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Factors Creating Systematic Risk for Rainfed Wheat Production in Iran, Using Spatial Econometric Approach

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ABSTRACT

In this study, the factors creating systematic risk for dry farming wheat crop in Iran were investigated. Using production functions as well as spatial econometric approach, the effects of changes in climatic parameters such as temperature and precipitation, and also input levels of seed, urea, and phosphate fertilizers in warm, moderate, and cold climates were examined. The results showed that the fluctuations of climatic parameters in the three climates were severe enough to be identified as systematic risk factors. The findings also indicated that, in a warm climate, lack of sufficient heat during cultivation time (October), overheating during initial growth months (December and January), lack of sufficient precipitation during initial growth months (November and December) and inadequate seed and urea fertilizer and overusing phosphate fertilizer were the systematic risk factors. In moderate climate, these factors included lack of sufficient heat in cultivation time (October) and in late harvest time (July), lack of sufficient precipitation in the cultivation time (October) and lack of urea fertilizer and seed phosphate overuse. Finally, in the cold climate, insufficient heat in vegetative growth time (March), inadequate precipitation in the cultivation and initial growth time (October and December), and also lack of phosphate fertilizer and seed overuse were identified as the systematic risk factors.

Keywords: Climate change, Insurance precipitation, Temperature, Iran.

INTRODUCTION

Due to a general increase in the world's temperatures, the possibility of drought in the future will intensify. Because of industrial activities and human-induced environmental pollutants, climates have experienced more severe changes over the last few decades. Thus, these changes would be one of the greatest challenges human beings will face in this century. Since the agricultural sector is affected by climate changes, meeting food requirements of people would be difficult (Intergovernmental Panel on Climate Change, 2007). Wheat is considered as the most important cereals. Unlike other grains, this crop can be used in different ways such as cooking bread, biscuits, cookies, cakes, pasta, spaghetti, etc. So, it plays a significant role in the basket of household food. Throughout the world, Iran is ranked eighteenth and fourth in terms of wheat production and consumption, respectively. The cities of Eghlid, Fasa and Marvdasht, in the province of Fars, are the most important wheat producers in Iran. In addition, Khuzestan, Golestan, East Azerbaijan, Kurdistan, Hamadan, and Ardabil Provinces are major producers of this crop in Iran. Cool weather during the vegetative growth, mild weather during the seed formation, and the warm and dry weather during the harvest time are regarded as ideal conditions for wheat growth. Therefore, in regions with harsh winter, cultivation of wheat will experience some problems including winter frostbite. Besides, wheat is not so tolerant of dryness and cannot tolerate water shortage for a long time. The harvest time is affected by factors such as precipitation, relative humidity, temperature, and seed ripening time (Ministry of Jihad

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Agriculture, Department of Planning and Economic Affairs, 2012). For this reason, it is important to investigate the impact of climatic variables on dry farming wheat yields.

There have been a large number of studies evaluating the effects of weather on wheat yield. Some are briefly mentioned here. Lobell, *et al.*, (2005) used CERES-Wheat simulation model for the climate trend effect on wheat production in the Mexico region. They studied the climate trend and wheat yield for the last two decades from 1988 to 2002 and found that the climate had favored wheat growth during the two decades and resulted in 25 percent increase in wheat production. It means climate was having positive effect on the wheat yield for this region. However, 25 percent increase is less than expected compared to the previous studies which predicted higher increase in wheat productivity for this region.

Hussain and Mudasser (2007) used Ordinary Least Square (OLS) method to assess the impact of climate change on two regions of Pakistan, “Swat” and “Chitral”. They investigated whether increase in temperature up to 3oC would decrease the Growing Season Length (GSL) of wheat in this county. Their result showed that increase in temperature would create positive impact on Chitral district due to its location on high altitude and negative impact on Swat because of its low altitude position. They suggested adaptation strategies of cultivating high yielding varieties for warmer areas of northern region of Pakistan because of expected increase in temperature in the future.

Cerri *et al.* (2007) used simulation model for Central South region of Brazil up to 2050. They revealed that 3-5oC increase in temperature and 11 percent increase in precipitation would cause decrease in the productivity of wheat to the level equal to one million ton of wheat. They ascertained that, in Brazil, wheat was being cultivated at the threshold level of temperature and any further addition to this level of temperature would cause decline in agricultural production, specially wheat. They further concluded that most of the developing countries lying on the tropical belt and relying on agriculture would face losses in agricultural yield.

In a study on the effects of climate changes on agriculture in Iran, Esmaeili and Vaseghi (2008) used chronological combined series of weather data from 1984 to 2004 and Ricardian model in 17 provinces and concluded that climatic variables had significant and non-linear effect on net income per hectare of wheat. They also showed that the increase in temperature and decrease in rainfall in the next 100 years would cause the reduction of yields per hectare by 41 percent.

Sabzevary *et al.* (2012) conducted a study to examine the impact of climatic factors on dry farming and irrigated wheat yields in selected stations of Hamadan province. The investigation was done using bivariate linear regression analysis and the impact of each factor on wheat yield was compared utilizing explanatory and correlative coefficients. Overall, sensitivity of dry farming wheat yields index to atmospheric and agro climatic parameters was higher compared to irrigated wheat.

Reidsma *et al.* (2009) examined the effects of climate changes and variations on the regional yield of maize using a process-based model in Europe. The results revealed that the potential performance would increase with temperature rise, which was against the model simulations.

Employing Ricardian model as well as data of three time periods, Amiraslany (2010), studying agriculture of Canada, showing high importance of precipitation in the Canadian plains, has found out that the climate changes have complex and nonlinear effects on agriculture. Marginal effects of transpiration, precipitation, and relative humidity indicate that there is a direct and positive relationship between farmlands and values and the climate related variables.

Travis *et al.* (2012) have reported that the climate has direct and evident effects on agricultural crops. Development and dissemination of new methods of farming and technology can largely increase the adaptability of farmers to climate changes.

The results of these studies show that the effect of factors are dependent on regions. As mentioned, due to global warming and temperature rise, the possibility of drought in the future will intensify. In addition, these changes would be one of the greatest challenges human beings will face in this century. Since the agricultural sector is affected by climate changes, meeting food requirements of people would be difficult. In the abovementioned studies, the

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geographical contiguity effect of selected areas on each other has been neglected. In fact, the impact of climatic factors has been separately considered, regardless of the effect of location of selected regions on yields. Also, the climatic factors and consumer inputs have not been used simultaneously. Weather is an important production factor and at the same time one of the greatest sources of risk in agriculture (cf. e.g, Isik and Devadoss, 2006). In addition, climate change will likely reinforce weather-related risk by rising temperature, precipitation as well as the occurrence and severity of droughts or floods (Carter *et al*., 2007; Morton, 2007). Insurance is a prominent mechanism for risk transfers. In addition, a remaining level of risk which cannot be diversified away, and this non-diversifiable risk is called systematic risk. Systematic risk in production agriculture could be viewed similarly using a commodities portfolio (Todd *et al*., 2009).

Weather risks are correlated within a region. This spatial covariance makes it difficult for local insurers with limited regional diversification to pool risks and offer affordable insurance coverage (Skees, 2000).

The aim of this study was to evaluate the effect of climatic variables such as temperature and precipitation to reduce the risk of wheat production in Iran. In fact, the range of change in temperature and precipitation in the investigated climates is different, and because this study investigated the weather among three different climates, hence it is important the effects of temperature and precipitation investigate. Therefore, in this study, we tried to measure the degree of impressionability of dry farming wheat yields from climate changes, considering geographical location of selected areas over the last few decades. For this purpose, the impact of climate changes (temperature and precipitation) along with consumer inputs of seed and fertilizer on dry farming wheat yields in different provinces of Iran were investigated for 21 years i.e. 1991-2012.

MATERIAL AND METHODS

Ricardian model can be used to estimate the impact of climatic, socio-economic and geographical variables on the value of agricultural lands. Ricardian model proportion to evaluate the impact of climate changes on agriculture has been determined through quantitative relationship between farmlands value and climate and non-climate factors (Amiraslany, 2010). Adopting Ricardian approach, we consider the direct impacts of climate on yields of crops (Mendelsohn *et al.*, 1994). Because weather risks are correlated within a region, we measured the effect of climate change in each region.

The reason for choosing inputs of seed, urea, and phosphate fertilizers among the inputs of production is the relationship between these inputs and climate variables such as temperature and precipitation (which in fact shows the dryness of the soil). In fact, the changing of temperature and rainfall affect the impact of inputs of seed, urea, and phosphate fertilizers, so, the yield of dry farming wheat is much changing over time. Since the crop is dry farming here, there is no irrigation and water is supplied to the crops only by precipitation. In fact, rainfall has been considered as an input of consumed amount of water. Therefore, investigating the effect of climatic factors such as precipitation and temperature along with inputs of seed, urea and phosphate fertilizers on dry farming wheat yields seems necessary. The empirical model is as follows:

$$y = f(x_1, x_2, x_3, x_4, x_5) \qquad (1)$$

Where, y is the yield of dry farming wheat, x_1 is the average temperature, x_2 is precipitation during planting period (early October) to harvesting period (mid September), $x3$ amount of seed, x_4 and x_5 are the amount of urea and phosphate fertilizer, respectively.

Spatial Econometric Model

To investigate the impact of climate changes on dry farming wheat yields in Iran, we firstly need to determine the relationship among dry farming wheat regions. In other words, it should be determined how the regions of provinces in the same climate are related. Using aggregate

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data from different geographic areas (such as provinces or regions) in the regression analysis, the existence of spatial autocorrelation in the error terms seems to be natural. The spatial heterogeneity among the studied regions will be of great importance as well. It should be noted that the term spatial heterogeneity refers to deviation of the existing relations between observations at the geographical location level in the space. For this reason, due to the existence of spatial heterogeneity and spatial autocorrelation in spatial studies, spatial econometrics should be used. To describe the spatial heterogeneity a linear relationship is considered as follows:

$$y_i = X_i \beta_i + \varepsilon_i \qquad (2)$$

Where, i stands for the observations collected at i= 1,…,n points in space, X_i represents a matrix of explanatory variables with a related set of β_i parameters , y_i is the dependent variable at observation (or location) i and ε_i indicates a stochastic disturbance (random error). This equation represents a spatial simple model (Lesag, 1999).

The three following ways are used to represent the spatial location: (1) Determining location on screen coordinates; (2) Vector of distances, and (3) Geographically Weighted Regression (GWR) method. As spatial matrix has been used to represent the spatial contiguity in this study, spatial contiguity needs to be reflected as a matrix in the model. So, geographically weighted regression method was used to weigh each variable. In this method, y represents $N \times 1$ vector of dependent variable observations collected at n points in space, X is $N \times K$ matrix of explanatory variables, and ε $N \times 1$ vector of normal errors, which has constant variance. Given W_i represents $N \times N$ diagonal matrix containing distance-based weights reflecting the distance between observations i and other observations, GWR model can be as follow:

$$W_i y = W_i X \beta_i + \varepsilon_i \qquad (3)$$

Where, i in β_i is the indicator of K×1 vector of i observation related parameter. The GWR Model estimates n cases of such vectors which each represents an observation (McMillan *et al.*, 1996).

Generally, autoregressive spatial models are categorized into five different models: (1) First-order Spatial Autoregressive Model (FAR); (2) Spatial Autoregressive Model (SAR); (3) Spatial Error Model (SEM); (4) Spatial Durbin Model (SDM); (5) Spatial Autoregressive Model with Auto Regressive disturbances (SAC), and (6) Generalized Spatial Panel Random Effect Model (GSPRE).

The reason why panel data has been used in this study is that it gives a cross-sectional and chronological estimation of the model at the same time and consequently better results could be obtained. In fact, this study consists of complete and comprehensive data for a long period of time, so that the results would be more reliable and lead to more accurate decisions. The general form of the spatial panel model is as follows (Belotti *et al.*, 2013):

$$y_{it} = \alpha + \tau y_{it-1} + \rho \sum_{j=1}^{n} w_{ij} y_{jt} + \sum_{k=1}^{K} x_{itk} \beta_k + \sum_{k=1}^{K} \sum_{j=1}^{n} w_{ij} x_{jtk} \theta_k + \mu_i + \gamma_t + v_{it} \qquad (4)$$

$$v_{it} = \lambda \sum_{j=1}^{n} m_{ij} v_{it} + \varepsilon_{it} \qquad i = 1,...,n \qquad t = 1,...,T \qquad (5)$$

Where, θ, λ, ρ are the spatial parameters of the model. Given $\theta = 0$, the model is SAC; $\lambda = 0$, it is SDM; $\lambda = 0$ and $\theta = 0$, it is SAR; $\rho = 0$ and $\theta = 0$, it is SEM; and $\rho = 0$, $\theta = 0$ and $\mu_i = \phi \sum_{j=1}^{n} w_{ij} \mu_i + \eta_i$, it is GSPRE. In fact, all of the models consider a weight matrix, but the considering weight matrix of each one is different.

After one by one estimation of five stipulates of Equation (4), in terms of both "Random" and "Fixed Effects", "Hausman test" can be used to evaluate the random effects versus fixed effects (Baltagi, 2005). It should be noted that the Hausman test can be just applied to SAR, SDM, and SEM models. Hausman test cannot be applied to SAC and GSPRE models because the former is only assumed to be fixed and the latter is just random (Elhorst, 2008). Also, the *LR* test could be used to select more appropriate functional form out of the five functional forms: SDM, SAR, SEM, SAC, and

GSPRE. In order to compare the models using *LR* test, one model is considered unrestricted and the other one restricted. Considering the number of constraints, the following four ways to compare the models will be possible: (1) SDM unrestricted model versus SAR restricted model. Here, the given constraint is weight matrix of variables; (2) SAC unrestricted model versus SEM restricted model. Here, the constraint is spatial correlation coefficient (ρ); (3) SAC unrestricted model versus the SAR restricted model. Here, the constraint is spatial correlation coefficient between error terms (λ), and (4) GSPRE unrestricted model versus the SEM restricted model. Here, the constraint is the spatial correlation coefficient between climatic variables (θ). *LR* test is shown as follows:

$$LR = -2(\ln L_R - \ln L_{UR}) \sim \chi^2_{(M)} \qquad (6)$$

In the *LR* test, the hypothesis H_0 means accepting restricted model and the hypothesis H_1 means accepting unrestricted model. So, if the amount of *LR* statistic is more than *Chi* square table (with M degree of freedom that it is the number of constraints), H_0 will be rejected and H_1, i.e. selecting unrestricted model as the more accurate one is accepted. Finally, among the five functional forms, the form is chosen that is superior in two criterions: the number of significant coefficients and higher *R2*.

Quantifying Spatial Contiguity (Contiguity and Neighborhood)

This technique reflects the relative position in the space of a single regional observation unit, compared to other units. The criterion of contiguity has been determined using the information obtained from the map of Iran. Before estimating the model, it is necessary to determine the spatial contiguity of the provinces within each climate. Spatial contiguity is shown as either matrix 0 or matrix 1. In fact, if one province has common border with the other one, it is shown as matrix 1 and if there is no common border, it is shown as matrix 0. In this study, considering the main hubs of dry farming wheat cultivation, the country has been divided into warm, moderate, and cold climates. To achieve our goal, that is the evaluation of the effects of climate changes (temperature and precipitation) on dry farming wheat production in Iran, the required information was gathered from the following sources:

Data of monthly temperature and precipitation averages of provinces from the Iranian Meteorological Organization (http://www.irimo.ir). Data related to yields and inputs of production (seed, phosphate and urea fertilizers) of provinces for dry farming wheat crop from Jihad Agriculture Organization, Department of Plant Production (http://www.maj.ir), 1991-2012. The yield data was collected at regional level and were balance data. It should be mentioned that the determination of the geographical position for each province and their kind of contiguity is essential. For this purpose, contiguity and non-contiguity of the provinces has been determined using the map of provincial divisions. We considered 3 climates (warm, cold and moderate) that included 24 provinces, as shown in Table 1. To analyze the tests data and models, Stata software (version 12), was employed.

RESULTS AND DISCUSSION

Descriptive statistics of temperature, precipitation, and yields as well as the inputs of seed, urea, and phosphate fertilizers for the main producer hubs of dry farming wheat and the planting and harvesting period in 3 warm, moderate and cold climates for 1991-2012 is shown in Table 1. For example, according to Table 1, in warm climates, the mean monthly temperature for dry farming was 21.47°C, the annual mean of total precipitation was 368.18 mm, the yield annual mean was 968.54 kg ha-1, the consumed seed rate mean is 176.83 kg ha-1, the consumed urea fertilizer rate mean is 78.07 kg ha-1 and phosphate fertilizer rate mean is 72.13 kg ha-1. In moderate climates, the temperature, precipitation, yield, seed, urea and phosphate fertilizers means are 16.25°C, 449.60 mm, 985.25 kg ha-1, 145.18 kg ha-1, 59.32 kg ha-1 and 50.83 kg ha-1, respectively. Also in cold climate, these amounts are 12.60°C, 320.82 mm, 943.18 kg ha-1, 134.02 kg ha-1, 50.21 kg ha-1and 51.69 kg ha-1, respectively. SDM, SAR,

Table 1. Descriptive statistics of weather variables and planting and harvesting time of dry farming wheat in warm, moderate, and cold climates.[a]

Climates	Planting period	Harvesting period	Province	Statistics	Temperature (c)	Precipitation (mm)	Yield (kg ha^{-1})	Seed (kg ha^{-1})	Urea fertilizer (kg ha^{-1})	Phosphate fertilizer (kg ha^{-1})
Warm	Late October- late December	Early May- late June	Khozestan, Kerman, Eelam Kohkiloye and Boyer ahmad, Golestan, Boshehr,	Lowest	16.38	63.96	122.81	26.61	5.10	2.83
				Mean	21.47	368.18	968.54	176.83	78.07	72.13
				Highest	27.21	1025.7	3476.63	812.34	557.14	436.25
				SD	3.38	216.60	641.18	111.76	69.76	58.30
Moderate	Mid October- mid December	Early June- mid July	Fars, Khorasan, Esfahan, Kurdestan Lorestan , Semnan, Tehran, Gilan, Mazandaran	Lowest	8.29	38.30	136.36	30.87	2.61	5.06
				Mean	16.25	449.60	985.25	145.18	59.32	50.83
				Highest	20.60	1895.3	2947.44	490.06	222.45	211.41
				SD	2.31	391.29	535.79	72.13	35.87	27.84
Cold	Early October- Early December	Early August- Mid September	Markazy, East Azarbayjan, West Azarbayjan, Kermanshah, Hamedan, Chaharmahal and Bakhtiary, Zanjan, Ghazvin, Ardabil	Lowest	8.40	122.13	87.2	61.71	2.53	12.41
				Mean	12.60	320.82	943.18	134.02	50.21	51.69
				Highest	17.31	722	1696.15	496.83	147.27	138.24
				SD	1.92	96.51	322.80	50.82	26.46	17.41

[a] Source: The author, using data from the Office of Agronomy; Ministry of Jihad-e-Agriculture.

SEM, SAC and GSPRE models as well as two fixed and random effects for each model for all three climates have been estimated. The results of estimation of models for the 3 climates are as follows:

Warm Climate

In this climate, the input of seed, phosphate, and urea fertilizers, the average temperature in October, December, and January, and total precipitation in November and December were significant in the estimated models. In fact, they are the effective variables of the model. The results of model estimation are shown in Table 2.

According to Table 3, the Hausman test shows that in the SDM and SEM models, the random effects model is superior to the fix effects model, and in the SAR model, the fix effects model is superior to random effects. Since in two models, the random effects mode is superior to the fixed effects model, the random effects mode is more appropriate. Also, the results of *LR* test to select the more appropriate model are shown in Table 3. Based on the Husman test, there are two modes for *LR* test, so, comparison could be made between the random SAR and random SDM models as well as between the random SEM and random GSPRE models. In fact, the fixed SAC model is removed, because the random effects model is superior. Based on the results in one mode the random SAR model and in the other mode, the random SEM model is selected. Thus, the random SAR model is rejected, and as the result, the random SEM model is firmly accepted and has been selected as the more appropriate one. In fact, the "random SEM model", compared to other spatial models, better explains the impact of climate variables and the spatial correlation coefficient among the error terms in warm climate.

According to Table 2, based on the SEM random model, the constant is 229.56 which is

Table 2. Estimation of panel spatial models for dry farming wheat in warm climates.[a]

Variable	SDM		SAR		SEM		SAC	GSPRE
	Random effects	Fixed effects	Random effects	Fix effects	Random effects	Fixed effects	Fixed effects	Random effects
Constant	411.11		346.36		229.56			455.08
	(0.96)		(0.74)		(0.49)			(0.80)
Seed	0.50*	0.50*	0.37	0.37	0.49*	0.47*	0.47*	0.48*
	(1.69)	(1.73)	(1.25)	(1.28)	(1.65)	(1.65)	(1.65)	(1.63)
Urea fertilizer	1.20*	1.22**	1.18*	1.12*	1.29**	1.24**	1.24**	1.28**
	(1.92)	(2.00)	(1.86)	(1.81)	(2.07)	(2.03)	(2.03)	(2.04)
Phosphate fertilizer	-2.35***	-2.40***	-2.32***	-2.30***	-2.58***	-2.55***	-2.55***	-2.56***
	(-3.01)	(-3.14)	(-2.90)	(-2.94)	(-3.24)	(-3.28)	(-3.28)	(-3.21)
Average temperature in October	84.42***	85.27***	51.66***	56.27***	66.51***	71.27***	70.64***	67.86***
	(4.05)	(4.10)	(2.79)	(3.11)	(3.28)	(3.59)	(3.48)	(3.30)
Average temperature in December	-52.63***	-51.83***	-35.74**	-32.65**	-45.55***	-42.61***	-42.13**	-45.65***
	(-2.62)	(-2.60)	(-2.36)	(-2.20)	(-2.60)	(-2.47)	(-2.41)	(-2.59)
Average temperature in January	-45.06**	-44.88**	-35.99**	-34.40**	-41.87**	-40.45**	-40.26**	-42.58**
	(-2.22)	(-2.18)	(-2.24)	(-2.19)	(-2.30)	(-2.26)	(-2.25)	(-2.36)
Precipitation in November	1.10*	1.06*	1.00*	1.01**	1.01*	1.05*	1.04*	1.03*
	(1.90)	(1.85)	(1.95)	(2.01)	(1.80)	(1.91)	(1.90)	(1.83)
Precipitation in December	1.24***	1.23***	1.14***	1.15***	1.16***	1.21***	1.21***	1.19***
	(2.88)	(2.88)	(2.83)	(2.93)	(2.76)	(2.94)	(2.94)	(2.80)
Seed *W	-0.44*	-0.45*						
	(-1.65)	(-1.69)						
Urea fertilizer *W	-1.05	-1.03						
	(-1.24)	(-1.21)						
Phosphate fertilizer	1.64**	1.64**						
	(2.14)	(2.17)						
Average temperature in October *W	-35.98***	-36.02**						
	(-3.37)	(-2.11)						
Average temperature in December *W	21.80*	21.16*						
	(1.80)	(1.72)						
Average temperature in January *W	19.44	19.12						
	(1.49)	(1.47)						
Precipitation in November *W	-0.04	-0.04						
	(-0.14)	(-0.13)						
Precipitation in December *W	-0.02	-0.03						
	(-0.10)	(-0.14)						
ρ	0.0993*	0.1035*	0.0747	0.0913*			0.0101	
	(1.76)	(1.85)	(1.45)	(1.83)			(0.14)	
λ					0.1453***	0.1462***	0.1404**	0.1457***
					(2.74)	(2.83)	(2.12)	(2.75)
ϕ								0.6869*
								(1.88)
Ln	-937.54	-922.04	-945.26	-928.22	-943.15	-926.48	-926.47	-942.15

a *, **, and *** denote significance at 10%, 5%, and 1% levels respectively. The numbers in the ( ) are the *t*–statistics. Source: Research findings.

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Table 3. Results of selection model tests for dry farming wheat in warm climate.[a]

	Hypothesis H_0 (Restricted model)	Hypothesis H_1 (Unrestricted model)	Value of the test statistic (P-value)	
Hausman test (To select the random effects and the fixed effects model)	SDM Random	SDM Fix	*H*= 1.74 (1.000)	SDM Random
	SAR Random	SAR Fix	*H*= 3.25 (0.000)	SAR Fix
	SEM Random	SEM Fix	*H*= 9.40 (0.949)	SEM Random
LR test (For nested models)	SAR Random	SDM Random	*LR*= 15.44 (0.975)	SAR Random
	SEM Random	GSPRE Random	*LR*= 2 (0.991)	SEM Random

[a] Source: Own calculation.

not significant even at the probability level of ten percent. The coefficient of seed is 0.49, which means for an increase of one kg seed per hectare, the rainfed wheat yield increases 0.49 kg per hectare. So, by increasing the amount of seed, the wheat yield can be increased. The coefficient of urea fertilizer is 1.29, which means that for an increase of one kg urea per hectare, the dry farming wheat yield increases 1.29 kg per hectare. Therefore, by increasing the amount of urea, the wheat yield can be increased. The coefficient of phosphate is -2.58, which means that for an increase of one kg phosphate per hectare, the dry farming wheat yield decreases 2.58 kg per hectare. This reduction may be the result of excessive consumption of phosphate fertilizer which in turn leads to disturbance in the plant and eventually decreases yield. The coefficient of average temperature in October is 66.51, which means that for one degree increase in temperature, the crop yield increases 66.51 kg per hectare. This increase can be the result of the fact that October is cultivation month; therefore, sufficient heat to provide the cultivation condition is required that leads to yield increase. The coefficient of average temperature in December and January are -45.55 and -41.87, respectively, which means that for an increase of one degree temperature, the dry farming wheat yield decreases 45.55 and 41.87 kg per hectare, respectively. As dry farming wheat requires hibernation and a cold period in its growing time and since December and January are the hibernation months, any increase in temperature leads to disturbance in the growth stages and thereby causes yield decrease. The coefficients of total precipitation in November and December are 1.01 and 1.16, respectively, which means that for an increase of one-millimeter rainfall, the dry farming wheat yield increases 1.01 and 1.16 kg per hectare, respectively. Because November and December are considered as the months of crop initial growth, it requires sufficient irrigation, therefore, increase in rainfall causes increase in yield. The spatial correlation coefficient among the error terms is 0.1453, which is significant at one percent level. Thus, while measuring effect of factors such as temperature and precipitation on crop yield, to avoid the variance heterogeneity, considering the position and contiguity of the given place in the model is needed. Significance of this coefficient means spatial correlation significance in relation to yield, which is based on the geographical location. Regarding the coefficients and their impacts on the yield, lack of sufficient heat during planting time (October), overheating during initial growth months (December and January), lack of sufficient precipitation during initial growth months (November and December), and lack of seed, and urea fertilizers, as well as overusing phosphate fertilizer are the systematic risk factors for dry farming wheat in warm climate.

Moderate Climate

In this climate, the input of seed, phosphate and urea fertilizers, the average temperature in October and July, and total precipitation in October have all been significant in the models. The results of the model estimation are shown in Table 4.

According to Table 5, the Hausman test shows the superiority of the fixed effects model to the

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Table 4. Estimation of panel spatial models for dry farming wheat in moderate climates.

Variable	SDM		SAR		SEM		SAC	GSPRE
	Random effects	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Fixed effects	Random effects
Constant	-679.05		-537.39		-516.30			-282.87
	(0.96)		(-0.92)		(-0.78)			(-0.44)
Seed	-1.38**	-1.32**	-1.24**	-1.25**	-1.33**	-1.32**	-0.98**	-1.41***
	(-2.46)	(-2.41)	(-2.41)	(-2.46)	(-2.46)	(-2.49)	(-2.30)	(-2.64)
Urea fertilizer	4.33***	4.21***	4.59***	4.33***	4.88***	4.61***	3.39***	4.88***
	(3.54)	(3.58)	(4.23)	(4.07)	(4.30)	(4.16)	(3.64)	(4.31)
Phosphate fertilizer	-2.98**	-2.99**	-3.51***	-3.46***	-3.71***	-3.70***	-2.73***	-3.58***
	(-2.24)	(-2.34)	(-2.89)	(-2.90)	(-2.91)	(-2.97)	(-2.67)	(-2.83)
Average temperature in October	31.99	28.52	25.53*	26.01*	30.05*	30.14*	19.19*	34.80**
	(1.44)	(1.31)	(1.67)	(1.72)	(1.82)	(1.84)	(1.68)	(2.21)
Average temperature in July	25.18	-0.65	33.68*	42.37**	35.48	46.27**	37.98**	25.69
	(1.09)	(-0.03)	(1.62)	(1.62)	(1.53)	(1.99)	(2.25)	(1.11)
Precipitation in October	1.41***	1.40***	1.49***	1.42***	1.50***	1.42***	1.34***	1.78***
	(2.79)	(2.83)	(3.00)	(2.82)	(2.93)	(2.75)	(3.02)	(3.66)
Seed *W	0.11	0.10						
	(0.35)	(0.32)						
Urea fertilizer *W	0.34	0.16						
	(0.50)	(0.25)						
Phosphate fertilizer	-0.64	-0.15						
	(-0.91)	(-0.22)						
Average temperature in October *W	-3.04	2.25						
	(-0.30)	(0.23)						
Average temperature in July *W	7.11	39.97***						
	(0.93)	(3.02)						
Precipitation in October *W	0.35	0.43						
	(1.11)	(1.38)						
ρ	0.0395	0.0189	0.0670**	0.0684**			0.1659***	
	(1.16)	(0.55)	(2.33)	(2.33)			(4.65)	
λ					0.0512	0.0456	-0.1598***	0.0536
					(1.34)	(1.21)	(-2.99)	(1.41)
ϕ								-0.6517***
								(-6.20)
Ln	-1398.52	-1370.76	-1400.68	-1377.66	-1402.43	-1379.55	-1374.71	-1401.46

a *, **, and *** denote significance at 10%, 5%, and 1% level. The numbers in the () are the *t*–statistic. Source: Study findings.

Table 5. Results of model selection tests for dryland wheat in moderate climate.[a]

	Hypothesis H_0 (Restricted model)	Hypothesis H_1 (Unrestricted model)	Value of the test statistic (P-value)	The test result
Hausman test (To select the random effects and the fixed effects model)	SDM Random	SDM Fix	*H*=34.61 (0.991)	SDM fix
	SAR Random	SAR Fix	*H*= 29.19 (0.000)	SAR Fix
	SEM Random	SEM Fix	*H*= 37.57 (0.000)	SEM Fix
*L*R test (For nested models)	SAR Fix	SDM Fix	*LR*=13.8 (0.001)	SDM Fix
	SEM Fix	SAC Fix	*LR*= 9.68(0.001)	SAC Fix
	SAR Fix	SAC Fix	*LR*= 5.9 (0.005)	SAC Fix
	SEM Random	GSPRE Random	*LR*= 1.94 (0.970)	SEM Random

[a] Source: Research findings.

random effects model in SDM, SAR, and SEM models. Based on the results of *LR* test, that are shown in Table 5, the SAC model was selected as appropriate model. Based on the results, SAC model in two states, and SDM model in one state were fixed and in one case random SEM has been selected. Thus, since the SAC model is superior in the two modes, it is more likely to be accepted and as a result has been selected as the more appropriate model. In fact, the "fixed SAC model", compared to other spatial models, better explains the impact of climate variables and the spatial correlation coefficient among the error and the spatial correlation in dry farming wheat producing provinces in moderate climate.

According to Table 4, based on the SAC fix model, the coefficient of seed is -0.98, which means that for an increase of one kg seed per hectare, the dry farming wheat yield decreases 0.98 kg per hectare. This reduction may be the result of this fact that more use of seed leads to ignoring them quality and eventually yield decrease. Moreover, maybe it means that use of seed more than a specific level ("reference level") would decrease yield. The coefficient of urea fertilizer is 3.39, which means that for an increase of one kg fertilizer urea per hectare, the dry farming wheat yield increases 3.39 kg per hectare. So, by increasing the amount of urea fertilizer the wheat yield can be increased. The coefficient of phosphate fertilizer is -2.73, which means that for an increase of one kg fertilizer phosphate per hectare, the dry farming wheat yield decreases by 2.73 kg per hectare. This reduction may be the result of excessive consumption of phosphate fertilizer which in turn leads to disturbance in the plant and eventually decreases yield. The coefficient of average temperature in October is 19.19, which means that for one degree increase in temperature, the crop yield increases 19.19 kg per hectare. This increase can be the result of the fact that October is cultivation month; therefore, sufficient heat to provide the cultivation condition is required that leads to yield increase. The coefficient of average temperature in July is 37.98, which means that for one degree increase in temperature, the crop yield increases 37.98 kg per hectare. Dry farming wheat requires the warm and dry weather at harvest time and since July is the last month of harvesting, the temperature rise causes the yield increase. The coefficient of total precipitation in October is 1.34, which means that for an increase of one millimeter rainfall, the crop yield increases 1.34 kg per hectare. Because October is one of the initial months of crop growth, it requires sufficient water to provide the cultivation condition; therefore, increase in rainfall causes yield increase. The spatial correlation coefficient among error terms is -0.1598 which is significant at the level of 1%. The spatial correlation coefficient among the provinces producing dry farming wheat is 0.1659, which is significant at the level of 1%. Thus, while measuring effective factors on crop yield such as temperature and precipitation, to avoid the variance heterogeneity, considering the position and contiguity of given place in the model is needed. Significance of this coefficient means spatial correlation significance in relation to yield, which is based on the geographical location. Regarding the coefficients and their impacts on the yield, lack of sufficient heat during cultivation time (October), insufficient heat in late harvest time (July), lack of sufficient precipitation at harvest time (October), and lack of urea fertilizer, as well as overusing phosphate fertilizer and seed are the systematic risk factors for dry farming wheat in moderate climate.

Cold Climate

In this climate, the input of seed and urea fertilizer, the average temperature in March, and total precipitation in October and December were significant in the estimated models. In fact, these variables were effective in the model. The results of estimation of the models are shown in Table 6.

According to Table 7, the Hausman test shows that in SDM, SAR, and SEM models, the fixed effects model is superior to random effects model. Based on the results of *LR* test, SAR model in two states, and SEM model in one state were fixed and in one case random SEM was selected. Thus, as fixed SAR model is superior in two modes and, based on Hausman test, random SEM model will be rejected, the fixed SAR is more likely to be accepted. Indeed, based on the results, the fixed SAR was selected as the more appropriate model. In fact, the "fixed SAR model", compared to other spatial models, better

Table 6. Estimation of panel spatial models for dry farming wheat in cold climate.[a]

Variable	SDM		SAR		SEM		SAC	GSPRE
	Random effects	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Fixed effects	Random effects
Constant	605.84***		467.95***		748.71***			888.88***
	(5.13)		(3.10)		(6.56)			(5.65)
Seed	-1.87***	-2.14***	-2.10***	-2.15***	-1.81***	-2.05***	-2.21***	-1.77***
	(-4.04)	(-4.96)	(-4.83)	(-5.11)	(-4.04)	(-4.76)	(-5.01)	(-3.49)
Phosphate fertilizer	3.85***	3.94***	3.62***	3.71***	3.77***	3.95***	3.95***	3.69***
	(3.29)	(3.49)	(3.09)	(3.26)	(3.35)	(3.57)	(3.41)	(3.29)
Average temperature in March	36.04***	26.34**	13.97**	13.27**	22.50**	26.82**	20.35**	22.17**
	(3.03)	(3.03)	(2.20)	(2.16)	(2.04)	(2.47)	(2.06)	(2.01)
Precipitation in October	1.98**	1.71**	1.86***	1.80***	2.01**	1.86**	1.97***	2.11**
	(2.27)	(2.06)	(2.77)	(2.76)	(2.40)	(2.28)	(2.56)	(2.51)
Precipitation in December	2.11***	1.81***	1.31**	1.26**	1.85***	1.74***	1.59***	1.87***
	(3.40)	(3.06)	(2.51)	(2.49)	(3.10)	(2.97)	(2.68)	(3.13)
Seed *W	-0.06	0.08						
	(-0.26)	(0.35)						
Phosphate fertilizer *W	-0.97	-0.72						
	(-1.39)	(-1.06)						
Average temperature in March *W	-9.03**	-5.32						
	(-2.14)	(-1.18)						
Precipitation in October * W	-0.19	-0.06						
	(-0.51)	(-0.18)						
Precipitation in December * W	-0.78**	-0.54*						
	(-2.49)	(-1.82)						
ρ	0.1783***	0.1935***	0.1814***	0.1912***			0.1246**	
	(9.56)	(11.00)	(10.14)	(11.39)			(2.07)	
λ					0.2043***	0.2032***	0.1150*	0.2042***
					(12.13)	(12.20)	(1.71)	(12.10)
ϕ								0.2365***
								(3.16)
Ln	-1347.80	-1327.32	-1355.19	-1330.40	-1348.35	-1330.26	-1328.83	-1347.36

[a] *, **, and *** denote significance at 10%, 5%, and 1% level. The numbers in the () are the *t*–statistic. Source: Study findings.

Table 7. Results of selection model tests for dryland wheat in cold climate.[a]

	Hypothesis H_0 (restricted model)	Hypothesis H_1 (unrestricted model)	Value of the test statistic (P-value)	The test result
Hausman test (To select the random effects and the fixed effects model)	SDM Random	SDM Fix	*H*= 43.11 (0.018)	SDM Fix
	SAR Random	SAR Fix	*H*= 239.61 (0.000)	SAR Fix
	SEM Random	SEM Fix	*H*= 31.10 (0.000)	SEM Fix
LR test (For nested models)	SAR Fix	SDM Fix	*LR*= 6.16 (0.975)	SAR Fix
	SEM Fix	SAC Fix	*LR*= 2.86(0.965)	SEM Fix
	SAR Fix	SAC Fix	*LR*= 3.14 (0.985)	SAR Fix
	SEM Random	GSPRE Random	*LR*= 1.98 (0.995)	SEM Random

[a] Source: Research findings.

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explains the impact of climate variables and the spatial correlation coefficient among the provinces that produce dry farming wheat crop in cold climate.

According to Table 6, based on SAR fix model, the coefficient of seed input is negative, which means use of seed more than a specific level ("reference level") would decrease yield. This may be the result of the fact that excessive consumption of seed leads to the high density of cultivation and reduction of crop quality and eventually yield decreases. The coefficient of phosphate fertilizer input is 3.71, which means for an increase of one kg phosphate fertilizer per hectare, the dry farming wheat yield increases 3.71 kg per hectare. So, by increasing the amount of phosphate fertilizer, the wheat yield can be increased. The coefficient of average temperature in March is 13.27, which means that for an of one degree increase temperature, the dry farming wheat yield increases 13.27 kg per hectare. In vegetative growth period, dry farming wheat requires cool climate. As March is one of the vegetative growth months, increase in temperature can better the conditions for growth, thereby the yield will rise. The coefficients of total precipitation in October and December are 1.80 and 1.26, respectively, which means that for an increase of one millimeter rainfall, the dry farming wheat yield increases 1.80 and 1.26 kg per hectare, respectively. Because October and December are regarded as planting and initial growth months of this crop, sufficient water is required, so, increase in rainfall leads to yield increase. The spatial correlation coefficient among the provinces producing dry farming wheat is 0.1912, which is significant at the level of one percent. Thus, while measuring the effect of factors such as temperature and precipitation on crop, to avoid the variance heterogeneity, the position and contiguity of a given place in the model needs to be taken into consideration. Significance of this coefficient means spatial correlation significance in relation to yield, which is based on the geographical location. Regarding the coefficients and their impacts on the yield, lack of sufficient heat in vegetative growth time (March), insufficient precipitation in the planting and initial growth period (October and December), and misuse of seed and phosphate fertilizer inputs are the systematic risk factors for dry farming wheat in cold climate.

The results indicate that there are different types of systematic risk factors in different regions producing dry farming wheat crop. In the warm climate, insufficient heat during cultivation time (October) reduces dry farming wheat production. In fact, drought can be considered as the systematic risk factor. Also, lack of awareness among farmers about the methods of using agricultural inputs, especially seed and phosphate and urea fertilizers, has affected the yields. In the moderate climate, lack of sufficient heat during cultivation time (October), insufficient heat in late harvest time (July), lack of sufficient precipitation at cultivation time (October), are considered as important factors, so that the crop yield can be increased by controlling cultivation time. If the crop is cultivated earlier, the necessary heat for the cultivation will be provided, but the problem is that warm and dry weather at harvest time will not be provided. To solve this problem, the serotinous cultivars can be used in moderate climate. In general, inadequate heat and precipitation during the growing time can be the systematic risk factors. Also, the lack of knowledge among farmers, about using agricultural inputs, especially seed and fertilizers, has negative effects on yield. On the other words, farmers have used urea fertilizer less, and seed and phosphate fertilizer more than "optimum level". The reason is that farmers have limited access to different appropriate fertilizers for rainfed wheat. Also, price differences of fertilizers could be another reason. Then it is necessary, different kinds of fertilizers for rainfed wheat with reasonable prices and easy access provide for farmers. In the cold climate, lack of sufficient heat in vegetative growth time (March), lack of sufficient precipitation in the cultivation and initial growth time (October and December) are of great importance so that the crop yield can be increased by controlling cultivation time. Accordingly, it is necessary the fewer days of vegetative growth period put in the cold wave of March. To solve this problem in cold climate, we can either use early and cold-resistant cultivars or cultivate the crop later. Eventually, the winter coldness, March in particular, and lack of sufficient precipitation in the cultivation time are regarded as systematic risk factors. Also, lack of awareness about the way of using the agricultural inputs, especially seed and phosphate and urea fertilizers, among farmers has affected the yields. In fact, using less phosphate fertilizer and overusing the seed has influenced the yield. To solve this problem, practices similar to the recommendations for the moderate climate are suggested.

In all three studied climates, the temperature in cultivation, vegetative growth, and harvesting periods is of great importance. Therefore, the ideal conditions for dry farming wheat growth are as follows: cool climate in vegetative growth time, moderate climate during the seed formation, and the warm and dry weather during the harvest time. Due to literature, Weather is an important production factor and at the same time one of the greatest sources of risk in agriculture. Also, weather risks are correlated within a region. However, these conditions for the risk-reducing effect of using temperature and precipitation options are theoretically possible by reducing temperature in warm climate and increasing it in moderate and cold climates in different cultivation periods. Hence, it is necessary to determine the type of seed and its cultivation time for each province according to its own geographical map. Proper selection of the seed type and time of cultivation reduce the damage caused by climate change and control the dry farming wheat yield. In fact, we can't reduce temperature in warm climate and increase it in moderate and cold climates, then determination the type of seed and its cultivation time for each province according to its own geographical location might compensate a little the effect of changing weather. Considering that these effective factors are natural factors, no one knows when they occur. The natural factors may become severe one year, or be balanced in another one. Therefore, control of the effect of changing weather is impossible and no one knows when they occur, then, to avoid such a problem, it is necessary that farmers be insured against such incidents. Nevertheless, because of high risk of insurance in such cases, private insurance companies are not motivated enough to do so. Therefore, a strategy in which insurance companies invest in this field without any losses, on the one hand, and the farmers do not face damage resulting from natural events, on the other, should be adopted. Preparation of the climatic map of each province and determining its climatic conditions, we can identify systematic risk factor for each one. Insurers can consider common risk factors in two different climates and insurance can be done for drought in moderate and warm climates. At least, in this case, the insurer can make profits in one of the climates. However, the problem would be that farmers are not willing to pay for drought insurance because they believe it is unreasonable. Instead, the insurers can insure less-risky crops than rainfed wheat against drought in moderate climate. By doing this, the farmers are not only more motivated to insure their products, but also they better trust insurers. It can be used for both warm and cold climate considering the environmental conditions. As providing insurance against climate changes is a high risk-taking action, alternative policies such as agricultural crop subsidization instead of input subsidization is to be considered. Therefore, by lowering insurance costs, insurers would be more motivated to invest, on the one hand, and farmers would be willing to insure their products easily.

CONCLUSIONS

Finally, according to Tables 2, 4, and 6 for the warm, moderate, and cold climates, it can be found that temperature and precipitation in warm and cold climates have more and less impact on dry farming wheat yield, respectively. Also, according to Table 1, the mean yield of wheat in warm, moderate, and cold climates are the same, thus, the three climates do not have a difference in terms of the yield. As can be seen, the warm and cold climate compared to the moderate climate have a higher standard deviation, supporting the theory that the temperature and precipitation in warm and cold climates have, respectively, more and less impact on rainfed wheat yield. Therefore, we can realize that the cultivation of rainfed wheat in the warm climate compared to the moderate and cold regions is at higher risk; and, compared to the warm and moderate climates, it is at lower risk in the cold climate. According to Ricardian model, each climate that is less sensitive to weather changes has a superior value, thus, the cold climate has superior value over warm and moderate climates.

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Therefore, economically speaking, it is better to expand cultivation of the dry farming wheat in cold climate than in the other two climates, since this would lead to lower risks for the insurance companies, thereby causing higher motivation for them. Also, the reliability of dry farming wheat production will increase.

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عوامل ایجاد ریسک سیستماتیک در تولید گندم دیم در ایران از طریق کاربرد رهیافت اقتصادسنجی فضایی

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چکیده

در این پژوهش عوامل ایجاد ریسک سیستماتیک بر محصول گندم دیم در ایران بررسی گردید. با استفاده از مدل ریکاردین و روش اقتصادسنجی فضایی تأثیر تغییرات اقلیمی نظیر دما و بارش و میزان نهاده‌های مصرفی بذر و کود اوره و فسفات در ۳ اقلیم گرم، معتدل و سرد در کشور، بررسی شد. نتایج نشان داد که شدت نوسانات تغییرات اقلیمی در هر سه اقلیم مطالعه شده به اندازه‌ای بوده است که به عنوان عامل‌های ریسک سیستماتیک شناسایی شوند. با توجه به نتایج به دست آمده در اقلیم گرم، کمبود گرمای کافی در فصل کشت (ماه مهر)، دمای زیاد در ماه‌های اولیه رشد (ماه‌های آذر و دی)، کمبود بارش در ماه‌های اولیه رشد (ماه‌های آبان و آذر) و همچنین کمبود بذر و کود اوره و مصرف بیش از حد فسفات و در اقلیم معتدل، کمبود گرما کافی در فصل کشت (ماه مهر)، نبود گرما کافی در اواخر فصل برداشت (ماه تیر)، کمبود بارش در فصل کشت (ماه مهر) و همچنین کمبود کود اوره و مصرف بیش از حد بذر و کود فسفات از عوامل ریسک سیستماتیک به حساب می‌آیند. در اقلیم سرد، نبود گرمای کافی در فصل رشد رویشی (ماه اسفند) و کمبود بارش در فصل کشت و رشد اولیه (ماه‌های مهر و آذر) و همچنین کمبود کود فسفات و استفاده بی‌رویه از بذر عامل تآثیرگذار محسوب می‌شود.

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