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Water saving role and environmental impacts of price liberalization in agriculture: An experience in Iran

Hamidreza Gerami[1], Seyed Nematollah Moosavi[1]*, Abbas Aminifard[2]

1. Agricultural Economics and Natural Resources and Environment, Islamic Azad University, Marvdasht Branch, Marvdasht, Iran
2. Department of Economics, Shiraz Branch, Islamic Azad University, Shiraz, Iran

** Corresponding author's Email: seyed_1976mo@yahoo.com*

ABSTRACT
Government intervention in the agricultural market, including guaranteed purchases and subsidy payments, has raised many environmental concerns due to the resulting pressure on and pollution of natural resources. In this study, the economic and environmental effects of price liberalization and reduction of government interventions in the agricultural products and inputs market were investigated in Shiraz City, Iran. For this purpose, five scenarios were designed, and a positive mathematical programming model with a cost function approach was used to assess their impacts. The results showed that the increased prices of agricultural products after eliminating dictated prices along with global prices enhanced the incentive to produce high-yield crops. There has been a 9.94% drop in farmers' net income due to the decrease in the total cultivated area of crops in the region. However, if this policy is accompanied by the elimination of agricultural input subsidies, the change in cropping patterns and elimination of cost-intensive crops from the pattern may result in 1.53% growth in profitability. The most important environmental impact of this policy was associated with water savings in agricultural use, which was estimated to equal 14.61%. Overall, it appears that changing in the cropping pattern after implementing the combined scenario increases profitability and reduces water consumption. However, this policy also results in a 3.95% increase in chemical fertilizer consumption in the region, which is a factor in environmental pollution.

Keywords: Liberalization, Environment, Positive mathematical programming model, Input subsidy.
Article type: Research Article.

INTRODUCTION
The growth of the agriculture sector is considered a prerequisite for economic growth and development in developing countries (Białowąs & Budzyńska 2022). The growing demand due to population growth and the expansion of nutritional knowledge, along with the need to preserve and sustain basic resources and the environment, has intensified the need for developing the agriculture sector (Parhizkar *et al.* 2013). There are generally accepted reasons to justify government interventions in agricultural markets in the form of price setting, income support, and input subsidy payments (Osabohien *et al.* 2022). Countries, whether developed or developing, support agricultural producers through various methods (Mokgomo *et al.* 2022), although the type and extent of supports in many countries are not obvious. Interestingly, industrialized and advanced countries, as advocates of free markets, provide the most support to their agricultural sector (Akinbamowo 2013). One of the reasons for government intervention in agricultural product markets is the inefficiency of market mechanisms in increasing the welfare of consumers and producers (Gholizade *et al.* 2021). The need to support producers' incomes is one of the main reasons for government interventions (Lencucha *et al.* 2020). In Iran, considering the vital role of the agricultural sector in the economy, the policies to support farmers have a long history (Layani & Mehrjou 2023). The experience of most countries shows that the use of limited support tools reduces the efficiency of support policies, and therefore, the adoption of a set of tools known as a support basket is recommended

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(Granvik *et al.* 2012). In general, the main support policies by the Iranian government in the agriculture in recent years have included the distribution of inputs to farmers, such as subsidized fertilizers, pesticides, and machinery (Azik *et al.* 2021), low-interest loans with long repayment periods (Negintaj & Omidikia 2014), paying part of the agricultural product insurance premium (Pishro *et al.* 2011), guaranteed purchase price (Pishbahar & Ferdowsi 2023), and tax exemptions for agricultural producers (Parhizkar *et al.* 2015). Due to the importance of the agricultural sector in providing food, raw materials for industries, exports, and employment, the scope of support for this sector has been expanded and strengthened continuously (Noroozi *et al.* 2020). Compared to other economic sectors, the agriculture has a closer and stronger relationship with the environment, which is the infrastructure and foundation of productive activities in agriculture (Olanipekun *et al.* 2019). The undesirable effects of input consumption, coupled with the necessity of ensuring food security, require serious attention to sustainability issues. The implementation of price and non-price support policies by the government in the agricultural sector is recommended and welcomed when it does not undermine sustainability and ensures social, economic, and environmental sustainability (Layani & Mehrjou 2023). In Iran, the high consumption of agricultural inputs, especially chemical fertilizers and fuel carriers, has created various environmental problems, including water resource depletion, soil erosion, and the production of low-quality products, ultimately leading to increased production costs (Agha *et al.* 2015). On the other hand, the increasing demand for agricultural products and the need for development projects have created a dilemma of sustainable agriculture and intensive agriculture (Kahnesal & Sarvari 2013). Currently, the most concerning environmental aspects related to agricultural activities are the use of inputs sourced from non-agricultural sectors, such as fertilizers and pesticides and the depletion of groundwater resources (Layani *et al.* 2021; Hashemi *et al.* 2022). This overreliance on inputs, particularly chemical fertilizers and reckless water resource exploitation, imposes heavy environmental pressure (Darzi-Naftchali *et al.* 2020). Therefore, there is a need to revise support policies, and it is necessary to reconsider these policies with a focus on sustainability. Therefore, it is highly important to examine the impacts of changes in price and non-price policies (towards liberalization) on agricultural sustainability since the implementation of each of these policies will have substantial economic, social, and environmental consequences (Mozaffari 2015). Limiting the government's involvement in agricultural activities was proposed and pursued by the World Bank and other global economic organizations in recent decades. Among the most important goals of liberalization is to prevent using production facilities in the low-efficiency production sector, increasing production and encouraging competition, reducing resource consumption, and alleviating damage to the environment. The general direction of Iran's economic policies towards reducing government interference and liberalizing economic activities. However, despite the fact that these tendencies can lead to economic benefits for society, their effects should also be considered and liberalization should be well-defined and implemented. This point is extremely important for Iranian society since excessive use of chemical fertilizers and increasing consumption of fossil resources caused environmental pollution such as severe soil erosion, land infertility, desertification and reduced quantity and quality of agricultural products, and water quality issues. Within this context, the rest of the paper is structured as follows: The next section introduces the methodology of the PMP model and the policy analysis. Optimal crop pattern is presented in the results section. The final section offers discussion and conclusions.

Literature review

Barnes *et al.* (2016) examined the effects of the Common Agricultural Policy (CAP) reform in the European Union (EU) on food security in Scotland. They focused on livestock production and collected data by surveying 1,764 livestock farmers. The results of their study indicated that the implementation of tax policies could have a negative impact on livestock numbers and livestock production in the study area. Cortignani & Dono (2018) investigated the effects of agricultural policies and climate change. The European Union has recently revised its CAP so that milk production quotas have been removed. These changes have had significant consequences on land use and the use of inputs, including water. Furthermore, their results showed that policy reforms had positive but limited effects and, in some cases, had negative impacts on the economy of agricultural production. Garrone *et al.* (2019) examined the effects of CAP on employment in the agricultural sector. Specifically, they investigated the relationship between EU agricultural subsidies and the exit of labor from agriculture using the data of a panel of 210 regions in the EU during 2004-2014. The results showed that a 10% increase in the CAP budget prevents the exit of 16,000 people from agricultural employment. Barown *et al.* (2019) assessed the long-term consequences of policy measures on agricultural productivity in Finland. The results of this study indicated that policies such as the green measures of the CAP significantly improved productivity. Generally, actions that encourage the use of compost are promising. However, complementary policies were proposed to better implement these measures and achieve long-term objectives. Jamali Moghaddam *et al.* (2019) examined the effects of water supply on the sustainability of the agricultural system. They used a positive mathematical programming (PMP) approach and collected data through questionnaires from 150 farmers in 90 regions in Iran. The scenarios examined included a reduction in available groundwater levels. The results showed the negative impact of reduced water availability on sustainability indicators of different farm groups. Elahi *et al.* (2020) conducted a study to examine the effects of allocating agricultural lands to farmers on the productivity of crop production in the Punjab Province of Pakistan. They showed that the targeted policy led to an increase in the yield of wheat, rice, cotton, and sugarcane in the region. Their findings also indicated that in addition to land allocation, the government should focus on providing formal and informal training to farmers. Numerous studies have been conducted to evaluate the effects of government policies in Iran. Pishbahar & Sani (2018) concluded that the implementation of guaranteed purchase policy resulted in barley producers selling their products for an average of 847 Iranian Rials higher than before the implementation of the policy. Shabanzadeh *et al.* (2019) conducted a study titled "Transition from guaranteed purchase policy to price support and its effects on cropping patterns in Qazvin Plain, Iran" and found that in all three scenarios, the area of crops with less water consumption like wheat decreased, while the area of crops with high water demand such as alfalfa and tomatoes upraised. Noroozi *et al.* (2019) in their study titled "Examining the effects of support policies for producers and consumers on employment in the agricultural sector" concluded that policies had a positive and significant effect on employment in the agriculture sector. Moradni Najafabadi & Mirzaei (2019) in an article titled "Evaluation of policies for achieving water resource sustainability goals in Qazvin Plain" found that implementing a policy to reduce irrigation water available by 10% for farms smaller than 25 ha in the Qazvin Plain encourages farmers to manage water resources properly. This policy led to a reduction in water consumption of approximately 10% and 16% for small and medium-sized farms respectively. However, to encourage farmers to manage water resources properly in large farms in the Qazvin Plain (farms larger than 25 ha), an elevation in water prices by 50% was recommended. Mirzaei & Ahmadpour Borzajani (2016) used a positive mathematical programming model and a constant elasticity of substitution production function to examine the effects of irrigation water rationing on cropping patterns and farmers' gross profits in the Amol region, Mazandaran Province, Iran. Their results showed that the irrigation water rationing policy led to a reduction in the area under cultivation for most selected crops in the studied areas. Additionally, the gross profits of farmers in all regions dropped as a result of implementing this policy.

MATERIALS AND METHODS

Environmental effect of price liberalization

The study area

Fars Province and Shiraz City are considered as agricultural hubs in Iran. The irrigated and rainfed land area in this city was equal to 24,078 and 45,808 ha respectively in 2021. The production of irrigated crops was equal to 411,000 tons, and the production of rainfed crops was 51,000 tons. Among the agricultural crops, cereals account for 110,000 tons. Wheat and barley rank first and second in terms of cultivated area. The cultivated area of alfalfa and forage corn was 4,972 ha and 2,101 ha, respectively. Canola cultivation is also popular among farmers in this city and in terms of cultivated area it is among the top 5 crops.

Positive mathematical programming (PMP) model

Policy analysis based on normative models that show a significant difference between the results of the model and the existing level of activities is generally not acceptable. At the same time, measuring or adding non-linear constraints is not very satisfactory. For this reason, the results of policy making are limited to a set of restrictions that are suitable only for the base year and not for examining policy changes. This problem is exacerbated when regional models are designed with a small number of empirical constraints and with a wide range of variability in crop production (Heckelei & Britz 2000). Recent studies have increased the interest in PMP as a tool to analyze the potential effects of agricultural policies in the agriculture sector. The general idea of PMP is to use the information available in binary variables as calibration constraints that limit the solution to the linear programming problem to the level of existing activities. These binomial values are used to specify a nonlinear objective function that reconstructs the observed activity level using an optimal solution for a new programming problem that does not have calibration constraints (Preckel *et al.* 2002).

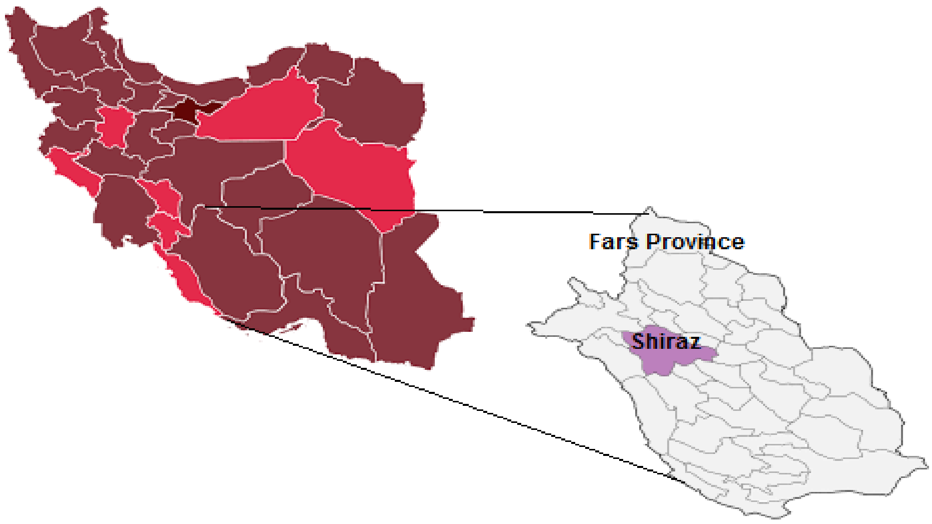

Fig. 1. Study area (Shiraz City, Fars Province, Iran).

In general, PMP models have three stages. The first consists of solving a linear programming model to maximize farmers' profits according to resource limitations and calibration.

$$\begin{aligned} & Max\ Z = R'x - c'x \\ & subject\ to \\ & Ax \le B\,[p] \\ & x \le (x^0 + \varepsilon)\,[\lambda] \\ & x \ge 0 \end{aligned} \quad \textbf{(1)}$$

where Z refers to the goal that must be maximized, R refers to income vector of products (price multiplied by yield), X and c refer to cultivation area and variable cost vector for each unit of crop, respectively. A refers to technical coefficient matrix, B refers to available resources vector and dual variables of resources (with shadow prices) respectively, x^0 refers to activity level observed in base year, and ε and λ refer to a vector of small positive numbers and double variable of calibration limitation respectively. Adding the calibration limitation makes the optimal solution of linear programing be exactly the same as the observed activity in the base year (Howitt *et al.* 2012). Resource constraints consist of three constraints including land, water, and work force. Land constraints indicate that the whole area under cultivation may not exceed the total farmland area.

irrigated lands constraint:

$$\sum_{w=1}^{n} x_w \le TX_W \qquad w \in i \quad \textbf{(2)}$$

Non-irrigated lands constraint: **(3)**

$$\sum_{r=1}^{n} x_r \le TX_r \qquad r \in i$$

where TX_w and TX_r refer to total irrigated and non-irrigated lands (ha) in the region, respectively. X_w is the cultivated area for crop w (ha) and X_r is the cultivated area of crop r (ha). Taking into account the value of water in farming and its supply limitation, it is essential to have an optimum use of water resources. To achieve an optimum way of using water, the limitations of water resources were also taken into account:

$$\sum_{i=1}^{n} \frac{ET_i^a}{efficiency} \times x_i \le TW \quad \textbf{(4)}$$

where TW refers to the maximum water resources available (m^3), ET refers to water needed for each crop based on CROWPWAT software, and *efficiency* refers to the mean irrigation efficiency in the region.

Another constraint included is labour one, which mean the total labour required might not exceed the available labour.

$$\sum_{i=1}^{n} L_i \times x_i \leq TL \tag{5}$$

where TL refers to total labour available and L_i is the required labour per ha of i^{th} crop.

In the second phase of PMP, the values of λ are needed to estimate a nonlinear variable cost function. To simplify the computation and given lack of any reason to choose other functions, 2^{nd} order variable cost function was adopted in this study.

$$C^v = d'x + \frac{1}{2}x'Qx \tag{6}$$

where C^v refers to variable cost, d refers to a vector of cost parameters, Q refers to specific positive symmetric matrix (n*n) of the parameters related to the second part of cost function. This nonlinear variable function of cost can be solved only when the final cost of activities is equal to the book cost of activities (c) and double variable of calibration limitation (λ). Therefore, the parameters of the function of cost can be calculated provided that:

$$MC^v = \frac{\partial C^v(x^0)}{\partial x} = d + QX^0 = C + \lambda \tag{7}$$

where, n parameters for vector d, as Q is symmetric, and n(n+1)/2 parameter for Q should be calculated. This means that the numerical value of n+n(n+1)/2 parameter should be obtained; however, n equations (one equation for each product) exist in the relationship. Where the number of parameters to be calculated is greater than the number of equations, we have an ill-posed problem. In some studies, these problems are solved by considering the off-diagonal elements of Q equal to zero (Arfini & Paris 1995; Howitt 1995; Helming *et al.* 2000; Muniz & Hurle 2006). Although this method satisfies the first-order condition and calibrates the baseline solutions well, the resulting behavioural responses by these models are entirely arbitrary and potentially unsatisfactory. The reason is that the calibrated behavioural response by the model is highly dependent on the second-order derivatives of the objective function (changes in MC when the level of activity changes), which are disregarded in these methods (Heckelei 2002). Paris & Howitt (1998) proposed maximum entropy to find all n+n(n+1)/2 parameter for the vector d and matrix Q. Maximum entropy was first introduced by Shannon in 1948. Shannon provided a way to measure information and created several revolutionary tools in information theory (Howitt 1995). Using maximum entropy in econometrics was proposed by Allen & colleagues (1998) and in 1998, this method was applied to PMP problems with negative degrees by Paris & Howitt (1998). The formula of maximum entropy to estimate the parameters d and Q are as follows. In these equations, H represents the entropy of the model that needs to be maximized. The first constraint is the key relationship in PMP, which has a negative degree of freedom and was explained above. The next two constraints define the matrices d and Q, and the final equation is added to ensure the symmetry of the Q matrix. The next two equations also indicate that the sum of probabilities must be equal to one.

$$\max_p H(P) = -\sum_{k=1}^{K}\sum_{i=1}^{n} pd_{k,j}\ln pd_{k,i} - \sum_{k=1}^{K}\sum_{i=1}^{n}\sum_{j=1}^{n} pq_{k,i,j}\ln pq_{k,i,j} \tag{8}$$

$$subject\ to:$$

$$d_i + \sum_{j=1}^{n} q_{i,j}x_j^0 = c_i + \lambda_i, \quad \forall_i$$

$$d_i = \sum_{k=1}^{n} pd_{k,i}zd_{k,i}, \ \forall_i$$

$$q_{i,j} = \sum_{k=1}^{K} pq_{k,i,j}zq_{k,i,j}, \quad \forall_{i,j}$$

$$\sum_{k=1}^{k} pd_{k,i} = 1, \ \forall_i$$

$$\sum_{k=1}^{K} pq_{k,i,j} = 1, \quad \forall_{i,j}$$

$$q_{i,j} = q_{j,i} \quad \forall_{i,j}$$

Using the above equations, it is possible to obtain all elements of the vector d and the matrix Q. However, these equations do not guarantee that the second-order conditions for the obtained cost function are satisfied. According to the second-order conditions, it is necessary to have a definite and negative Hessian matrix of the cost function. This requires a positive and definite Q matrix. To achieve this, the Cholesky decomposition theorem was utilized. According to this theorem, a square matrix is positive, definite, semi-defined, and symmetric if and only if it has a Cholesky decomposition. The Q matrix, in the Cholesky decomposition, is transformed into the product of a lower triangular matrix (L) and its transpose, which is an upper triangular matrix (L'). This can be expressed as follows (Howitt *et al.* 2012):

$$Q = L.L^{'}$$

For instance, let Q be a 3*3 matrix, then Cholesky decomposition is

$$\begin{bmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ q_{31} & q_{32} & q_{33} \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \times \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ 0 & l_{22} & l_{23} \\ 0 & 0 & l_{33} \end{bmatrix} \qquad \textbf{(9)}$$

By adding these equations as constraints and imposing the condition that the diagonal elements of the Q matrix should be greater than zero (not less than or equal to zero), it can be ensured that the second-order conditions for the obtained cost function are satisfied.

In the third stage of PMP, a nonlinear calibrated cost function and resource constraints were used to construct a nonlinear programming model as follows:

$$Max \;\; Z = p^{'}x - d^{'}x - x^{'}Qx/2 \qquad \textbf{(10)}$$

$$Subject\ to:$$

$$Ax \le b$$

$$x \ge 0$$

The coefficients and variables in this model are the same as described. There is no need for calibration constraints in this model, and by using the calibrated objective function and resource constraints alone, the solution in the baseline conditions will precisely match the baseline activity levels. Using this model, it is possible to analyze the policy by changing the conditions and defining different scenarios.

Designing policy scenarios

One of the government's supportive policies in the agriculture sector, aimed at supporting domestic producers to promote production and reduce farmers' production costs, is providing subsidies to inputs (chemical fertilizers, pesticides, electricity, and fuel). In this study, it was assumed that there was no subsidy for the inputs, and the prices of imported inputs were based on their price at customs, taking into account the market exchange rate. Chemical fertilizers and pesticides are among tradable inputs, and the prices were converted to domestic prices in this scenario using the market exchange rate at the beginning of 2021. Another government support policy covered here was the guaranteed purchase. In this scenario, instead of the predetermined prices as guaranteed purchase prices in the base year (2020-2021), the declared prices for the crops in the agricultural year 2021-2022 were taken into account. The prices of other crops not covered by this policy were calculated based on the base year rates and the average annual price growth rate of these crops in the last three years. Additionally, in another scenario aimed at reducing government interventions in the agricultural market, no guaranteed prices were taken into account, and the global prices were taken into account (market exchange rate).

Table 1. Scenarios studied in this research.

Crops price determined by the market	Guaranteed purchase of 2021-2022	No subsidy on inputs	Scenario
		√	1
	√		2
√			3
	√	√	4
√		√	5

RESULTS AND DISCUSSION

Effects of policies on cropping patterns

The results related to the optimal cropping pattern in Shiraz are presented in Table 2. Clearly, in Scenario 1, the area under cultivation decreased for all crops. Crops such as barley and dryland wheat are totally absent from the cropping pattern. Based on the results, the projected areas under cultivation for wheat, dryland wheat, maize (grain), forage maize, and rice in the cereal group are 5,473, 2,745, 35, 1898, and 69 ha respectively. The changes in the area under cultivation of these crops compared to the current cropping pattern are -67%, -66%, -87%, -9%, and -70%, respectively. The reduction in the cultivated area of these crops is due to the increased production costs resulting from the liberalization of input prices, including energy and chemical fertilizers. Among these crops, forage maize shows the least change in the area under cultivation. The area under cultivation for alfalfa in the optimal pattern under Scenario 1 decreases from 4972 ha to 457 ha compared to the base scenario. Due to the probable increase in production costs and drop in gross profit, the motivation to expand the cultivation of this crop decreases. The results obtained for rapeseed are also consistent with the results for alfalfa. As listed in Table 2, the proposed cropping pattern is an area of 125 ha for rapeseed. Rapeseed is considered as an important crop in the current cropping pattern in Shiraz, and its cultivated area has been growing in recent years. This crop is a government priority in achieving self-sufficiency in vegetable oil production. Government support for the expansion of cultivated areas for strategic crops includes providing facilities for cultivation, purchasing agricultural machinery, monitoring the stages of planting, cultivation, and harvesting these crops, and guaranteed purchase price (Noroozi *et al.* 2020). Additionally, this plant requires less water compared to other crops and has the capability of being cultivated in rainfed and green water conditions, making it a suitable substitute for high-water-demand crops during drought conditions (Bastaki 2006). The cultivated areas for onion and tomato in the base pattern are 848 and 838 ha, respectively. These areas decrease to 102 and 671 ha, respectively, under the scenario of eliminating agricultural input subsidies. Watermelon is an important crop in the agricultural pattern in Shiraz, and its cultivated area decreases by 73% under Scenario 1. The cultivated area of watermelon decreases from 698 ha in the base pattern to 187 ha in the optimal pattern. The cultivated area for sugar beet in the optimal pattern under the scenario of eliminating agricultural input subsidies is 106 ha, which represents a 43% drop compared to the base conditions. Sugar beet is one of the drought-tolerant crops. Since drought is a persistent challenge for various agricultural crops, including sugar beet, changing the cropping pattern, improving irrigation efficiency, elevating water productivity, and implementing water-saving techniques (such as extending irrigation intervals and reducing irrigation when the plant is less sensitive to water scarcity) are necessary (Vaziri *et al.* 2016). The employment of modern irrigation methods should also be emphasized. Due to the sugar beet high resistance to drought stress, the adoption of water-saving techniques can significantly reduce water consumption as a suitable alternative for many high-water-consuming crops (Asadi 2007). Finally, irrigated and non-irrigated kidney beans and lentils are among the recommended crops in the optimal pattern under Scenario 1, with respective cultivated areas of 49.32, 4.42 and 11.71 ha respectively.

Table 2. Changes in cropping pattern by different scenarios (ha).

	Base condition	Scenario 1	Scenario 2	Scenario 3
Irrigated wheat	16648	5473.78	11326.76	15916
Rainfed wheat	8226	2745.34	2141.51	9492.50
Irrigated barley	2952	0	215.60	2864.88
Rainfed barley	4140	0	0	2870.81
Alfalfa	4972	457.47	0	0
Forage maize	2101	1898.65	2968.67	9606.80
Rapeseed	1506	125.32	115.08	1273.28
Onion	848	102.25	3754.60	967.78
Tomato	838	671.61	860.07	509.31
Watermelon	698	187.66	1094.60	0
Potato	367	51.64	84.40	286.48
Maize (grain)	276	35.27	70.80	0
Rice	237	69.55	141.83	222.82
Sugar beet	190	106.64	162.20	0
Kidney bean	186	49.32	16.01	184.64
Irrigated lentil	12	4.42	5.35	0
Rainfed lentil	117	11.71	0	119.68
Cultivated area	44315	11990 (%-72.94)	22957 (%-48.19)	44315

Implementation of the guaranteed price policy, in Scenario 2, resulted in the exclusion of dryland barley, alfalfa, and dry lentils from the cropping pattern. Among the agricultural crops, the area under cultivation increased for forage maize, onions, tomatoes, and watermelons compared to the base conditions. The cultivated areas for other crops dropped due to changes in product prices based on the new guaranteed prices for the current year. According to Table 1, the projected areas under cultivation for irrigated and dryland wheat under this scenario are 11,326 and 2,141 ha respectively. The change in the area under cultivation of dryland wheat is greater than that of irrigated wheat. The projected area under cultivation for barley is 215 ha. Clearly, the area under cultivation for maize rises by 41.27% from 2,101 to 2,968 ha. The area under cultivation for rapeseed also drops to 115.08 ha due to the implementation of the new guaranteed price. Watermelons, onions, and tomatoes exhibit positive changes in their cultivated areas. The higher prices of these crops and the financial incentives increase the cultivated areas (Boone *et al.* 2019). The area under cultivation for potatoes decreased by 76% compared to the base conditions. The changes in the cultivated areas of grain maize, rice, and sugar beet were -74%, -40%, and -14% respectively. Despite the exclusion of dry lentils from the cropping pattern, kidney beans and lentils had a negligible share of the cultivated area. It is expected that the price changes of these two crops based on the guaranteed prices for 2020-2021 result in a cultivation area of 16.01 and 5.35 ha respectively. Next, the effects of the liberalization policy of the crops prices on cultivation were examined. As shown in Table 2, the cultivated areas of dryland wheat, forage maize, onions, and dry lentils increase. As a result of price changes for agricultural products, the cultivated areas for these crops are expected to be 9492.50, 9606.80, 967.78, and 119.68 ha respectively. As listed in Table 2, the cultivated area for irrigated wheat decreases by 4% to 15916 ha. The cultivated areas for irrigated barley and dryland barely are projected to be 2864.8 and 2870.81 ha respectively. The area under cultivation for rice also drops by 5.94% from 237 to 222.82 ha. Alfalfa, watermelon, sugar beet, and dryland lentils are among the agricultural products that are not prioritized under this scenario. On the other hand, forage maize and rapeseed exhibit a significant share of the cultivated area, with 9606.80 and 1273.28 ha respectively. Table 3 lists the effects of the combined policies on the agricultural pattern in Shiraz. Under scenario 4, which includes the implementation of both guaranteed prices for agricultural products and the elimination of agricultural input subsidies, rainfed barely, alfalfa, and rainfed lentil are excluded from the cultivation pattern. In addition, the areas under cultivation for forage maize, onions, and watermelon increase. Under this scenario, the cultivated areas for irrigated and dryland wheat are projected to be 8974.76 and 3033.22 ha, respectively. The cultivated area for dry barley drops by 97% to 75.32 ha. The area under cultivation for forage maize elevates to 2912.39 ha. On the other hand, the cultivated area for rapeseed decreases to 202.86 ha. The cultivated areas for onions and tomatoes are projected to be 3953.04 and 797.43 ha, respectively. The area under cultivation for watermelons rises by 53.36% to 1070.31 ha. Rice is prioritized with a cultivated area of 106.72 ha. This result also applies to sugar beet, with a cultivated area of 174.87 ha. Finally, the cultivated areas for kidney beans and lentils are projected to be 39.29 and 5.5 ha respectively. Generally, and without government support, the cultivated area for kidney beans is mainly influenced by market prices, with occasional consideration for crop rotation with wheat. Although kidney beans have a guaranteed price, the price is not sufficient to encourage farmers to expand the cultivation area for this crop compared to others (Elahi *et al.* 2020). As listed in Table 3, the shift towards a free market (Scenario 5) leads to the exclusion of dryland wheat, dryland barely, alfalfa, watermelon, grain maize, sugar beet, and irrigated lentils from the cropping pattern. Meanwhile, the cultivated areas for forage maize, rapeseed, onions, potatoes, rice, and kidney beans experience positive changes. Under Scenario 5, the cultivated area for dryland wheat drops by 5.73% compared to the base conditions. The cultivated area for irrigated barley is also projected equal to 2511.07 ha. The move toward a free- market results in an elevation in the cultivated areas for forage maize, rapeseed, and onions to 7216.62, 1569.42 and 2438.67 ha, respectively. The cultivated area for tomatoes drops by 30.88%. The changes in the cultivated areas for potatoes, rice, and kidney beans compared to the base conditions are 73%, 66%, and 87%, respectively.

Effects of Policies on Economic-Environmental Indicators

Effects of the examined scenarios on the economic indicator (gross profit) and the environmental indicator (agricultural water demand and chemical fertilizer consumption) are as follows: One of the key findings in this section is the alterations in the total cultivated area of agricultural crops under different scenarios. The greatest reduction in the cultivated area occurred as a result of eliminating agricultural input subsidies. Although there were alterations in the crop composition based on global prices, all available lands were utilized. The program's efficiency reduction in different scenarios ranged from -2.67% to 67.80% (Table 4). The highest reduction in farmers' profits was due to the elimination of production input subsidies, while the lowest reduction observed by altering crops prices based on the guaranteed price of 2021-2022. Therefore, it appears that the first proposed cultivation pattern should not be favored by farmers due to significant economic losses. Hence, if the government's objective is to reduce the environmental impacts of agricultural production, it is necessary for the policy of eliminating agricultural input subsidies to be accompanied by complementary policies to compensate for farmers' economic losses. Furthermore, it is expected that by reducing government interventions in the crops market (under the combined Scenario 2), the profit from production will experience a growth of 1.53% compared to the base conditions. Under these circumstances, a 10.37% reduction in agricultural water demand and a 3.95% elevation in chemical fertilizer consumption are anticipated. The highest reduction in agricultural water demand was the result of eliminating agricultural input subsidies, while the lowest reduction occurred under the combined Scenario 2.

Table 3. Changes in cropping pattern by combined scenarios (ha).

	Base condition	**Mixed scenario**	
		Scenario 4	**Scenario 5**
Irrigated wheat	16648	8974.76	15694.23
Rainfed wheat	8226	3033.22	0
Irrigated barley	2952	75.32	2511.07
Rainfed barley	4140	0	0
Alfalfa	4972	0	0
Forage maize	2101	2913.39	7216.62
Rapeseed	1506	202.86	1569.42
Onion	848	3953.04	2438.67
Tomato	838	797.43	579.19
Watermelon	698	1070.31	0
Potato	367	60.04	363.62
Maize (grain)	276	46.88	0
Rice	237	106.72	295.52
Sugar beet	190	174.77	0
Kidney bean	186	39.22	347.09
Irrigated lentil	12	5.5	0
Rainfed lentil	117	0	94.16
Cultivated area	44315	21454 (-51.58%)	31483 (-28.95%)

Table 4. Effects of Changes in Cropping Patterns on Economic-Environmental Indicators

Economic-environmental indicators	**Current area under cultivation**	**Alterations in the area under cultivation and inputs used in different scenarios**				
		No inputs subsidy	**Guaranteed price for crops**	**Global price of crops**	**No inputs subsidy and guaranteed price of crops**	**No inputs subsidy and global price of crops**
Gross margin (million Rials)	1214717.70	-67.80	-2.46	-9.94	-6.26	+1.53
Water consumption (million m^3)	393.76	-73.04	-33.63	-14.61	-39.74	-10.37
Fertilizer use (MT)	13748.64	-67.82	-26.95	+15.21	-32.66	+3.95
Total area under cultivation (ha)	44315	-7294	-48.19	0.00	-51.58	-28.95

CONCLUSION

The policies examined in this study included the elimination of agricultural input subsidies, guaranteed prices, and global prices for products and including combined scenarios. There were five scenarios in total. The results showed that by implementing the scenarios, the cultivated area of agricultural crops decreased. Crops such as alfalfa, watermelon, grain corn, sugar beets, and irrigated lentils were not prioritized for cultivation in the region. However, crops such as rainfed wheat, forage corn, rainfed lentils, and onions led to the increased cultivation area. An elevation in crop prices following price liberalization upraises the incentive to produce high-yielding crops. This policy is also important from the perspective of self-sufficiency, since both wheat and corn are considered strategic crops in terms of self-sufficiency and exhibited an upraise in cultivated area in this model. On the other hand, crops such as grain corn, rice, beans, and barley displayed a drop in cultivated area. Therefore, in the case of crop price liberalization, if the policymaker intends to maintain or elevate the cultivated area of these crops, the focus should be on upraising their profitability through improved performance and efficiency. Notably, the removal of rice from the cultivation pattern in southern provinces is already on the agenda of the Iranian Ministry of Agriculture Jihad, which aligns with the results of this study. Overall, it appears that the proposed cultivation pattern in the context of eliminating agricultural input subsidies and price liberalization of products can increase farmers' profitability and reduce water consumption. However, the implementation of these policies leads to an elevation in the application of chemical fertilizers in the region, which can lead to significant environmental effects. Therefore, complementary policies for supplying these inputs should be considered. Education about using these chemical inputs and their adverse effects on the environment and human health can also be influential in managing their consumption. Thus, it is expected that by combining the examined policies, the agricultural system of the region will be in a better position in terms of sustainability compared to the baseline conditions. Therefore, moving towards price liberalization and the competitive world can be an effective step towards achieving sustainability. The saved costs of government interventions in crops market and the guaranteed prices for products can be invested in improving irrigation efficiency, producing alternative inputs, or alternative methods of chemical fertilizer consumption. Through this and along with making a better use of water resources, the damage to soil and the environment can be minimized. The current market atmosphere in the agricultural sector (including guaranteed purchase, contractual agreements, various supportive purchases, and customized cultivation) in the country, do not exhibit desirable efficiency. The results of simultaneous elimination of price and input subsidies for agricultural products, confirms the inefficiency of government interventions in the agriculture sector. Therefore, moving towards market liberalization for agricultural products is emphasized. The theory of the invisible hand (price mechanism), as well as the balance of demand and the supply of crops supports the findings of the present study.

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