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The Effects of Climate Change on Sugar Beet Yield with an Emphasis on Crop Production Risk in Iran

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Abstract

Climate change and the resulting changes in climatic parameters influence all agricultural activities. The present study aimed to explore the effect of climatic variables on sugar beet crop yield in two climates – cold climate and hot and arid climate – using the Just and Pope stochastic function. First, the most effective climatic variables on sugar beet yield were identified by the Feiveson algorithm and the Just and Pope function. Data stationarity test was applied to assess the stationarity of the included variables. The interrelationship of the dependent and independent variables was analyzed by the co-integration test. Finally, the coefficients of the Just and Pope function for sugar beet crop in two studied climates for the time period of 1998-2017 were estimated. The results of sugar beet yield function in cold regions show that sugar beet yield in cold regions was significantly influenced by acreage and maximum temperature at $p<0.10$ level and by minimum temperature deviation, production lag, and trend at $p<0.01$ level, but the variable of precipitation was significant in none of the levels. The estimation of the Just and Pope function for sugar beet crop in hot and arid regions indicates that the effects of maximum temperature, production lag, and trend are significant on sugar beet yield at $p<0.05$ level, but the effects of acreage, precipitation deviation, and minimum temperature deviation were insignificant. Given temperature variations and unexpected precipitation, it is recommended to encourage sugar beet farmers to use crop insurance in order to mitigate local farmers' risk and alleviate the damages of climate change.

Keywords:
Climate change; Just and Pope function; production risk; sugar beet; yield function

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INTRODUCTION

Climate change in recent decades has been responsible for the changes in the amount of greenhouse gases, temperature, rainfall, and the melting of polar ice. The study of this phenomenon and its impact on human and environmental activities has become a major challenge. A study on 43 synoptic stations of Iran over the period 2010-2039 using the outputs of the ECHO-G general circulation model has projected a 9 percent decrease in average precipitation and a 0.5°C increase in annual temperature of Iran (Babaeian et al., 2009; Fellmann et al., 2018). Agriculture is an important driver of production and economic development in Iran. To develop sound management policies for this sector, it is imperative to understand the factors underpinning production and the environment required to increase yields. It has been found that the projected climate change in Iran would reduce agricultural production by 5.37 percent during 2000-2025 (Khaleghi et al., 2015).

According to reports from the International Panel on Climate Change (IPCC), it can be said with certainty that climate change caused by greenhouse gas emissions has had many effects on biological and physical systems over recent years (IPCC, 2010; To et al., 2018). Agriculture is vulnerable to climate change due to its close relationship with climate conditions and because of the optimum growth and optimal yield of crops in the range of climatic variables, and climate change is able to change the optimal range in relation to the temperature required for plant growth (Gregory et al., 2005). Although climate change in some parts of the world, especially those in the northern latitudes above 55°C, has a positive impact on agricultural production (Amiri Nezhad & Assadpour Kordi, 2017). But the negative effects of climate change in warm and dry areas are very severe (Gregory et al., 2005). As the temperature in developing countries increases and precipitation decreases more severely, the severity of the occurrence of climate phenomena (drought, heat, cold and flood) is intensified (IPCC, 2007). The impact of climate on the agricultural sector, especially in the production sector, is result of unfavorable outcomes in the future (Ackerman & Stanton, 2013, Steiner et al., 2018). Climate change is a phenomenon that affects a variety of human activities, has a variety of effects on human activities. In recent decades, one of the most important factors in climate change is the increase in the pressure of human activities on the environment (Najaf Poor, 2006).

The assessment of the effect of climate change on agricultural crops requires an analysis of the effect of the variations of climatic parameters on crop yields as the changes in the climatic parameters accounts for a significant part of agricultural production risk and the loss of the crop yields. Thus, the study of the impact of climate change on the risk of crop production and yield can be a valuable step towards improving policy-making and management of agricultural crop production.

Among the industrial products, sugar production is among the most important industries; sugar can play an important role in securing the daily energy of humans and livestock in third-world countries with limited energy resources. Sugar beet with cane are two major sugar and sugar producers in the world; the importance of sugar beet is not just about sugar production, it plays an important role in crop rotation, increasing the productivity of its sources and products, and in the various industries and livestock feeds. Sugar beet is considered as an important industrial product of the country. It is important to pay attention to the impact of climate conditions, especially on temperature and atmospheric precipitation on beetroot. In 2014-15, sugar beet production was ranked first in the industrial group with 22.5 percent of the total harvesting of industrial products. The area under cultivation of sugar beet in the country was 110,204 hectares and its production was 5965628 tons and its yield was 54133 kilograms (Department of Statistics and Information Technology, Ministry of Agriculture, 2015).

There are several ways to estimate these effects on crop yield and production risk. Three categories of models have been investigated in attempts to analyze the impact of climate change on yield, productivity, land value, and/or the profit of crops. The first is the time series models for the relationship between returns and climate variables. The second encompasses the methods that are based on spatial or cross-sectional changes, such as the Ricardian method. Finally, the third concerns the models that are concurrently based on spatial and temporal changes or panel data methods that integrate time series and spatial data, such as the generalized Ricardian method and Just and Pope (1978, 1979)'s stochastic production function (Shahraki et al., 2017). The effects of climate change on crops have been analyzed throughout the world.

In a study using a hybrid regression model, Kaufmann and Snell (1997) found that the climatic variables contributed 19 percent to corn yield variations in the Western US. Studies on the effects of climate change on crop yields have focused on analyzing the effects of predicted increases in average values of climate variables on the average crop yields (Adams et al., 1999). Various studies indicate the important impacts of variations of climatic parameters on the average yields of agricultural crops (Dinar et al., 1998; Seo and Mendelsohn, 2008; Mall et al., 2006; Cline, 2007).

Cabas et al. (2010) used the Just and Pope stochastic function to investigate the impact of climatic and non-climatic factors on the mean and variance of wheat, corn, soybean, and winter wheat production in the southwest of Ontario, Canada. They reported that the increase in temperature and precipitation variations would reduce the average yield and would increase the variance of crop yields. Mirzabaev (2013) addressed the effect of climate change on agricultural income in four Central Asian countries using the panel data and found that climate change would influence mainly agriculture profitability. Hasanthika et al. (2013) used the Just and Pope production function to show that precipitation, maximum temperature, and production factors including labor, machinery cost, and weeds have a positive relationship with paddy yield with respect to the probability distribution of yield.

Sharghi et al. (2016), in a study to simulate the effects of climate change and the policy of water transfer from agriculture to industry on water resources and its impact on garden production in Yazd province. The results indicate that the number of orchards will be reduced to 37,000 tons by 2025 compared to 2013. The results of the simulation of the implementation of the agricultural exit policy in climatic conditions showed that the amount of orchards decreased by 6.5 thousand tons. Amiri Nezhad and Asadpur Kordi (2017), the effects of climate change on wheat production in Iran have been studied. The results showed that in both the short-run and long-run, the climate variables and the surface area of grazing had a positive and significant relationship with wheat production, and seed variables and fixed capital in machinery are not meaningful. Zimmermann et al. (2017) integrated agricultural, economic and environmental models to examine the sensitivity of the parameters of yield, acreage, production, and environmental variables to climate change up to 2005 for six main crops in 27 European countries. On average, the variation in crop yields would be in the range of -6 to +21 percent if the management scenario is not adopted, but it would be in the range of +12 and +53 percent in case the management scenario for the sowing date optimization is adopted.

In Iran too, multiple studies have focused on the effects of climate change on the risk and yield of agricultural crops in different regions. Alijani et al. (2011) examined the effect of temperature and precipitation on the yield of irrigated wheat with the estimated GLS method across 14 provinces of Iran. They found that the precipitation decline and temperature rise in the study period have resulted in the loss of yields and that the precipitation decline was more influential on yield loss than the temperature rise.

Azizi and Yarahmadi (2003) related climatic parameters and rain-fed wheat yield in Silakhor Plain, Lorestan province, Iran using regression models. They found that precipitation influences wheat yields positively. Vaseghi and Esmaeli (2008) used the Ricardian method to measure the economic impacts of climate change on corn yield and wheat farmers' net income. According to their results, temperature rise and precipitation decline in the next 100 years will reduce corn return by 29 percent (584,000 IRR/ha) resulting from the increased emission of greenhouse gases. Also, climatic variables will influence the net income of corn farming per ha significantly.

Ghahremanzadeh and Golbaz (2015) addressed the impact of climatic variables on the yield and yield risk of rain-fed wheat, irrigated wheat, and corn in Qazvin province using the Just and Pope stochastic production function. They figured out that urea fertilizer, average maximum temperature, and wind speed in the growth period had a positive effect on yield risk and these three factors were identified as risk-inducing inputs.

Mahmoodi and Parhizkari (2016) employed positive mathematical programming (PMP) to explore the impacts of climate change on various crop yields and farmers' gross margin in Qazvin Plain, Iran. The scenario of 1°C increase in temperature and 1 mm decrease in rainfall resulted in 15, 24, 13, and 17 percent higher yield of barley, corn, beet, and alfalfa and 29, 20 and 23 percent lower yield of wheat, tomato, and canola, respectively. In an assessment of the impact of climate change on wheat crop in Tehran, Iran using the ClimGen statistical model and the APSIM agricultural model, Shakiba et al. (2015) observed that 4 and 1°C increase in temperature and the increase in CO_2 resulted in 10 and 12 percent loss of crop yield as compared to control scenario. Shahraki et al. (2017) addressed the effect of the increase in climatic parameters on yield and production risk of wheat in Iran. They estimated the Just and Pope stochastic production function for four different climatic zones. The results indicated the effectiveness of local temperature and precipitation parameters. Bocco and Napoletano (2017), they have studied The prospects of terrace agriculture as an adaptation to climate change in Latin America. They review the historical geography of slope management in variable climates and highlight the role of social, rural innovation, and hybrid knowledge in the face of climate change's effects on agriculture. Although the literature on terrace agriculture in the region is extensive, further research is needed to better foresee the future of terrace agriculture, particularly in terms of its role in facing sustainability challenges posed by future climate change. Passel et al. (2017), they have studied a Ricardian analysis of the impact of climate change on European agriculture. The results suggest that European farms are slightly more sensitive to warming than American farms with impacts from +5 to −32 percent by 2100 depending on the climate scenario. Farms in Southern Europe are predicted to be particularly sensitive, suffering losses of −5 to −9 percent per degree Celsius. Fellmann et al. (2018) they have studied major challenges of integrating agriculture into climate change mitigation policy frameworks. The results underline four major challenges for the general integration of agriculture into national and global climate change mitigation policy frameworks and strategies, as they strengthen requests for (1) a targeted but flexible implementation of mitigation obligations at national and global level and (2) the need for a wider consideration of technological mitigation options. The results also indicate that a globally effective reduction in agricultural emissions requires (3) multilateral commitments for agriculture to limit emission leakage and may have to (4) consider options that tackle the reduction in GHG emissions from the consumption side. Steiner et al. (2018), they Reviewed reVulnerability of Southern Plains agriculture to climate change. However, the extent to which these strategies are adopted is variable and influenced by both biophysical and socioeconomic considerations. Inadequate local- and regional-scale climate risk and resilience information suggests that climate vulnerability research and climate adaptation approaches need to include bottom-up approaches such as learning networks and peer-to-peer communication.

In summary, the review of the literature shows that climate change in Iran directly influences agricultural production and, in turn, crop yields and farmers' income. The present study uses the Just and Pope function and 20-year time series data to explore the climatic variables and crop yield. Sugar beet is a major crop in Iran that accounts for a significant part of Iran's arable lands. In addition to the supply of a remarkable part of the raw material for sugar industries, this crop plays a critical role in the employment by agricultural, industrial, and commercial sectors (Nikooie, 2007). The study explores the climatic parameters influencing the yield of this crop and the impact of the variations of the given parameters on the crop yield in cold climate and hot and dry climate.

Therefore, according to previous studies of innovation, this research is that in Iran, research that simultaneously assesses the effect of climate variability on the average and risk (fluctuation) of crop production has not been. Most of the studies in the field of effecting effects have been carried out using the models of product growth simulation and the hedonic approach. One of the implications of this model is that of models that are considered in similar foreign studies, This is due to the combination of Step-wise regression (1960) and Feiveson 's (2012) algorithm based on the mass of available cluster variables rather than the optional choice of variables in the empirical model. Therefore, according to researches of the researchers according to previous studies of innovation, this study is in Iran, a study simultaneously does not investigate the effects of climate variability on the average and yield risk of sugar beet cultivars due to the distinction of climatic zones.

METHODOLOGY

Given the limitation in data availability, we adopted the climate classification of (Gangi, 2003) who used the Köppen method and divided Iran's climate into four climates including temperate and humid (southern coasts of the Caspian Sea), cold (western mountains), hot and arid (central plain), and hot and humid (southern coasts of Iran) as shown in Table 1 (Shahraki et al., 2017)

Most studies on yield risk have been based on the model presented by Just and Pope (1978). They presented their model on the basis of eight postulates for stochastic production function. One postulate holds that the impact of an input on yield risk may be positive, negative, or neutral (zero). In other words, the inputs may increase or decrease the risk of yield. The general form of the Just and Pope production function is as below:

$$y = f(X;\beta) + \mu = f(X;\beta) + h(X;\alpha)\varepsilon \qquad (1)$$

in which is the amount of production, is the average production function, is the yield risk variance function, is a vector from production factors, and and are function parameters, respectively. Also, shows the stochastic factors and it has the average of 0 and the constant variance of . The Just and Pope function displays the effect of average and variance of the changes in climatic inputs on crop production separately. The three steps of the Feasible Generalized Least Squares (FGLS) have been recommended to estimate the Just and Pope model. In the first step, the variable of yield is estimated over the function and then, the results of the second power of the least squares are estimated as in which is a compatible estimation of with heteroscedastic distribution and the average of 0. In the second step, the estimated is fitted over its asymptotic expectation. In the final step, the error term forecasted in the previous step is used as the weight of the first equation (average yield function), and the yield function is re-estimated. In these conditions, the estimator β is compatible and efficient for the stochastic production functions. In fact, this technique enables us to correct the variance heteroscedasticity of the first step (Cabas et al., 2010). In these steps, the model was tested for the presences of the variable of the trend.

The present study employed the Just and Pope model to explore the impacts of climate change on mean yield and yield risk of sugar beet in Iran. Data on acreage, yield, and production of sugar beet-growing provinces were collected from Jihad-e Agriculture Organization and Crop Statistics for the time periods of 1999-2017. Also, the climatic data on the years and crops in the respective provinces were obtained from the Meteorological Organization of Iran. The model was estimated by the STATA13 software package.

RESULTS AND DISCUSSION

The final results of the Feiveson algorithm and stepwise regression (2012) to select the best and most effective climatic variables are presented in Table 1. Tables 2 and 3 summarizes the descriptive statistics for the variables of the Feiveson algorithm selected for the Just and Pope function for cold climate and hot and arid climate for beet crop over 1999-2017, respectively.

The stationarity and co-integration of the data were tested separately for the climates in the Eviews software package whose results are presented in Tables 4 and 5. In fact, after employing unit root tests for the panel data to check the stationarity of the studied variables, their co-integration was examination with ADF test. We applied Levin, Lin and Chu (LLC) (2002), Im, Pesaran, and Shin (IPS) (2003), Phillips and Perron (PP) (1988), and Dickey-Fuller (ADF) (2001)'s unit root tests to check the stationarity of the variables. Table 5 presents the results of unit root tests for the panel data for the selected variables

Table 1
The Selection of the Most Effective Predicted Variables to Be Included in the Just and Pope Function

Climatic zone	The best predicted variables
Cold	Acreage, mean precipitation, maximum temperature, minimum temperature deviation, production lag, trend
Hot and arid	Acreage, precipitation deviation, minimum temperature deviation, maximum temperature, production lag, trend

Table 2
Descriptive Statistics of the Variables in Cold Zone

	Average	Maximum	Minimum	Standard deviation
Acreage	107.67	219.0	1.0	64.18
Mean precipiation	28.67	444.24	4.39	29.44
Maximum temperature	-0.055	16.07	-3.12	1.67
Minimum temperature deviation	-0.15	6.24	-5.55	1.75

Table 3
Descriptive Statistics of Variables in Cold and Arid Zone

	Average	Maximum	Minimum	Standard deviation
Acreage	48.0	95.0	1.0	27.56
Precipitation deviation	21.31	88.63	4.58	13.17
Minimum temperature deviation	0.100	21.43	-3.15	2.43
Maximum temperature	0.120	14.54	-3.98	1.90

estimated by the Feiverson method for cold climate and hot and arid climate in the Just and Pope function for sugar beet crop in Iran. According to the results of LLC, IPS, Fisher-ADF, and Fisher-PP, the hypothesis of non-stationarity is not refuted for some variables. Therefore, given their non-stationarity, data were entered into the surface and after the stationarity status of the panel data was recognized, KAO test was applied to check the co-integration. The results are presented in Table 6. According to the results of the co-integration test, the co-integration can be accepted for the model with respect to the ADF statistic and the related likelihood. Thus, it can be said that there exists a long-term relationship between dependent variable and independent variables.

Tables 7 and 8 present the results of the three-step estimation of the Just and Pope function for the 1999-2017 period. The forecasted variables are in log form, and the independent variable in the average function is the log of sugar beet annual yield.

As was mentioned, the Just and Pope function was used to account for the relationship between yield and the climatic variables and special attention was paid to the impact of temperature and precipitation on average and variance of yield. Table 7 includes the results for the effect of climatic variables on average and variable of sugar beet yield.

The results of sugar beet yield function in cold regions are shown in Table 7. Accordingly, sugar beet yield in cold regions was significantly influenced by acreage and maximum temperature at $p<0.10$ level and by minimum temperature deviation, production lag, and trend at $p<0.01$ level, but the variable of precipitation was significant in none of the levels. On the other hand, since the values of the variables are in the log form in Tables 8 and 9, the coefficients of each variable show that how much change will happen in sugar beet yield by 1 percent change in the variable. That is, the estimated coefficient of precipitation indicates that a 1 percent increase in annual precipitation in cold regions will increase the yield by 0.004 percent or a 1 percent increase in minimum temperature deviation and maximum temperature will result in 4.87 and 2.38 percent loss of sugar beet yield in these regions, respectively. The variable of acreage is directly related to sugar beet crop yield. This means that the increase in sugar beet acreage will enhance its yield and production rate in cold regions. In other words, higher acreage is related to a higher production rate of sugar beet. Production lag positively influences crop yield significantly ($p<0.05$). The effect of the trend is significant at $p<0.01$ level, and its coefficient (4.77) implies its positive effect of this crop yield. These results are not surprising given the climate of provinces classified within the category of cold zone. The estimated coefficient of sugar beet yield risk function in cold zone implies the increasing risk. This implies that although the effect of climatic variables is positive on yield function, the variability of these variables is positive for the variance of sugar beet yield in cold regions.

The results estimated for the Just and Pope function for sugar beet crop in hot and arid

Table 4
Results of Unit Root Tests for the Variables Included in the Just and Pope Model for Cold Zone

Variables	Lag length	LLC test	IPS test	ADF test	PPE test
Acreage	0	-3.95	-3.57	53.96	88.04
		(0.00)	(0.00)	(0.00)	(0.00)
Mean precipitation	0	-5.38	-4.82	66.87	106.46
		(0.00)	(0.00)	(0.00)	(0.00)
Maximum temperature	2	-4.77	-13.65	171.88	364.82
		(0.00)	(0.00)	(0.00)	(0.00)
Minimum temperature deviation	0	-7.71	-2.49	39.31	54.32
		(0.00)	(0.00)	(0.00)	(0.00)

Table 5
Results of Unit Root Tests for the Variables Included in the Just And Pope Model for Hot and Arid Zone

Variables	Lag length	LLC test	IPS test	ADF test	PPE test
Acreage	0	-1.66	-6.72	56.95	73.58
		(0.00)	(0.00)	(0.00)	(0.00)
Mean precipitation	1	-3.52	-6.69	57.24	479.10
		(0.00)	(0.00)	(0.00)	(0.00)
Minimum temperature deviaiton	1	-1.92	-6.69	56.82	375.66
		(0.00)	(0.00)	(0.00)	(0.00)
Maximum temperature	1	-2.91	-3.23	31.14	84.62
		(0.00)	(0.00)	(0.00)	(0.00)

Table 6
The Results of Co-Integrationt Est for Cold and Hot and Arid Zones

Zone	KAO co-integration	t-statistic	Probability
Cold	ADF	0.79	0.01
Hot and arid	ADF	-0.04	0.00

regions are presented in Table 8. It shows that the variables of maximum temperature, production lag, and trend have significant effects on sugar beet yield in hot and arid regions at $p<0.05$ level, but the effects of acreage, precipitation deviation, and minimum temperature deviation are insignificant. Given the log transformation of the variables, these coefficients reflect the elasticity of the climatic variables. This means that a 1 percent increase in the variables of precipitation deviation, minimum temperature deviation, and maximum temperature will reduce sugar beet yield by 0.009, 0.60, and 4.32 percent re-

Table 7

Estimation of the Coefficients of the Just and Pope Function for Beet Crop in Cold Zone

	Variable	Coefficients			
		Coefficients	Standard deviation	z-statistic	Probability
Meanfunction	Acreage	0.071	0.42	1.69	0.09
	Mean precipitation	0.004	0.092	0.04	0.96
	Maximum temperature	-2.38	1.40	-1.69	0.09
	Minimum temperature deviation	-4.87	1.92	2.53	0.01
	Production lag	1481.4	261.96	5.66	0.00
	Trend	4.40	0.684	6.43	0.00
Wald chi^2 (17) = 571.91; Prob > chi^2 = 0.00; Number of obs. = 192					
Variancefunction	Acreage	0.025	0.06	0.41	0.68
	Mean precipitation	0.18	0.11	-0.17	0.86
	Maximum temperature	3.42	1.67	2.04	0.04
	Minimum temperature deviation	5.45	2.93	1.86	0.06
	Production lag	709.16	359.42	1.97	0.04
	Trend	4.77	0.97	4.89	0.00
Wald chi^2 (17) = 228.37; Prob > chi^2 = 0.00; F(1,11) = 68.34; Prob > F = 0.00					

Table 8

Estimation of the Coefficients of the Just and Pope Function for Beet Crop in Hot and Arid Zone

	Variable	Coefficients			
		Coefficients	Standard deviation	z-statistic	Probability
Meanfunction	Acreage	0.017	0.078	0.22	0.82
	Mean precipitation	-0.009	0.202	-0.05	0.96
	Minimum temperature deviation	-0.60	0.714	-0.85	0.39
	Maximum temperature	-4.32	1.947	-2.22	0.02
	Production lag	33.87	16.031	2.11	0.00
	Trend	1.39	0.484	-2.89	0.03
Wald chi^2 (10) = 37.64; Prob > chi^2 = 0.00; Number of obs. = 85					
Variancefunction	Acreage	0.101	0.090	1.11	0.004
	Mean precipitation	0.007	0.315	0.03	0.47
	Minimum temperature deviation	1.847	1.891	0.98	0.001
	Maximum temperature	0.707	1.254	-0.56	0.02
	Production lag	-32.47	18.39	-1.77	0.00
	Trend	-2.55	0.543	-4.71	0.00
Wald chi^2 (10) = 29.16; Prob > chi^2 = 0.00; F(1,4) = 0.741; Prob > F = 0.0006					

spectively. The variable of the trend of the Just and Pope function for beet in hot and arid regions shows that crop production is annually increased by 1.39 percent by the effects of technology and development. The review of the stochastic part of the Just and Pope function for sugar beet crop shows that in hot and arid regions, the variables of acreage, precipitation deviation, minimum temperature deviation, and maximum temperature are risk-inducing, implying that their increase will bring about the increased variance of sugar beet yield. The variables of production lag and trend were found to be risk-reducing.

CONCLUSIONS AND RECOMMENDATIONS

This study addressed the effects of climatic parameters on sugar beet yield and crop risk. In general, the results revealed that climatic variables such as temperature, precipitation, and acreage are among the factors influencing sugar beet yield variations. In mean yield function for the cold zone, the increase in precipitation and the decrease in minimum temperature deviation and maximum temperature enhance sugar beet yield. Also, the yield function of hot and dry zones shows that yield per unit area is escalated when an increase occurs in acreage, trend, and production lag and a decrease occurs in precipitation deviation and minimum temperature deviation. Therefore, given the unpredictable climate change of recent years, it is necessary to develop plans and policies to increase sugar beet crop yield per the unit area. The increase in acreage and the enhancement of crop yield per unit area is a recommendation to policymakers and decision-makers in order to improve sugar beet yield and production. On the other hand, given the unexpected climate change and temperature variations of recent years, policies are required to improve sugar beet production in cold and hot and arid regions. The followings are some approaches and plans:

Results for the cold zone and hot and arid zone show that the rise in maximum temperature is pursued with the decline of sugar beet yield. Since a major reason for temperature rise is the emission of greenhouse gases, Jihad-e Agriculture Organizations and other responsible agencies should hold training courses to improve farmers' awareness.

Given temperature variations and unexpected precipitation, it is recommended to encourage sugar beet farmers to use crop insurance in order to mitigate local farmers' risk and alleviate the damages of climate change.

According to the results, besides climatic factors, acreage in the studied regions improves sugar beet yield per unit area. Thus, policymakers should adopt policies to increase acreage and defragment the land pieces.

The results for hot and arid regions indicate that precipitation deviation and maximum temperature reduces sugar beet yield and crop production. Therefore, sugar beet farmers are recommended to cultivate seeds that are less sensitive to precipitation and maximum temperature.

Among policy options, it is suggested that various organizations, such as the Environmental Protection Agency, use the resources allocated to counteract the negative effects of volatility.

Improvement of water transfer system and high-performance irrigation methods such as sprinkler and drip irrigation

Improvement of the state financing system for solving financial problems and shortage of farmers' capital (low-income loans, product insurance, production subsidies.)

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS

Each of the authors contributed to the development of the paper.

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