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The Forecast of Economic Welfare and Food Security of Iran Under Climate Changes

Soroush Kiani Ghalehsard, Javad Shahraki*, Ahmad Akbari, Ali Sardar Shahraki

Department of Agricultural Economics, University of Sistan and Baluchestan., Zahedan, Iran

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Abstract

Food security and economic welfare strongly depend on agricultural production, and the loss of this production can be a serious challenge for food security and economic welfare. Agricultural production is also influenced by environmental and climatic factors so that the variations of climatic parameters can trigger extensive fluctuations in agricultural production. This study classifies climate changes into four scenarios of normal climate change (scenario 1), climate change (scenario 2), climate variability (scenario 3), and concurrent climate change (scenario 4). Then, economic welfare and food security are studied in each scenario for a 20-year period. We use data on costs and production of three crops – barley, potato, and maize – as three major agronomic plants that influence food security of Iran and the technique of positive mathematical programming. The results reveal the severe loss of acreage, farmer income, and producer and consumer welfare surplus and the increase in crop prices under four scenarios. In all calculation sections, scenarios 4, 2, 3 and 1 had the greatest impact on the studied variables, respectively. In scenarios 1 to 4, average acreage is 372.76, 270.3, 374 and 270 thousand ha and farmers' net revenue is 24238.85, 19156.21, 24304.26 and 19143.11 billion IRR, respectively. The average price of the three studied crops under the four scenarios is 99.7, 125.65, 99.54 and 125.76 billion IRR, respectively. Also, in these scenarios, consumer welfare surplus will be 12286.8, 12072.91, 12277.87 and 12070.19 billion IRR and producer welfare surplus will be 13972.3, 13652.6, 13960.5 and 13648.8 billion IRR, respectively. Changing cropping pattern, using modern irrigation methods, supporting farmers by the government, desert greening, and curbing the emission of greenhouse gases are some practices that can alleviate the consequences of climate change for food security and economic welfare.

Keywords: Climate Change, Climate Variability, Economic Welfare, Food Security, Iran.

Introduction

The climate of the Earth is changing in response to a series of disorders brought about by human behavior and performance, especially due to the emission of greenhouse gases (GHG) (Sardar Shahraki et al., 2018). It is of paramount importance for the global community to understand the rate, state, and scale of this change. The climate parameters that are considered include temperature, rainfall, humidity, and wind direction and speed (Dowsett and Robinson,

* Corresponding author E-mail: j.shahraki@eco.usb.ac.ir

2013; Sardar Shahraki et al., 2018). Classic environmental parameters, such as sunny or frost days, marine limestone, and desert moving sand, have been recently added to the set of parameters indicating climate changes. These new parameters contain most biological matters (fossil pollens, insects, marine algae) and chemical proxies (e.g. Mg/Ca ratio in biogenic carbonates) (Zalasiewicz and Williams, 2016; Sardar Shahraki et al., 2019).

Intensive use of fossil fuels and land use change have increased and are increasing GHG emission to the atmosphere. The heat that is normally irradiated generates the greenhouse effect by reflecting back to space, and this cause's climate change. The major features of climate change are the rise of mean global temperature (global warming), the changes in cloud cover and rainfall, the melting of ice caps and natural glaciers and the reduction of snow cover, the warming of oceans and the increase in their acidity due to heat and atmospheric CO_2 absorbed by waters (Meehl et al., 2007; Sardar Shahraki et al., 2018; Sardar Shahraki et al., 2016).

Climate change will radically influence the environment and the related socioeconomic sectors including water resources, agriculture and food security, human health, terrestrial ecosystems, biodiversity, and coastal areas. Changing rainfall patterns will create extreme water events including both floods and severe water scarcity. Melting of glaciers can aggravate floods and soil erosion. High temperatures may change the growing season of the crops, and this will affect food security and the distribution of diseases. Although scientists argue that the long-term trends of climate change are caused by human behavior, climate variability is mainly rooted in natural fluctuations in climate systems (though there are some exceptions). Climate variability influences the aspects of access to food security and economic welfare, especially through two channels by which it can be effective – productivity and income. Furthermore, climate variability affects relative production and input prices, as well as the dimensions of indirect access to food (Wheeler and von Braun, 2013).

The risk of food security loss due to climate change has turned into a major challenge of the 21st century. The impacts of climate change on crop yields can be observed in different statistics (Lobell et al., 2011). Climate change (e.g. the change in the patterns of temperature and rainfall) has very specific impacts on welfare in different regions. The first consequence targets millions of poor people who have the most interactions with nature. It has been established that developing countries that are heavily dependent on agriculture and other nature-dependent activities are profoundly influenced by climate change. Depending on the level and extent of dependence of different climate-susceptible sectors, climate change may affect productivity and income distribution, thereby influencing earnings and welfare severely.

Research Objectives

- The forecast of economic welfare under climate changes in Iran
- The forecast of food security climate changes in Iran

The subject matter of the present work has been subject to some studies that are briefly reviewed in Table 1.

Methodology

The present study used positive mathematical programming (PMP) technique for modeling. PMP technique was first presented by Howitt (2005). It is the most commonly used method to calibrate a mathematical programming model in three stages:

1. Generating a linear programming model considering calibration constraints

2. Using dual values generated in the first stage to find out the parameters of the nonlinear objective function
3. Using the calibrated objective function as a nonlinear programming model to analyze the policies

In the first stage, calibration constraints are added to the set of resource constraints of a linear programming model. These constraints limit activities levels to the levels observed in the base period. The initial model is generated as below assuming maximization of the programmed efficiency:

Table 1. A brief review of the relevant literature

Source	Subject matter	Findings
Studies in Iran		
Ibrahimi Khosfi et al. (2013)	The role of climate change in agriculture and food security	Climate change will affect the life cycle of pests, diseases, and weeds, and this will impair crop production and, consequently, food security
Momeni and Zibaei (2013)	The impacts of climate change on agriculture in Fars province	Temperature and precipitation influence crop yields significantly and non-uniformly. According to comparative results, the welfare impacts of climate change is positive in most cases and its impacts on producers are much more significant than its impacts on consumers
Amirnejad and Asadpour Kordi (2017)	The impacts of climate change on wheat production in Iran	The use of distributed lags autoregressive model showed that both in the short and long run, climate variables, and acreage have a positive significant relationship with wheat production, but the variables of seed and fixed capital in machinery are insignificant.
Adavi and Tadayon (2017)	The impacts of climate change on potato production in Fereidonshahr region of Isfahan	Potato tuber yield will be reduced in future due to climate change and this reduction will be greater in scenario a2 than other two scenarios.
Studies in other parts of the world		
Ahmad et al. (2011)	Climate change and poverty susceptibility in Tanzania	Climate changes and instability have been very effective in aggravation of poverty in Tanzania.
Wheeler and von Braun (2013)	Impacts of climate change on global food security	Given climate change, a ‘climate-smart food system’ is required to reduce the damages of climate change.
Gohar and Cashman (2016)	Impacts of climate change	It was concluded that climate changes and exposure to these changes would negatively influence future water resources and food security and would increase the price of foodstuff. However, some climatic conditions will be an opportunity for food producers to give a positive response to technological programs in order to improve the consequences of these conditions.
Guillermo et al. (2018)	Food security and climate change impact of maize production in Mexico	Climate change can not only affect agricultural products but also the spatial distribution of land use. There has been a linear correlation (r = 0.45) between average annual precipitation and maize production in spring in the 1980-2012 period. This correlation has been stronger during the 2005-2012 period (r = 0.91).

$$\begin{aligned}
&\text{Maximize } Z = p'x - c'x \\
&\text{Subject to: } AX \le b \left[\lambda\right] \\
&x \le x_0 + \varepsilon \qquad \left[\rho\right] \\
&x \ge 0
\end{aligned} \tag{1}$$

In which Z = objective function value, p = the n × 1 vector of crop prices, x = the non-negative n × 1 vector of the production activity levels, c = the n × 1 vector of the cost of each activity unit, A = the m × n matrix of technical coefficient in resource constraints, b = the m × 1 vector of the values of available resources, x_0 = the non-negative n × 1 vector of observed production activity levels, ε = the n × 1 vector of positive small numbers to hinder the linear dependence of structural constraints and calibration constraints, λ = the m × 1 vector of dual variables related to resource constraints, and ρ = the n × 1 vector of dual variables related to calibration constraints.

The difference of this model with linear programming is that the model includes calibration constraints too (Bakhshi et al., 2011).

By solving the model, the dual values related to these constraints that reflect the shadow price of the products are calculated. Howitt (2005), Paris and Howitt (1998), interpreted the dual values of ρ related to calibration constraints to be representative of any error in the model, data error, cointegration error, risky behavior, and price expectations. The ρ dual vector reflects the final and mean production value in the calibration of a diminishing nonlinear performance function. In addition, the ρ dual vector is interpreted as the vector of differential final cost in the calibration of an ascending nonlinear cost function. Along with the vector (c), it specifies the final cost and real cost of the production of an observed activity X_0. In the second stage, the dual values obtained from the first stage are used to estimate the parameters of the nonlinear objective function. In other words, dual values are used in this stage to calibrate the parameters of the nonlinear objective function. In this state, the activity levels observed in the reference period are regenerated by the aforementioned nonlinear model excluding the calibration constraints.

In the third step of the PMP method, the nonlinear cost function that has been studied in the previous step is examined in the context of the objective function in question and is used in a nonlinear programming problem akin to the initial problem but excluding the calibration constraints; also, other systemic constraints are included (Bakhshi et al., 2011):

$$\text{Maximize } Z = p'x - c'x - x'\hat{Q}x/2$$
$$\text{Subject to: } AX \le b \quad [\lambda] \tag{2}$$
$$x \ge 0$$

In which the vector $\hat{d}$ and the matrix $\hat{Q}$ denote the calibrated parameters of the nonlinear objective function. Now, the calibrated nonlinear model can correctly regenerate the observed levels of activities in the base status and the dual values of the resource constraints and is ready to simulate the variations of the desired parameters. When compared to the first-step model, the model of the third step lacks the calibration constraints and its objective function is non-linear too. This calibration method has been used in numerous studies at farm, district, county and national levels in developed countries like Germany, Finland, and Italy and in developing countries like Egypt, Turkey, and Morocco.

Climate scenarios

The climate scenarios of the present study will be developed with respect to climate variability and change in terms of mean annual precipitation. So, data of monthly precipitation were collected from the 1990-2015 period, and the average annual precipitation was calculated. Four different climate scenarios were developed using the normal distribution technique. Average precipitation per unit area of land (ha) will be estimated by:

$$\mathrm{Pr}_{ct} = N \sim \left(\overline{P}_{ct}, s_c\right) \tag{3}$$

In which, on average, in Pr_{ct} there are *c* climate assumption and the time period *t* is a function of average annual precipitation ($\overline{P}_{ct}$) under climate variability and change. In fact, $\overline{P}_{ct}$

reflects average precipitation per thousand m^3 (CM) per ha, and s_c represents the variance of annual precipitation under climate assumptions.

Scenario 1 represents normal climate change in which no change or variability is considered in climate. This scenario considers normal random numbers with present average precipitation and 0.05 of the variance of the present precipitation. This assumption is compared with three other assumptions about climatic conditions. *Scenario 2* hypothesizes climate change in which normal random numbers are considered with the half of the present average precipitation and 0.05 of the variance of the present precipitation. *Scenario 3* is the hypothesis of climate variability in which normal random numbers are considered with the present average precipitation and 0.30 of the variance of the present precipitation. *Scenario 4* assumes the second and third assumptions concurrently so that normal random numbers are considered with half of the present average precipitation and 0.30 of the variance of the present precipitation (Gohar and Cashman, 2016).

The research model was estimated by the GAMS software package. Also, the CROPWAT package was employed in the costs and crop production section to estimate water demand. Total water volume obtained from rainfall is equal to the total area of the region in ha multiplied by the rate of rainfall within each climate assumption.

$$RHS_t = \sum hectare_t \times Pr_t \tag{4}$$

Production costs

Crop production incurs various costs. We divided the total average costs per ha (ATC_{ct}) in the cultivated lands into three types as shown below:

$$ATC_{ct} = NWC_{ct} + CC_{ct} + PC_{ct} \tag{5}$$

In which NWC_{ct} represents non-water costs, CC_{ct} represents capital costs of the irrigation system, and PC_{ct} represents energy pumping costs. Non-water costs of production include land rent, land preparation, planting, the control of weeds, pests and diseases, harvest, transportation, and irrigation. Irrigation system capital costs cover the costs of purchasing, installing and maintaining drip irrigation systems.

Farmers income

Net revenue per ha is equal to crop yield ($Yield_{ct}$) multiplied by crop price (P_{ct}) minus average production costs (ATC_{ct}) and water costs (WC_{ct}). In fact, total net revenue (TNB_{ct}) for a crop is equal to net revenue per ha multiplied by total crop acreage. As agricultural crops are produced to a greater extent, market prices should decrease possibly resulting in the reduction of farmer income because agricultural crops have low elasticity. The variation of crop prices is related to the market demand and supply forces. For the different assumption, crop prices are considered unknown that is solved by the model.

$$TNB_{ct} = \left(P_{ct} \times Yield_{ct} - ATC_{ct}\right) \times hectare_{ct} - WC_{ct} \tag{6}$$

The present value ($PTNB_c$) in the discount rate (r) from total net benefits is equal to:

$$PTNB_{ct} = \sum \frac{TNB_{ct}}{(1+r)^t} \tag{7}$$

Finally, acreage is obtained from:

$$hectare = \frac{W}{ET} \tag{8}$$

In which total acreage is equal to total water per crop water requirement.

Consumer surplus, producer surplus, and food security

Consumer surplus is an important part of the consequences of food policies for economic welfare, especially when these policies affect food prices directly. In fact, consumer surplus can be used to estimate the economic gain or loss of consumption advantages arising from price changes over a specific time period (Ferreira et al., 2016). Consumer surplus can be used in exploring the problems related to the availability of natural resources like water too (Banzhaf, 2010). The measurement of the variations of consumer welfare resulting from irrigation policies and/or drought assumption needs data on crop price elasticity and production level. To calculate consumer surplus for each individual crop, we need the standard relationship between the demand curve and price elasticity of demand. The reverse demand function can be stated as:

$$P_{ct} = \theta 0_a + \theta 1_a \times \sum TP_{ct} \quad (9)$$

Consumer surplus is calculated by Equation (10). Actual price will increase with the decrease in irrigation water availability under the assumptions of climate variability and change:

$$CS_c = \sum \frac{0.5 \times \left[(\theta_0 - P_{ct}) \times \sum TP_{ct} \right]}{(1+r)^t} \quad (10)$$

To measure producer welfare variations too, we need price elasticity of crop demand and production level. In fact, the standard relationship between the supply curve and demand price elasticity is used to calculate producer surplus for each individual crop. The reverse demand function can be expressed as:

$$P_t = \gamma_0 + \gamma_1 \times \sum TP_{ct} \quad (11)$$

Therefore, producer surplus is obtained from Equation (12) (Gohar and Cashman, 2016):

$$PS_c = \sum \frac{0.5 \times \left[(\gamma_0 - P_{ct}) \times \sum TP_{ct} \right]}{(1+r)^t} \quad (12)$$

Research data

The generalization and examinations of this study require a distinctive set of data and information from various sources, and it is very time-consuming to find the sources, collect the data, and integrate them. Climate data can be considered at different temporal levels, i.e. daily, weekly, monthly, and/or yearly, and at different spatial scales including city, province, and/or country. The present study used yearly data from 2000 to 2015 at a country level. Data of the agricultural sector were related to crop water use, crop yield, production costs, wholesale price, water extraction cost, and other agronomic data such as crop water requirement. We focused on three very important crops of barley, potato, and maize with an effective role in ensuring food security. The data on these crops were provided by the Ministry of Agriculture. The climate data we applied included average precipitation, mean maximum temperature, mean minimum temperature, number of sunny hours, humidity, and wind speed. They were taken from Iran Meteorological Organization.

Results

After the research models were estimated and the calculations were made, the results are presented in six distinct sections. First, we deal with precipitation, acreage, and income in the context of the four scenarios. Then, crop price (as per ton) and consumer and producer welfare surplus are presented.

Table 2. The results of the model

Year	Precipitation (mm)				Acreage (000 ha)				Income (10 billion IRR)			
	Assumption 1	Assumption 2	Assumption 3	Assumption 4	Assumption 1	Assumption 2	Assumption 3	Assumption 4	Assumption 1	Assumption 2	Assumption 3	Assumption 4
1	312.9873	155.2462	316.4591	156.9073	388.946	261.563	392.581	262.128	2461.242	1919.212	2476.707	1921.617
2	313.7897	157.5785	311.0729	156.3133	375.098	255.4347	372.4357	255.0183	2420.89	1880.7	2408.872	1878.819
3	313.9598	157.9632	315.6974	151.2917	371.111	255.126	372.7663	253.17	2483.767	1927.084	2491.713	1917.696
4	311.0888	155.7834	317.0601	156.6863	366.051	256.3747	370.6617	256.6487	2555.987	1999.469	2581.925	2000.849
5	312.4637	155.4388	315.9659	155.7228	364.422	254.4947	367.107	254.577	2566.167	2004.595	2581.405	2005.016
6	312.1633	156.6974	308.9932	155.7863	356.008	249.3347	353.5627	249.064	2410.045	1862.496	2396.397	1861.127
7	312.8864	155.4448	319.8162	153.217	350.702	243.197	356.846	242.5967	2350.956	1796.552	2382.643	1793.455
8	314.5494	155.5545	315.4442	152.9355	372.042	262.5753	372.042	261.8473	2619.876	2024.049	2619.876	2020.085
9	312.429	157.5193	313.8975	156.5171	376.3417	264.269	376.3417	263.9543	2409.932	1842.283	2409.932	1840.689
10	313.38	158.6562	318.4362	157.14	373.5563	261.368	378.2543	260.8823	2360.432	1798.661	2383.959	1796.227
11	312.2418	159.4603	317.2665	154.8353	397.2217	279.808	402.1587	278.2763	2620.857	2011.14	2646.493	2003.187
12	313.8099	155.9077	318.9147	160.6576	415.856	291.7463	421.0483	293.4317	2741.859	2101.776	2768.638	2110.468
13	312.5504	156.4166	309.5523	156.0935	421.8777	296.929	418.7943	296.8197	2671.758	2034.66	2656.038	2034.103
14	312.771	155.4854	308.4921	159.0738	390.2367	292.6673	390.2367	293.917	2463.228	1973.974	2463.228	1980.24
15	315.7372	156.5551	310.8885	154.9514	357.6633	280.648	357.6633	280.1383	2248.501	1872.122	2248.501	1869.631
16	312.4773	156.361	310.9214	157.7658	358.389	279.9307	358.389	280.3883	2231.614	1852.597	2231.614	1854.807
17	311.7535	156.0306	311.7132	154.7504	357.1313	280.0763	357.1313	279.6833	2225.57	1853.049	2225.57	1851.149
18	311.6577	155.3918	317.3127	157.0226	355.896	279.9457	355.896	280.461	2219.645	1852.142	2219.645	1854.636
19	313.7797	159.1708	312.2114	149.0808	354.0223	280.6313	354.0223	277.6937	2210.716	1854.946	2210.716	1840.706
20	314.8654	157.724	311.1917	158.2213	352.756	279.869	352.756	280.035	2204.651	1850.906	2204.651	1851.713
mean	313.0671	156.7193	314.0654	155.7485	372.7664	270.2994	374.0347	270.0366	2423.885	1915.621	2430.426	1914.311

Table 2. Continued.

Year	Price per tone (10 million IRR)				Consumer welfare surplus (10 billion IRR)				Producer welfare surplus (10 billion IRR)			
	Assumption 1	Assumption 2	Assumption 3	Assumption 4	Assumption 1	Assumption 2	Assumption 3	Assumption 4	Assumption 1	Assumption 2	Assumption 3	Assumption 4
1	0.904	1.315667	0.892667	1.314	1118.696	1150.295	1113.955	1150.733	1236.6	1278.467	1230.018	1279.092
2	1.216333	1.664333	1.226	1.665667	1199.548	1177.022	1201.479	1176.553	1356.398	1322.569	1359.023	1321.909
3	1.498	2.025667	1.490333	2.034	1255.508	1221.058	1254.433	1218.621	1418.646	1368.451	1417.21	1365.056
4	1.850667	2.455	1.823333	2.453667	1321.471	1276.265	1318.731	1276.626	1486.481	1421.785	1482.973	1422.283
5	2.274	2.991	2.255	2.990333	1352.571	1294.577	1351.405	1294.695	1518.786	1436.879	1517.322	1437.041
6	2.800667	3.624333	2.820667	3.626667	1296.115	1226.363	1296.662	1225.953	1489.133	1391.608	1489.781	1391.045
7	3.335333	4.346333	3.277333	4.352333	1256.975	1188.948	1255.04	1188.027	1455.008	1360.361	1452.536	1359.1
8	3.419333	4.810333	3.419333	4.819667	1233.309	1247.244	1233.309	1246.594	1363.575	1377.789	1363.575	1376.897
9	4.176333	5.797667	4.176333	5.802333	1144.676	1150.328	1144.676	1150.045	1305.172	1309.207	1305.172	1308.816
10	5.274667	7.141667	5.196667	7.15	1169.896	1150.456	1166.254	1149.928	1350.439	1320.983	1345.658	1320.256
11	6.274	8.527667	6.179667	8.557	1290.753	1275.746	1286.594	1274.105	1469.029	1445.117	1463.613	1442.869
12	7.868333	10.486	7.758667	10.45033	1401.786	1360.274	1398.646	1362.336	1603.332	1543.784	1599.273	1546.606
13	9.121667	12.308	9.200333	12.31033	1323.176	1302.245	1325.401	1302.127	1534.677	1502.979	1537.58	1502.817
14	11.24767	14.417	11.24767	14.37633	1251.261	1237.225	1251.261	1238.31	1440.116	1418.185	1440.116	1419.681
15	13.811	17.04033	13.811	17.06167	1167.222	1156.553	1167.222	1156.176	1326.911	1309.871	1326.911	1309.347
16	16.54167	20.47867	16.54167	20.456	1156.959	1146.114	1156.959	1146.451	1316.565	1299.247	1316.565	1299.716
17	19.92567	24.56733	19.92567	24.591	1157.527	1146.226	1157.527	1145.935	1317.286	1299.406	1317.286	1299
18	23.99967	29.492	23.99967	29.45433	1158.061	1146.134	1158.061	1146.514	1317.962	1299.281	1317.962	1299.809
19	28.961	35.33467	28.961	35.58967	1158.82	1146.647	1158.82	1144.436	1318.925	1300.001	1318.925	1296.93
20	34.88433	42.484	34.88433	42.46633	1159.306	1146.091	1159.306	1146.214	1319.536	1299.233	1319.536	1299.404
mean	9.969217	12.56538	9.954367	12.57608	1228.682	1207.291	1227.787	1207.019	1397.229	1365.26	1396.052	1364.884

According to Table 2, it can be said that scenarios 4, 2, 3 and 1 had the highest impact in all calculation sections, respectively. The lowest precipitation will relate to scenarios 4, 2, 1 and 3, respectively. Under normal climate assumption, annual rainfall will amount to 67.313 mm. As Table 1 displays, under climate change assumption, annual rainfall will be 719.156 mm in 20 years. But, it will be 720.156 mm under climate variability assumption. When it is assumed that climate variability and change will happen concurrently, annual rainfall will reach 748.155 mm in the next 20 years. The results revealed that the lowest acreage will be related to scenarios 4, 2, 1 and 3, respectively. When it comes to net revenue, mean net revenue of farmers of the three crops will be 24238.85, 19156.21, 24304.26 and 19143.11 billion IRR in scenarios 1, 2, 3 and 4, respectively. The mean price of the three crops will be 99.7, 125.65, 99.54 and 125.76 million IRR under the four scenarios, respectively. The consumer welfare surplus for the three crops in scenarios 1 to 4 will be, on average, 12286.8, 12072.91, 12277.87 and 12070.19 billion IRR, respectively. Finally, scenario 4 will have the lowest producer welfare surplus followed by scenarios 2, 3 and 1, respectively.

Variations of precipitation

In scenario 1, the highest rainfall will be in years 4, 18 and 17 and the lowest will be in years 15, 20 and 18. It is evident in Table 1 that mean annual precipitation will be 719.156 mm in scenario 2 in which years 1, 18 and 5 will have the lowest and years 11, 19 and 10 will enjoy the highest rainfall, respectively. According to scenario 3, the lowest rain will fall in years 16, 6 and 13 and the highest in years 7, 12 and 10. This scenario projects that annual precipitation will be 720.156 mm. In scenario 4, the lowest rainfall will be experienced in years 19, 3 and 8 and the highest in years 12, 14 and 20.

Variations of acreage

According to scenario 1, years 13, 12 and 11 will have the highest crop acreage and years 7, 20 and 19 will have the lowest. The highest crop planting area will be in years 13, 14 and 12 and the lowest in years 7, 6 and 5 in scenario 2. Scenario 3 shows that the highest planting area will be observed in years 12, 13 and 11 and the lowest in years 20, 6 and 9. Finally, in scenario 4, the highest acreage will be related to years 13, 14 and 12 and the lowest to years 7, 6 and 3.

Variances of income

In the context of scenario 1, farmers will have their highest income in years 12, 13 and 14 and the lowest in years 20, 19 and 18. In scenario 2, the highest income will be produced in years 12, 13 and 8 and the lowest in years 7, 10 and 9. Assuming scenario 3, the highest income will be made in years 12, 13 and 11 and the lowest will occur in years 20, 19 and 18. In scenario 4, the highest income will happen in years 12, 13 and 8 and farmers will have their lowest income in years 8, 10 and 9.

Variations of prices

In all four scenarios, the highest prices will be observed in years 20, 19 and 18 and the lowest will occur in the first three years.

Variations of consumer welfare surplus

Consumer welfare surplus will be the highest in years 12, 5 and 13 and the lowest in years 1, 9 and 16 in scenario 1. In scenario 2, it will be the highest in years 12, 13 and 5 and the lowest in years 20, 16 and 18. In scenario 3, the highest consumer welfare surplus will occur in years 12, 5 and 3 and the lowest in years 1, 9 and 16. In scenario 4, it will be the highest in years 12, 5 and 3 and the lowest in years 19, 17 and 20.

Variations of producer welfare surplus

The highest producer welfare surplus will be the highest in years 12, 13 and 5 and the lowest in years 1, 9 and 16 in scenario 1. In scenario 2, the highest will be in years 12, 13 and 11 and the lowest in years 1, 20 and 16. Assuming scenario 3, the highest surplus will be observed in years 12, 13 and 5 and the lowest in years 1, 9 and 16. In scenario 4, produce welfare surplus will be the highest in years 1, 9 and 17 and the lowest in years 12, 13 and 11.

Conclusions and Recommendations

Climate change is one of the major issues in economics and agriculture. Hence, in this study, the forecast of economic welfare under climate changes in Iran and the forecast of food security climate changes in Iran considered.

The findings of the study in different sections lead us to several conclusions. Among all four scenarios, the scenario of concurrent change of climate and the scenario of climate change will have a much stronger impact on food security and economic welfare of Iran. The immediate impact of these two scenarios on water resources is the severe loss of irrigation over the 20-year period. This decline of rainfall is to an extent that mean precipitation in these two scenarios will be, on average, 50% lower than that in other two scenarios. In food security section, farmer income will have a descending trend. However, crop prices will be ascending due to the loss of production level. These will be much stronger in the two scenarios of concurrent climate change and climate change than in two scenarios of normal climate change and climate variability. These scenarios have similar impacts on welfare aspects, but consumer welfare surplus will have a much severer reduction. The results show that if climate change keep going on and appropriate policies are not adopted to cope with them, the adverse impacts of these changes will be unavoidable. The loss of precipitation and water reserves of the country will pose serious environmental and human risks unless sound plans are developed for the management of water resources and agricultural production. Also, the lack of sound management practices in the agricultural sector which are compatible with the coming climate will challenge food security and economic welfare dramatically. Price rises, income loss, and the reduction of consumer welfare surplus are the impacts of the climate change that call for proper policies. According to the results, the following recommendations can be drawn:

1. The development of modern irrigation methods, e.g. drip irrigation and pressurized irrigation, can alleviate the consequences of climate change.
2. In their policy-making, the governments should focus on strengthening and institutionalizing methods that can reduce the adverse impacts of climate change on the producers and consumers of the crops.
3. Changing planting methods and cropping pattern and going towards modern irrigation methods and crops with lower water requirement can be effective in alleviating the consequences of climate change.
4. Actions should be taken for desert greening and the replacement of renewable energy sources for fossil fuels.
5. Environmental policies should be taken to hinder the increasing rate of GHG emission.

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