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WATER RESOURCES MANAGEMENT SCENARIOS AND TRANSBOUNDARY HYDRO-POLITICAL CONCERNS IN IRAN'S EASTERN BORDER AREAS

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ABSTRACT

Motives: Since the main sources of some rivers are located in neighbouring countries, hydrological issues in the eastern part of Iran are critical. The water dispute between Iran and the neighbouring Afghanistan is related to environmental issues and human health.
Aim: The aim of this study was to demonstrate how transboundary water conflicts increase human vulnerability through economic issues such as reduced productivity in the agricultural sector.
Results: The study's originality lies in the application of the positive mathematical programming approach to the agricultural sector, specifically in evaluating the impact of water pricing policies on crop selection and irrigation water use. A quadratic cost function was calibrated to develop three scenarios of water resources consumption (30%, 40%, and 70% reduction for farmers in group 1, and 10%, 25%, and 75% reduction for farmers in group 2) and price increase (70%, 80%, and 100% increase). The calibration of the quadratic cost function revealed an increase in irrigation efficiency (water resources consumption) as well as an increase in the region's irrigated area.

Keywords: water resources, positive mathematical programming, economic scenarios, crop price, hydrology, reduction in productivity

INTRODUCTION

More than 2 billion people now live in areas with significant water high levels of stress of factors such as climate change, urban sprawl, urbanisation, industrial development, and the need to increase agricultural production. This figure is expected to rise in the coming decades. Business as usual will not be possible in the future because agriculture accounts for roughly 70% of global water withdrawals and more than 80% of withdrawals in agrarian economies. A confluence of inefficient policies and the absence

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of coordinated approaches across actors and scales impede systemic transformation in agricultural water use (Uhlenbrook et al., 2022). Using transboundary hydrological foundations is one of the most difficult problems in the world. It became extremely difficult to investigate these difficulties (Pahl-Wostl & Kranz, 2010). There are 276 river basins that cover more than 45% of the earth's land area and flow through several countries (De Stefano et al., 2012). At the subnational level, there are thousands of transboundary basins. The presence of numerous transboundary aquifers complicates governance even further (UNESCO, 2009). As a result multidisciplinary research is needed to provide an accurate assessment of the current and long-term consequences of improper or excessive use of transboundary water resources. This condition makes the global water scarcity challenge worse and makes it more difficult to reach Sustainable Development Goal (SDG) target 6.4, which calls for greater water usage efficiency across all sectors (Rossi et al., 2019). To produce practical improved and accurate assessments, improving transboundary hydrological concerns must be more integrated and involve science-policy processes in a variety of transboundary basin contexts (Armitage et al., 2015).

The water crisis is recognised as one of Iran's major environmental challenges, both currently and in the future. As Iran is located in a semi-arid environment, the impacts of climate change can be seen in the reduction of rainfall. Despite the fact that the most fertile soil can be found in the suburbs, sprawling informal urban expansion is destroying these valuable natural resources such as water and the hydrological system (Kamran et al., 2020; Kojuri et al., 2020). Water resources are essential natural resources in Iran under any long- or short-term scenario involving the many water and climate change scenarios that have to place sensitive areas on the highest alert. While political concerns between two countries that share a hydrological source (e.g., river) are important, hydrological challenges can also lead to instability and secondary environmental risks. Then, in order to understand how severely the impacts of a water crisis can seriously damage food security and human wellbeing, it is necessary to understand that water risk is not solely a function of hydrological hazards but also a function of a community's capacity for governance and resilience in the face of natural disasters (Ghalehteimouri et al., 2023). Therefore, decreased water availability or quality, excessive water consumption, and major flood episodes resulted from an inaccurate evaluation of water risk and water issues (Gleick & Iceland, 2018).

Significantly, a considerable portion of Iran is arid, semi-arid, or water-scarce. Rainfall is restricted to a few months each year, and the interaction between poor, unpredictable precipitation and high evaporation rates closely controls the geographical and temporal distribution of surface water. Surface water is scarce in these regions, and a higher dependence is made on water derived from underground aquifers for household, agricultural, and industrial purposes. There are various river basins between Iran and its neighbours that span international political borders (Janparvar et al., 2022). The availability of surface water in the eastern part of Iran such as Sistan and Baluchestan Province, where Iran and Afghanistan share the Hirmand River basin, rarely match up to the demands of these countries. Sistan and Baluchestan Province uses 3,001 wells, 6,006 Qanats, and 2,052 springs to supply its water needs, extracting 1.11 billion cubic metres of water from subterranean water sources. Water is used in amounts of 59.13, 59.13, 22.29, and 22.09 million cubic metres for drinking, agriculture, industry, and other uses, respectively (Akbari et al., 2022). These hydrological pattern features, which are shared by several provinces within each of these river basins, have a number of strategic ramifications for the countries' long-term economic development objectives.

Thus, it can be argued that 91%, 5.5%, and 3.5% of the province's underground water sources are used for agricultural, drinking, and industrial purposes, respectively. The arid climate, reduced incoming water from Afghanistan, over-exploitation of wells, urban and industrial development, and unauthorised wells have all contributed to the province's groundwater crisis (Yousefi et al., 2017). It is necessary to adopt

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an efficient technique in order to provide the region's limited access to water and the set water-related goals such as environmental goals, irrigation efficiency enhancement, pumping cost reduction, income growth, maximisation of farmers' profits, reduction of underground water and aquifer exploitation rate, and finally maximisation of social benefits. Because agricultural policies cannot be tested in vitro, their potential effects should be assessed before, during, and after implementation. The research method presented in this study enables us to put policies in place and achieve the aforementioned goals. The goal of this study was to look into surface and underground water exploitation management within an economic framework in border cities dealing with human and environmental challenges as a result of the water crisis.

LITERATURE REVIEW

The Hirmand River basin is an important water resource for both Iran and Afghanistan. The river originates in the mountains of Afghanistan and flows for approximately 1,100 kilometres before reaching the Hamun Lake in Iran. For Afghanistan, the Hirmand River basin is an important source of water for irrigation and agriculture. The basin supports a significant portion of the country's agricultural production, particularly in the southwestern province of Nimroz. The river also provides water for drinking and domestic use in some areas. In Iran, the Hirmand River basin plays a crucial role in sustaining the country's agriculture, particularly in the southeastern provinces of Sistan and Baluchestan and Kerman. The basin is also a key source of water for livestock and wildlife, as well as for industrial and domestic use. The length of the Hirmand River basin is approximately 1,100 kilometres, with the river itself stretching for about 650 kilometres. The basin covers an area of around 150,000 square kilometres, with approximately 20% of the basin located in Afghanistan and 80% in Iran. The river's geographical location is in the southern part of Afghanistan and southeastern Iran, and it is one of the few permanent rivers in the region, making it a crucial source of water for both countries (Fig. 1).

Fig. 1. Iran and Afghanistan border
Source: own elaboration based on NASA-Landsat (2023).

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MATERIALS AND METHODS

To account for variations in input consumption and agricultural production, the current study used two objective function varieties known as the constant elasticity of substitution production function and the quadratic cost function. One of the effective models that can show the flows of materials and production in an area is the mathematical expression of the dependent relationship between production factor inputs and outputs (Cheng, 2016). The needs for the different types of variables are established by the hierarchical constant elasticity of substitution production functions, which embed different substitution possibilities across inputs (Dixon & Jorgenson, 2012). The relationship between production results and the factors involved in the production process is described by the constant elasticity of substitution production function.

As a result, the replacement flexibility is the inverse of the comparative liking of diversity. This model demonstrates various impacts highlighted in production while ignoring explicit strategic interactions, and it uncovers novel findings with strong empirical support. We show how the relative satisfaction of variety differs with consumption level and how this affects market outcomes. In fact, the market outcome could follow two opposing patterns. There are many other models that have been used with different studies including Piecewise (Adamson et al., 2007; Connor et al., 2012), Continuous (Ortega Álvarez et al., 2004; Peña-Haro et al., 2010), the "CES function with scaling parameter for different scenarios" as well matched "Continuous" applied with (Nakamya & Romstad, 2020; Haqiqi & Horeh, 2021).

Each factor in agricultural production has a corresponding water type. Both the ground water and surface water sectors have no value-added, and their intermediate inputs are governed by a CES. Then following is the nonlinear regression method as mathematical programming model use in this paper following:

The objective function

In the gross return maximization mode, the mathematical programming model used in the first phase of the study has the following standard form (Banerjee & Maji, 2016; Ubukata, 2019; Ubukata et al., 2021):

$$Max\ Z = \Sigma_i^n = 1 C_i\ X_i \sum_{i=1}^{n} a_{ij} X_i \leq b_j \qquad (1)$$

where:

- C: gross profit from the -th activity (US Dollar per hectare);
- X: the decision variable or farm productive activities ($X_i \geq 0$);
- a: production technical coefficients;
- i: the variable associated with the name of the major crops grown in the study area (i = 1, 2, 3, …, n): wheat, barley, vegetables, summer crops, potatoes, onions, tomatoes, watermelons, melons, sunflowers, beets, and beans are the major irrigation crops cultivated in the border cities of eastern Iran in the 2020-2021 crop year, according to the study area;
- j: the variable related to cropping source constraints in study area representative farms (j = 1, 2, 3, …, m).

Model constraints

The most important cropping constraints in the study area are as follows:

Arable land constraints

This constraint means that the total amount of land devoted to agricultural activities cannot exceed the total amount of agricultural land available (Ghalehteimouri et al., 2022; Peters, 2015; Ren et al., 2022; Yu et al., 2022; Yuanyuan & XuXu, 2021). The following equation expresses this constraint (Bethwell et al., 2022; Jongeneel, 2018; Liu et al., 2022; Maes et al., 2018).

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$$\sum_{n=1}^{n} X_i \leq TL_{total} \quad (2)$$

where:

TL: the total available land in each farm within the study area (hectares).

Water constraint

Even though water is one of the most important and vital inputs in Iranian agriculture in general, and Sistan and Baluchestan agriculture in particular, it is viewed as a constraint in the study's model (Blackstock et al., 2021; Burkhard et al., 2012; Guo et al., 2022):

$$\sum_{i=1}^{n} W_{ij}\, X_i \leq \mathrm{TW}_{total} \quad (3)$$

where:

TW: the maximum amount of water input per crop year for each representative farm;

W_{ij}: the amount of water required for the *i*-th cropping activity per year (cubic metres per year).

Labour force constraint

The labour demand for various cropping activities varies according to the stages of planting, growing, and harvesting (Balibrea-Iniesta et al., 2021; Bohutskyi et al., 2016). The aforementioned constraint, expressed in the following equation, states that the total labour force required for production activities during a crop year cannot exceed the total labour force available in the region (Chowdhury, 2021; De Vries & de Boer, 2010):

$$\sum_{i=1}^{n} L_{ij}\, X_i \leq \mathrm{TL}_{total} \quad (4)$$

where:

TL: the total labour force available to the representative farm per year (person-days);

L_{ij}: the number of workers required for the *i*-th cropping activity per year (person-days per hectare).

Instrument constraint

The demand for cropping instruments is determined by operations during the planting, growing, and harvesting stages. According to the aforementioned constraint, which is expressed in the following equation, the total need for instruments during a crop year cannot exceed the total available instruments (Bethwell et al., 2022; Maes et al., 2018):

$$\sum_{i=1}^{n} INS_{ij}\, X_i \leq TINS_{total} \quad (5)$$

where:

$TINS_{total}$: the total number of instruments made available to the representative farm each year (working hours);

INS_{ij}: instruments required for the *i*-th cropping activity per year (working hours per hectare).

Crop rotation constraints

According to surveys conducted in the study area, crop rotations in traditional operation units show that wheat and barley have the most cultivation area in the region's farming model, and these crops are classified as major crops in almost all rotations.

Calibration constraints

We can calculate the binary values of the mentioned constraints, which represent the shadow price of the produced crops, by adding the calibration constraints (which bind the level of activities to the observed levels in the base period) to the other resource constraints of a typical linear programming model (Herbes et al., 2021; Li et al., 2021; Wang & Cuixia, 2009).

$$\sum_{i=1}^{n} X_i \leq X_j^0 + \in \quad (6)$$

where X_i^0 represents the values of the base year. It should be noted that the calibration constraints are added to the model constraints only in the first

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stage of the PMP process in order to obtain shadow prices and their role in estimating production function parameters or costs, but are excluded in subsequent stages.

Sampling method

To assimilate units within each group, cultivation areas dedicated to 40 farmers were randomly selected, and the correlation between farmers' income and some variables such as cultivated area, type of water resource, and the extent of input use in the production process, were taken into account. Finally, ANOVA was used to divide the study area (the eastern border areas of Iran) into two homogeneous groups covering less than 5 hectares and more than 5 hectares, and the sample size was calculated using Cochran's formula as follows:

$$\begin{cases} n_0 = \dfrac{Z^2 S^2}{d^2} \\ n = 1 + \dfrac{n_0}{N} \end{cases} \qquad (7)$$

where:

- n: the total population size;
- Z: the type I error value in the normal distribution table;
- S^2: the preliminary sample variance of the objective variable (cultivation area);
- N: the required sample size.

According to information obtained from the Fars Agriculture Jihad department, there are 12,120 operators available in eastern Iran's border cities. The cultivated area has a variance of 3.48 and a d of 0.33. The desired sample size (118) is obtained by incorporating the aforementioned parameters into the Cochran's formula. Once the sample size was determined, 48 questionnaires were randomly distributed to and completed by group 1 operators (lands covering less than 5 hectares) and 70 questionnaires were randomly distributed to and completed by group 2 operators (lands covering more than 5 hectares).

RESULTS

Using the positive mathematical programming approach, this section attempts to evaluate the consequences of an increase in water price, cropping pattern, and efficiency enhancement (reduction of water consumption) under various scenarios. The characteristics of the population members assigned to two groups of operators (operators of lands covering less than 5 hectares and operators of lands covering more than 5 hectares) are first evaluated, and the linear programming results are then analysed and compared with the results of positive mathematical programming. Finally, the outcomes of the scenarios involving an increase in water prices and a decrease in water consumption are evaluated using the positive mathematical programming approach.

Characteristics of the population members in both groups of operators

Tables 1 and 2 show the characteristics of the population members assigned to each operator group. As shown in Tables 1 and Table 2, the largest cultivation area is dedicated to what, with an average

Table 1. Characteristics of the population members assigned to group 1 operators (operators with lands covering less than 5 hectares)

Product	Number of operators	Total cultivation area (hectare)	Average cultivation area (hectare)	Percent
Wheat	40	62.5	1.30	18.87
Barley	35	42.5	0.88	19.63
Sugar beet	14	17.5	0.36	8.08
Potatoes	18	28	0.58	12.93
Tomatoes	21	28.95	0.60	13.37
Persian melon	30	15	0.31	6.93
Bean	10	9	0.18	4.15
Onion	10	7	0.14	3.23
Sunflower	8	6	0.12	2.77

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

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Table 2. Characteristics of the population members assigned to group 2 operators (operators with lands covering more than 5 hectares)

Product	Number of operators	Total cultivation area (hectare)	Average cultivation area (hectare)	Percent
Wheat	68	368	5.25	40.14
Barley	60	171.25	2.44	18.68
Sugar beet	24	107.4	1.53	11.71
Cucumber	8	10	0.14	1.09
Tomatoes	15	86.25	1.23	9.40
Vegetables	8	10	0.14	1.09
Potatoes	33	51.75	0.73	5.64
Persian melon	30	25	0.35	3.72
Bean	20	13.2	0.18	1.44
Onion	15	10.5	0.15	1.14
Sunflower	27	15.3	0.21	1.66
Watermelon	24	48	0.68	5.23

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

of 1.30 hectares of cultivated area dedicated to group 1 operators (n = 40), accounting for 28% of the total cultivated area in the region. While group 2 operators (n = 68) have an average of 5.25 hectares of cultivated area, accounting for 40% of the total cultivated area in the region. In group 1 operators, the largest cultivated area (after wheat) is dedicated to barley (19%), tomatoes (13%), and potatoes (12%), respectively, and the smallest cultivated area is dedicated to onions (4%), vegetables (3%), and cucumbers (2%). The region's largest cultivated area (after wheat) is dedicated to barley (18%), sugar beet (11%), and potato (9%), respectively, while the smallest cultivated area (less than 1%) is dedicated to sunflower, onion, bean, and cucumber.

Positive mathematical programming (calibration of the quadratic cost function) in the representative operator of group

The positive mathematical programming approach is used in this section to evaluate the results obtained from the representative operator of group 1 (with lands covering less than 5 hectares). The positive mathematical programming approach, as mentioned in the materials and methods section, is divided into three stages. To obtain the binary values of the aforementioned constraints, the calibration constraints (which bind activity levels to the observed levels of the base period) are added to the resource constraints of a typical linear programming model in the first stage. The binary values are used to calculate the quadratic function's parameters in the second stage, and the quadratic function is introduced into the objective function in the third stage to estimate the model without calibration constraints. As shown in Table 3, the BMP model reproduces the values of the base year; however, in the linear programming model, only two crops, barley and onion, have been introduced into the cropping pattern, while the remaining crops have been excluded. Furthermore, based on the percentage of variations shown in Table 3, it can be argued that calibration was performed optimally using the quadratic cost function.

Table 3. The positive mathematical programming results based on the quadratic cost function calibration in the representative operator of the group 1

Activity	Cropping pattern in the region (Hectare)	PMP model (hectare)	Percentage of variations	Linear programming model (hectare)
Wheat	1.3020	1.3033	0.1	0
Barley	0.8854	0.8863	0.1	1.94
Sugar beet	0.3645	0.3624	-0.578	0
Potatoes	0.5833	0.5839	0.1	0
Tomatoes	0.6031	0.6037	0.1	0
Persian melon	0.3125	0.3128	0.1	0
Bean	0.1458	0.1459	0.1	0
Onion	0.1875	0.1876	0.1	2.55
Sunflower	0.125	0.1208	-3.332	0
Fallow	0.5	0.5	–	0.5

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

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Positive mathematical programming (calibration of quadratic cost function) in representative operator of group 2

The cropping pattern in the region only allows for the inclusion of two crops, according to Table 4, when using the linear programming approach: barley (8 hectares) and fodder corn (5 hectares). The cropping pattern, however, allows for the inclusion of all crops planted in the base year when using the positive mathematical programming approach. Furthermore, the percentage of variations indicates that the quadratic cost function was properly calibrated.

Table 4. The positive mathematical programming results based on the calibration of the quadratic cost function in the representative operator of the group 2

Activity	Cropping pattern in the region (Hectare)	PMP model (hectare)	Percentage of variations	Linear programming model (hectare)
Wheat	5.2571	5.2624	0.1	0
Barley	2.4464	2.4488	0.1	8
Sugar beet	1.5342	1.5358	0.1	0
Cucumber	0.1428	0.1430	0.1	0
Potatoes	1.2321	1.2333	0.1	0
Vegetables	0.1428	0.1430	0.1	0
Tomatoes	0.7392	0.7400	0.1	0
Persian melon	0.3571	0.3575	0.1	0
Bean	0.1500	0.1501	0.1	0
Onion	0.1885	0.1887	0.1	0
Sunflower	0.2185	0.1752	0.1	0
Watermelon	0.6857	0.6864	-0.19833	5
Fallow	1	1	0.1	1

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

Positive mathematical programming method (calibration using CES production function) in the representative operator of group 1

Once the positive mathematical programming results have been evaluated using the quadratic cost function calibration, the positive mathematical programming results are also evaluated using the CES production function calibration. According to the results in Table 5, calibration with the CES production function is associated with lower variations than calibration with the quadratic cost function.

Table 5. The positive mathematical programming results based on the calibrations performed using the CES production function in the representative operator of the group 2

Activity	Cropping pattern in the region (Hectare)	PMP model (hectare)	Percentage of variations	Linear programming model (hectare)
Wheat	1.3020	1.3021	0/007	0
Barley	0.8854	0.8854	0	1.94
Sugar beet	0.3645	0.3624	-0.57	0
Potatoes	0.5833	0.5839	0.10	0
Tomatoes	0.6031	0.6037	0.09	0
Persian melon	0.3125	0.3128	0.096	0
Bean	0.1458	0.1459	0.068	0
Onion	0.1875	0.1876	0.053	2.55
Sunflower	0.125	0.1208	-3.36	0
Fallow	0.5	0.5	–	0.5

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

Positive mathematical programming method (calibration using CES production function) in the representative operator of group 2

Calibration using the CES production function is associated with lower variations than calibration using the quadratic cost function, such that in the representative operator of group 2, only the cultivation area dedicated to two crops, sugar beet and sunflower, experienced minor variations, while the cultivation area dedicated to other crops experienced no variations (Table 6).

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Table 6. Positive mathematical programming method based on calibrations carried out using CES production function in the representative operator of group 2

Activity	Cropping pattern in the region (Hectare)	PMP model (hectare)	Percentage of variations	Linear programming model (hectare)
Wheat	5.2571	5.2571	0	0
Barley	2.4464	2.4464	0	8
Sugar beet	1.5342	1.5343	0.006	0
Cucumber	0.1428	0.1428	0	0
Potatoes	1.2321	1.2321	0	0
Vegetables	0.1428	0.1428	0	0
Tomatoes	0.7392	0.7392	0	0
Persian melon	0.3571	0.3571	0	0
Bean	0.1500	0.15	0	0
Onion	0.1885	0.1885	0	0
Sunflower	0.2185	0.2165	-0.9153	0
Watermelon	0.6857	0.6857	0	5
Fallow	1	1	–	1

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

Scenarios of increase in water price for the representative operator of group 1 (calibration using the cost function)

In this section, the water price increase scenarios for the representative operator of Group 1 are examined. Similarly to the previous section, different scenarios are examined after 5% increases in water prices, and finally scenarios that have a greater impact on cropping patterns are chosen and analysed. The scenarios of a 70%, 80%, and 100% increase in water price are chosen as the chosen scenarios. Table 7 displays the results obtained from these scenarios.

As shown in Table 7, a 70% increase in water price increased the cultivation area dedicated to wheat, barley, and sugar beet, decreased the cultivation area dedicated to potatoes, tomatoes, Persian melons, beans, and onions, and excluded sunflower from the cropping pattern. In the second scenario (an 80% increase in water price), only sugar beet cultivation increased, while wheat, barley, potato, and onion cultivation decreased, while tomato cultivation remained unchanged. Sunflowers, Persian melons,

Table 7. The results of scenarios of increase in water price for the representative operator of group 1

Activity	PMP model (Hectar)	Scenario 1 (70% increase)	Percentage of variations	Scenario 2 (80% increase)	Percentage of variations	Scenario 3 (100% increase)	Percentage of variations
Wheat	1.30	1.38	6.55	1.30	0	1.12	-13.41
Barley	0.88	0.91	3.56	0.86	0	0.82	-7.28
Sugar beet	0.36	0.39	9.61	0.40	1177	0	-100
Potatoes	0.58	0.57	-0.2.26	0.56	-3.89	0.54	7.39
Tomatoes	0.60	0.56	-0.5.65	0.56	-5.65	0.53	-
Persian melon	0.31	0.08	-0.73.16	0	-100	0	-
Bean	0.14	0	-100	0	-100	0	-
Onion	0.18	0.15	0.18.49	0.14	-21.56	0.13	-
Sunflower	0.11	0	-100	0	-100	0	-
Economic value	-	0	-	0	-	0	-
Total gross benefit	211,670,000	143,340,000	-32.27	135,110,000	-36.16	120,380,000	-
Operator gross benefit	4,409,792	2,986,250	-32.27	2,814,792	-36.16	2,507,917	-

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

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and beans were excluded from the cropping pattern in this scenario. The variations in the third scenario (100 increase in water price) are nearly identical to those in the second scenario, except that the sugar beet was also excluded from the cropping pattern in this scenario. In all scenarios, the farm's net profit decreased, and the economic value of water was assumed to be zero.

Scenarios of increase in water price in the representative operator of group 2 (calibration using the cost function)

Similarly to the previous section, different scenarios are examined after 5% increases in water prices, and finally scenarios that have a greater impact on cropping patterns are chosen and analysed. Finally, the scenarios of a 70%, 80%, and 100% increase in water price are chosen as the best available scenarios. Table 8 displays the results obtained from these scenarios. Table 8 depicts variations in scenarios of water price increases for a representative operator in Group 2. Only the cultivation area dedicated to sugar beet increased in the first scenario (a 75% increase in water price), while the area dedicated to wheat, barley, cucumber, potato, vegetables, tomatoes, beans, onions, and watermelons decreased, and Persian melons and sunflowers were excluded from the cropping pattern. In the case of an 80% increase in water price, the area dedicated to cucumbers, tomatoes, and watermelons remained constant (in comparison to the first scenario), while the area dedicated to other crops decreased. Persian melons, sunflowers, and beans were excluded from the cropping pattern in this scenario.

Finally, a 100% increase in water price resulted in the exclusion of vegetables, Persian melons, beans, and sunflowers from the cropping pattern. In these scenarios, as in the scenarios considered for group 1 operators, the farm's gross profit decreased throughout the cropping period.

Table 8. Results of scenarios of water price increase for the representative operator of the group 2

Activity	PMP model (Hectar)	Scenario 1 (70% increase)	Percentage of variations	Scenario 2 (80% increase)	Percentage of variations	Scenario 3 (100% increase)	Percentage of variations
Wheat	5.26	4.32	-17.76	4.26	-18.94	4.01	-23.68
Barley	2.44	2.16	-11.60	2.14	-12.38	2.06	-15.47
Sugar beet	1.53	1.64	7.01	1.61	5.33	1.51	-1.40
Cucumber	0.14	0.11	-20.67	0.11	-20.67	0.10	-27.47
Potatoes	1.23	1.10	-10.74	1.08	-11.62	1.04	-15.16
Vegetables	0.13	0.03	-77.34	0/01	-89.17	0	-100
Tomatoes	0.74	0.67	-9.25	0/67	-9.25	0.64	-12.51
Persian melon	0.35	0	-100	0	-100	0	-100
Bean	0.15	0	-100	0	-100	0	-100
Onion	0.18	0.15	-19.95	0.14	-21.32	0.13	-26.80
Sunflower	0.21	0	-100	0	-100	0	-100
Watermelon	0.68	0.67	-2.01	0.67	-2.01	0.66	-2.52
Economic value of water	–	0	–	0	–	0	–
Total net profit	155,570,000	1,305,400,000	-16.08	1,289,800,000	-17.09	1,229,500,000	-20.96
Operator net profit	22,224,286	18,648,571	-16.08	18,425,714	-17.09	17,564,286	-20.96

Source: own elaboration on the basis of survey and Iran Ministry of Agriculture – Jihad (2020).

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CONCLUSIONS

Three scenarios were presented in this study, and they demonstrated that, compared to the scenario of an increase in water price, water resources had a significantly less substantial impact on the operators' gross profit. An econometric analysis method used to understand agriculture productivity in Iran's eastern border cities in the face of a water crisis, hydro-political issues, and the amount of water available to Iranian farmers. Since Afghanistan lacks an adequate irrigation system, water management is inadequate, and the Hirmand River only receives 10% of the precipitation in this province, and 90% of it evaporates quickly due to high evaporation and a lack of knowledge in water management. This mismanagement of water resources in Afghanistan had an impact on agricultural productivity in Iran's Sistan and Baluchistan provinces.

For example, in the third scenario (70% increase in water sources) the total gross profit was 4233.33 US dollars, while in the scenario of 100% increase in water price (the third scenario), the total gross profit was 4000 dollars. The scenarios of reduction in water sources and increase in water price had an almost equal impact on the cropping pattern.

In group 2, the total net profit and operator profit in the scenario of a 100% increase in water price (the third scenario), was found to be higher than the scenario of a 75% decrease in water sources alone. In the other two scenarios, a reduction in water sources led to more gross profit than the increase in water prices, and both groups had better apply the scenarios of reduction in water sources.

The results show that the increase in water price and the increase in the irrigation efficiency under different scenarios (calibration using the cost function) can bring about noticeable changes in the cropping pattern of the region. Water prices have not had a significant impact on productivity levels, though they do occasionally influence irrigation systems or changes in agricultural practices in specific geographic areas. Depending on the price of water, the agricultural situation may change to produce more profitable goods. Agriculture is influenced by commercial considerations as it becomes commercialized, meaning that some specific crops started to be cultivated not for domestic purposes but for sale in national and even international markets.

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