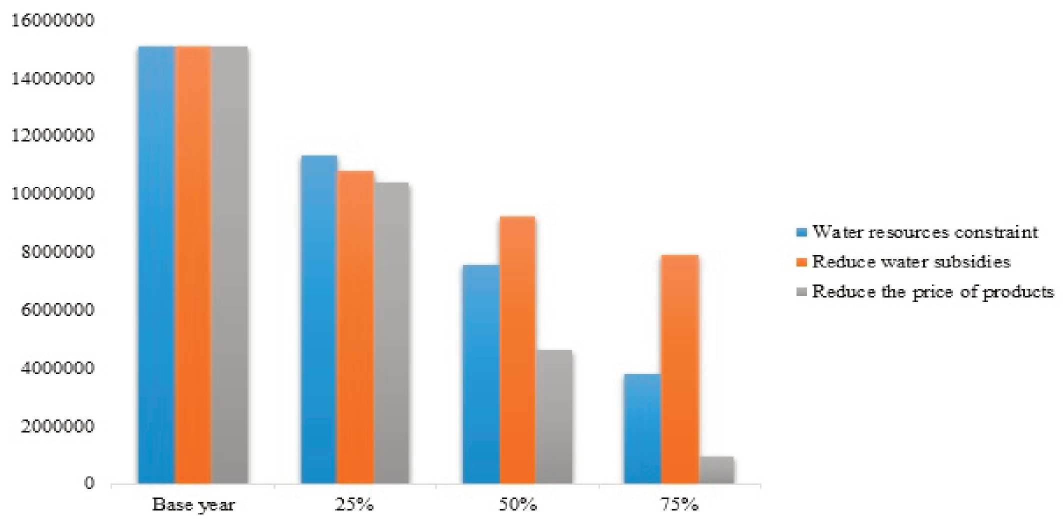

Figure 1. A Comparison of Policies Used to Reduce Water Consumption in the Region

CONCLUSION

Under various scenarios, the water resources of Dashtab Plain, Iran, are allocated by farmers to crops with low water demands and high yields. For instance, millet has a low water requirement and under different scenarios, there is not much reduction, but although watermelon demands more water than wheat, it is preferred to wheat due to its high yield. The two crops of alfalfa and sorghum exhibit the maximum variations due to their highest water consumption. Also, barley is removed from the cropping pattern due to its lowest yield and moderate water requirement under different scenarios. Under the scenario, the amount of water consumed and gross income decreases by 75 percent and gross revenue by 75 and 62 percent, respectively. This part of the study is in line with Rahnama et al. (2012).

Farmers in the region are turning to crops that have lower water demand and higher productivity under reduced subsidies on irrigation inputs. Under 25% scenario, barley has the most changes in its cultivated area, which reduces to 86 ha. Under the scenarios of 50 and 75 percent, barley is removed from the cropping pattern; other crops show a decreasing trend; the two crops of alfalfa and sorghum have the highest reduction due to their higher water requirement; millet and watermelon undergo the lowest changes, the former due to its low water requirement and the latter due to its high profitability; and wheat decreases by 25 percent due to its moderate water demand. Under this policy, 37 percent of farmers' water consumption is saved and added to underground aquifers, and their gross income is reduced by 48 percent. This part of the study is consistent with the studies of Shirzadi et al. (2018) and Sabouhi and Azadegan (2014).

Under the policy of lowering crop prices, farmers shift towards higher-yielding crops. Overall, a 75 percent reduction in crop prices results in the elimination of wheat, barley, alfalfa, and sorghum from the cropping pattern, with only millet and watermelon remaining with 56.66 and 20 percent reduction in the cropping pattern, respectively. Moreover, under this policy, the water consumed by farmers is saved by 93 percent and added to underground aquifers, reducing the gross income of farmers by 85 percent.

In general, by applying all the three aforementioned policies, barley and sorghum are removed from the cropping pattern of the region, and the millet and watermelon change the least. The policy of reducing water subsidies also has the least reduction in the cultivated area, the water consumed, and grosses income of the region so that it is more favorable than the other policies, as well as optimizing farmers' social welfare and water use.

Based on the results, the following recommendations can be drawn:

Since barley and sorghum show a significant downward trend in all scenarios, they are suggested to be eliminated from the region's cropping pattern and more attention is paid to millet (with a higher yield and lower water use) and watermelon (with a higher yield and lower water use than spring-sown alfalfa).

2. It is suggested that the irrigation water subsidy reduction policy be applied to protect the water resources and income of the farmers in the study area of Dashtab Baft plain, which considers water reserves, farmers' income, and their social welfare in the region.

3. It is suggested that studies be done to replace crops with high water requirements and low yields like barley, alfalfa, and sorghum, with crops that have low water requirements and high yields.

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