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Effect of Agricultural Sustainability on Food Security of Rural Households in Iran

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ABSTRACT

Population growth and loss of environmental capacities for food production have rendered the realization of food security a more complicated task as compared to the previous decades. To cope with this crisis, sustainable agricultural development can play a remarkable role in improving food security. The present study aimed to explore the spatial effects of agricultural sustainability on food security of rural households in 30 provinces of Iran over the period of 2006-2016. For this purpose, first, the overall level of agricultural sustainability using a Composite Sustainable Agriculture Index (I_{CSA}) and weighting indicators were calculated based on Analytic Hierarchy Process (AHP) method. The Aggregate Household Food Security Index (AHFSI) was used to determine the food security of households in rural areas. Also, the effectiveness of agricultural sustainability on food security of rural families, as well as other effective factors, was examined using the mixed Spatial Autoregressive (SAR) model with panel data. Results show that the spatial spillovers of the agricultural sustainability influence food security positively and significantly. In fact, 1% increase in the agricultural sustainability index of a certain province directly improves food security of the same province by 0.043%, while its food security is indirectly enhanced by 0.0131% with 1% increase in the agricultural sustainability index of other provinces. It is imperative for policymakers of the agricultural sector to invest in production infrastructure of different provinces in Iran and focus on enhancing sustainable production as a prerequisite for the establishment of sustainable food security.

Keywords: Analytical Hierarchy Process, Agricultural sustainability index, Mixed Spatial Autoregressive (SAR) model.

INTRODUCTION

Food security is, indeed, the foundation of a developed society and constitutes the main component of health, efficiency, and human learning (Hosseini *et al*., 2017; Fengying *et al*., 2010; Renzaho and Mellor, 2010; Carletto *et al*., 2013). According to the definition by the World Food Summit in 1996, food security means that "*all people, at all times, have physical, economic, and social access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (FAO 1996; Owusu *et al.*, 2011; Hosseini *et al*., 2017). Population growth and rising food requirements of humans have increased the demand for agricultural crops (Spiertz, 2010). Agriculture plays the most important role in ensuring food security. Buildup of agricultural production calls for modern technology; but the green revolution and the growing rate of the use of chemical fertilizers, pesticides, and improved seeds for production enhancement have had destructive impacts on natural resources, e.g. soil erosion, excessive exploitation of groundwater, water contamination by excessive use of chemicals, and environment degradation. Following the environmental impacts of green revolution-based

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agricultural development programs, a new concept, i.e. *sustainability*, was introduced into the terminology of agricultural resource utilization so that, according to FAO, one of the major criteria of sustainable agricultural development is the quantitative and qualitative supply of food for the present and next generations and, at the same time, the supply of agricultural products (Tatlidil *et al*., 2009; Munssing and Shearer, 1995). Here is where agricultural sustainability becomes a prerequisite for food security. In addition to sound management and use of agricultural resources for satisfying the food demand of people, sustainable agriculture improves the quality of the environment and natural resources and tries to safeguard the resources for future generations.

Work of Ozturk (2015), Schindler (2016), Ozturk (2017), Kumar (2003), and Naderi Mahdei *et al*. (2015) are examples of studies on the role and significance of the agricultural sustainability in food security. All these studies have emphasized the positive impacts of agricultural sustainability on the food security such that they have mentioned agricultural sustainability as a prerequisite for alleviating food poverty. With respect to the effect of economic macro variables on food security, we can refer to Salem and Mojaverian (2017), Hosseini *et al*. (2017), Dithmer and Abdulai (2017), Abdullah *et al*. (2017), Applanaidua *et al*. (2014), Faridi and Waddod (2010), Gustafson (2013), and Pyagay (2018). They have explored the effect of such variables as the Gini coefficient, poverty level, population growth, trade openness, economic growth, food price, income, etc. on food security in a time interval with different measurement methods and all have analyzed their positive or negative impacts on food security index.

Most studies have employed time series regression models and panel data to investigate the factors influencing food security. A major drawback of these studies is that the adjacency of the sites and the likelihood of spatial correlation of data are ignored while they may make the regression estimations unreliable. Accordingly, the present study aimed to perform a spatial analysis on the effect of agricultural sustainability and economic variables (the Gini coefficient, population growth, family income, and food price index) on food security of Iranian rural households in 30 provinces over the period of 2006-2016. The analysis aimed to use spatial panel econometrics approach in order to answer the following questions: (i) How much food security of households in a local area (province) is influenced by the food security of adjacent areas (adjacent provinces) and (ii) How much food security of households is influenced by agricultural sustainability and economic factors of their own province and the adjacent provinces.

MATERIALS AND METHODS

In this study, the Aggregate Household Food Security Index (AHFSI) was used to determine the rural households food security status. Then, the overall level of agricultural sustainability was calculated using a Composite Sustainable Agriculture Index (I_{CSA}). Finally, the effect of agricultural sustainability on the food security of the households was estimated using the mixed Spatial Autoregressive model (SAR). In the following sections, each of these steps will be described in detail, respectively.

Aggregate Household Food Security Index

FAO has developed Aggregate Household Food Security Index (AHFSI) as Equation (1) on the basis of Sen's work in 1976 and Bigman's work in 1993.

$$\mathrm{AHFSI}_{it} = 100 - \left[\begin{array}{c} H_{it}\left((G_{it} + (1 - G_{it}) I^{P}{}_{it}\right)) + \\ \frac{1}{2} CV_{it}\left(1 - H_{it}(G_{it} + (1 - G_{it}) I^{P}{}_{it})\right) \end{array} \right] * 100$$

$$H_{it} = \frac{P_{U_{it}}}{P_{T_{it}}}, \quad G_{it} = \frac{C_S - C_{AU}}{C_S \times H}, \quad CV_{it} = \frac{S}{\overline{X}}$$

, , , (i = 1,…, 30 provinces; t = 1, 2,…, 11 years) (1)

Where, H and P_U are the percent and headcount of individuals with less energy intake than standard, respectively, P_T is the total headcount of the Population, G is the intensity of food poverty, C_S is the standard energy or protein, C_{Au} is the average energy or protein intake that is less than standard, CV is the Coefficient of the Variation of energy and protein supply over time, S is the Standard deviation of energy or protein supply over time, $\overline{X}$ is the average energy supply over time, I^P is the Gini coefficient of energy distribution among poor people for which we used the Gini coefficient for expenditure distribution of the families due to unavailability of data for energy intake of individual poor families, N is the total headcount of undernourished people, j is the j^{th} undernourished individual, Y_j is the gross expenses of the j^{th} undernourished individual, and m is the average gross expenses of the undernourished individuals. The AHFSI index varies in the range of 0 and 100%. The value of < 65% shows that the food security is at a critical level, 65-75% refers to low food security, 75-85% implies moderate food security, and 85% is an indication of high food security (Yotopoulos, 1997). Standard energy intake is assumed to be 2,300 calories.

Agricultural Sustainability

Sustainable agriculture is a type of agriculture that is along human benefits, more efficient in the use of resources, and in balance with the environment; that is, sustainable agriculture should be ecologically appropriate, economically justifiable, and socially optimal (Fehér and Beke, 2013). To precisely measure the sustainability of an agricultural system, different aspects that are involved in the sustainability of the system should be integrated to allow a comprehensive calculation of the sustainability. Using the review of the literature and studies already done around the world (Sabiha *et al*. 2016; Liu and Zhang, 2015; Johanna *et al*., 2013; Ranjan and Weng Chan, 2012; José *et al.,* 2010; Sabouhi and Alvanchi, 2008; Sauer and Abdallah, 2007; Xu *et al.,* 2006; Bosetti and Locatelli, 2006; Zhen *et al.,* 2005; Krajnc and Glavi, 2005; Pereau *et al.,* 2017; Abay *et al*., 2004; Manoloadis, 2002; Cornelissen *et al*., 2001), the present study first listed the main indicators of the sustainability of the agricultural sector (amounting to 20 indicators) according to agriculture experts' opinions. To find out the overall level of the agricultural sustainability, the indicators were classified into five categories including economic, social, environmental, technical, and political dimensions (Table 1).

After the indicators of each dimension were specified, the positive or negative impact of each indicator on agricultural sustainability was examined. The main problem with the parameters of Composite Sustainable Agriculture Index (I_{CSA}) is that they may be expressed in different units. Thus, they need to be normalized before they are used. The parameters were normalized by Equations (2) or (3) (with respect to their positive or negative impacts) (Sabiha *et al*., 2016; Liu and Zhang, 2015; Krajnc and Glavi, 2005; Pollesch and Dale, 2016).

$$I^{+}_{N,ijt} = \frac{I^{+}_{A,ij} - I^{+}_{\min,ij}}{I^{+}_{\max,ij} - I^{+}_{\min,ij}} \qquad (2)$$

$$I^{-}_{N,ijt} = 1 - \frac{I^{-}_{A,ij} - I^{-}_{\min,ij}}{I^{-}_{\max,ij} - I^{-}_{\min,ij}} \qquad (3)$$

Where, $I^{+}_{N,ijt}$ is the normalized parameter i with a positive impact on a set of parameters j for year t, and $I^{-}_{N,ijt}$ is the normalized parameter i with a negative impact on a set of parameters j for year t. After the parameters were normalized, they were assigned with a weight showing their importance. We employed Analytical Hierarchy Process (AHP) method to assign the weights, for which a questionnaire was developed and was administered to 15 agriculture experts to express their opinions about the importance of an indicator against the other indicators by assigning a score from 1 to 9 (according to the 9-point table)

Table 1. The framework of dimensions and indicators to evaluate agricultural sustainability, as well as their definition, type, and weight.

Dimension	Weight[a]	Indicator	Indicator definition	Symbol	Parameter Weight[a]
Economic dimension	0.326	The share of agricultural sector in production value added	The production of agricultural sector divided by total gross domestic product (%)	I_{E1}^{+}	0.135
		Per capital product of agricultural sector workforce	Added-value of agricultural sector divided by headcount of agricultural workforce (Thousand IRR)	I_{E2}^{+}	0.266
		Income ratio of rural to urban family	Rural family income divided by urban family income	I_{E3}^{+}	0.065
		Crop yield	Yield of irrigated wheat per ha (kg)	I_{E4}^{+}	0.438
		Coefficient of mechanization	Horsepower per ha (hp ha^{-1})	I_{E5}^{+}	0.065
		Per capita acreage	Ratio of total crop acreage to total population (ha person^{-1})	I_{E6}^{+}	0.032
Social dimension	0.104	Share of employees in agricultural sector	Ratio of agricultural sector workforce to total employed population multiplied by 100	I_{S1}^{+}	0.088
		Rural employment rate	Ratio of employed rural population to active population multiplied by 100	I_{S2}^{+}	0.669
		Literacy level in rural areas	Literacy rate in rural areas (%)	I_{S3}^{+}	0.243
Environmental dimension	0.443	Share of agricultural use from underground water versus total production	The amount of underground water use in agriculture divided to total consumption multiplied by 100	I_{Z1}^{-}	0.321
		Chemical fertilization rate	Fertilizer Sustainability index= Total fertilization rate divided by crop acreage (kg ha^{-1})	I_{Z2}^{-}	0.105
		Agronomical diversity	H formula for agronomical diversity level (the index of Herfindahl, 1959)	I_{Z3}^{+}	0.073
		Efficient irrigation systems	Ratio of pressurized irrigated lands to total lands (%)	I_{Z4}^{+}	0.331
		Land fertility	Ratio of acreage to total arable lands	I_{Z5}^{+}	0.066
		Pesticide consumption rate	Pesticide sustainability index= pesticide consumption rate divided by crop acreage (L ha-1)	I_{Z6}^{-}	0.105
Technical dimension	0.056	Share of rain-fed farming in total arable lands	Ratio of rain-fed farms to total arable lands (%)	I_{T1}^{+}	0.258
		Annual precipitation	Annual precipitation rate (mm)	I_{T2}^{+}	0.637
		Crop acreage	Total annual crop acreage (ha)	I_{T3}^{+}	0.105
Political dimension	0.072	Imports	Value of imported crops (Million IRR)	I_{P1}^{-}	0.50
		Exports	Value of exported crops (Million IRR)	I_{P2}^{+}	0.050

[a] Calculated using the AHP method.

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(Saaty and Vargas, 1987). In AHP process, the elements are compared on a pairwise basis and this pairwise comparison yields an m×m matrix in which the elements of the main diagonal are 1. The other elements take values within a certain interval, showing their relative superiority against one another such that when we have $a_{ij} = k$, the opposite element is $a_{ji} = 1/k, (i, j = 1,2,3,\ldots,n)$, assuming that parameter i is preferred to parameter j. The final step is to normalize and find out the relative weights in the matrices. The weight of the parameters is determined by eigenvector method. One major advantage of AHP is the measurement and control of decision consistency. In other words, this process always allows calculating the consistency of a decision and judging its goodness/badness and/or its acceptability/unacceptability. Overall, Saaty (1990) suggests that if Consistency Ratio (CR) is greater than 0.1, the decision-maker is better to make re-judgments by pairwise comparison as long as CR falls below 0.1.

Each dimension was calculated by Equation (4).

$$I_{S.ji} = \sum_{jit}^{n} w_{ij}.I^{+}_{Nijt} + \sum_{jit}^{n} w_{ij}.I^{-}_{Nijt}$$

$$\sum_{ij}^{n} w_{ij} = 1, \quad w_{ij} \geq 0 \tag{4}$$

Whre, $I_{S.jt}$ represents each dimension of the agricultural sustainability index (j= 1 economic, j= 2 Social, j= 3 Environmental, j= 4 Technical, and j= 5 Political) in time t (year), and w_{ij} denotes the weight of parameter I for each parameter of sustainability dimension j, implying the importance of the parameter in the assessment of the agricultural sustainability.

Finally, the social, environmental, economic, technical, and political dimensions are integrated to show the composite sustainable agriculture index as represented by Equation (5).

$$I_{CSA,t} = \sum_{jt}^{n} w_j.I_{S,jt} \tag{5}$$

Where, w_j is the weight of each dimension of the agricultural sustainability index obtained by AHP process. The numerical value of the index lies within the range of 0-1, in which 1 shows the most sustainable state and 0 shows the most unsustainable state.

Spatial Econometrics Model

In 1988, Anselin presented an econometrics methodology in that spatial economic facts were included for the first time. The difference of spatial econometrics from the conventional econometrics is in the use of data that are spatially dependent on one another. When the sample data have a spatial component, two problems arise– spatial dependence or partial autocorrelation between the observations, and spatial heterogeneity or spatial structure. These two problems are typically ignored by conventional econometrics. The spatial dependence in a set of sample data means that observations in location *i* depend on other observations in location *j*. In other words,

$$Y_{it} = f(Y_{jt}), \quad i = 1,2,3,\ldots,n \quad i \neq j \tag{6}$$

This correlation may exist between different observations and error terms; that is, indicator i can take any value of i= 1,…,n. The data of a sample observed at one point in a location are expected to depend on the observed values in other locations. However, spatial heterogeneity refers to the deviation of the relations between observations at the level of spatial geographical locations. It is assumed that there is a linear relationship between spatial variance heterogeneity as below:

$$Y_{it} = X_{it}\beta_i + \varepsilon_{it} \qquad i = 1,2,3,\ldots,n \tag{7}$$

Where, i represents the observations obtained in space, X_{it} represents $(1 \times k)$ vector of descriptive variables with a set of relevant β_i parameters, Y_{it} shows the dependent variable in observation or location i, and ε_{it} denotes the random error of the relationship (Lesage, 1999).

The models used in spatial econometrics include First-order spatial Autoregressive model (FAR), Mixed Spatial Autoregressive model (SAR), Spatial Error Model (SEM), Spatial Durbin Model (SDM), and General Spatial Autoregressive Model (SAC). The main difference between these models is where spatial weight matrix is placed to solve spatial correlation.

$$y_{it} = \alpha + \rho \sum_{j=1}^{n} w_{ij} y_{jt} + \sum_{k=1}^{k} x_{itk}\beta_k + \sum_{k=1}^{k}\sum_{j=1}^{n} w_{ij} x_{jk}\theta_k + \mu_i + \gamma_t + v_{it} \qquad (8)$$

$$v_{it} = \lambda \sum_{j=1}^{n} m_{ij} v_{it} + \varepsilon_{it} \quad i = 1, \dots, n \quad t = 1, \dots, T$$

Where, y is an n×1 vector of the dependent variables, x represents the n × k matrix that includes descriptive variables, and w is the adjacency matrix that reflects the adjacency relationships of the regions and is shown as 0 or 1. If a province has a borderline with another province, this variable takes the value 1; otherwise, it takes the value 0 in the adjacency matrix. Finally, ρ, λ and θ are the spatial parameters of the model. If θ= 0, the model is of SAC type, if λ= 0, the model is of SDM type, if θ= 0 and λ= 0, the model is of SAR type, and if ρ= 0 and θ= 0, the model is of SEM type (Sun and Malikov, 2018; Belotti et al., 2013). To explore the effect of agricultural sustainability on food security of rural households, the present study used spatial econometrics method with panel data given the adjacency of the regions. The research model was estimated based on the Mixed Spatial Autoregressive model (SAR) with maximum likelihood method (according to the results in Table 2). In this model, the dependent variable y is influenced by the values of the dependent variable in adjacent areas. The model can be expressed as below:

$$Y_{it} = \rho \sum_{j=1}^{n} W_{it} y_{it} + \sum_{K=1}^{K} \beta_K x_{ki} + \varepsilon_{it} = \rho WY + X\beta + \varepsilon_{it} \quad \varepsilon_{it} \sim N(0, \sigma^2 I_n) \qquad (9)$$

Where, y is an n×1 vector of dependent variables, x is an n×k matrix of descriptive variables, and ρ, W_{it}, and ε_{it} are spatial lag coefficient, standardized weight matrix, and error term, respectively. The research model can be expressed as

$$AHFSI_{it} = f\left(I_{CSA_{it}}, POP_{it}, GINI_{it}, PIN_{it}, FPI_{it}\right)$$
$$i = 1,2, \dots, 30 \quad t = 1, \dots 11 \quad (10)$$

$$logAHFSI_{it} = \alpha + \rho W logAHFSI_{it} + \beta_1 logI_{CSA_{it}} + \beta_2 logPOP_{it} + \beta_3 logGINI_{it} + \beta_4 logPIN_{it} + \beta_5 logFPI_{it} + \varepsilon_{it} \quad \varepsilon_{it} \sim N(0, \sigma^2 I_n) \qquad (11)$$

Where, AHFSI denotes food security index, I_{CSA} represents the Composite Sustainable Agriculture Index, POP represents Population growth, PIN is the annual Income of the families, FPI denotes Food Price Index, and GINI is the Gini coefficient regarded as the indicator of income distribution across rural areas of different provinces in Iran.

Test of Spatial Effec

Before the spatial econometric model can be estimated, the spatial correlation should be checked. This was done by Moran's test with the null hypothesis of the lack of spatial correlation. Moran's statistic is the most commonly applied test to diagnose the spatial dependence in error terms of regression models and can be calculated by Equation (12) (Lee and Wong 2001):

$$I = \frac{n}{s_0} \; \frac{e' W e}{e' e} \qquad (12)$$

Where, W is the adjacency matrix, n is the number of rows in the adjacency matrix, S_0 is the sum of the elements of matrix W, and e is the vector of residual terms of the regression equation. If Moran's I statistic confirms the presence of spatial autocorrelation, then the standard regression results estimated with OLS will render unreliable and the spatial autocorrelation should be included in the model. The lack of spatial correlation in error terms and the lack of spatial dependence in the observations of the dependent variables are diagnosed by Lagrange Multiplier Error (LM Error) and Lagrange Multiplier Lag (LM Lag), respectively. If the null hypothesis of the lack of spatial correlation among error terms is refuted, Spatial Error Model (SEM) is employed, and if the null hypothesis of the lack of spatial dependence among the

Table 2. Results of estimation of Spatial lag model (SAR) with random-effects method.

Variable	Coefficient	P-value[a]	Critical t-statistic	Standard deviation
log I_{CSAit}	0.043	0.027	2.22	0.0198
log *GINI*	-0.062	0.012	-2.52	0.0249
log POP_{it}	-0.035	0.008	-2.67	0.0132
log *PIN*	0.073	0.000	4.31	0.0169
log *FPI*	-0.053	0.006	-2.74	0.0193
Constant (α)	1.082	0.000	9.71	0.111
Spatial lag coefficient (ρ)	0.237	0.000	3.63	0.0653
Moran I-statistic	7.78	0.000	-	-
LM error	55.12	0.000	-	-
LM lag	58.46	0.000	-	-
LMerror_Robust	1.38	0.240	-	-
LMlag_Robust	4.72	0.030	-	-
Wald test spatial Lag	2.32	0.312	-	-
Hausman	3.82	0.80	-	-
R^2	0.60	-	-	-
Log-likelihood	532.53	-	-	-

[a] Significance at P< 0.05, Source: Research findings.

observations of the dependent variables is refuted, the mixed Spatial Autoregressive model (SAR) is used. However, in case both null hypotheses are refuted, LMLag_Robust test is used for SAR and LMError_Robust test is used for SEM. In addition, the Hausman test is applied to select fixed effects model or random effects model. The null hypothesis of the Hausman test of random effects model is opposite to that of the fixed effects model (Elhorst 2014; Baltagi et al., 2007), whose results are presented in Section 3.

Data

Data required for 30 provinces of Iran for the period of 2006-2016 were collected from the Statistical Center of Iran, the Central Bank of Iran, the Ministry of Agriculture Jihad, the website of the Iran Meteorological Organization, the Iran Water Resources Management Company, and the Customs Administration. The weights were assigned to the dimensions and selected indicators of agricultural sustainability by the Expert Choice 11 software, and all calculations of the composite index of agricultural sustainability were performed in the MS-Excel software. The steps of spatial econometrics were done in the Stata 14 software package.

RESULTS AND DISCUSSION

Food Security Index

Food security index for rural of households in Iran was 85.12 in 2006, showing moderate security (Table 3). But, it reached 88.78 in 2016, implying improvement in food security.

Figure 1 shows the trend of average food security index for rural households over the studied period. According to Figure 1, overall food security index for rural of households has declined in 2008-2012, which means that rural poverty has been worsened in these years. The reasons can be sought in the lack of adequate employment, low income, the re-imposition of economic sanctions against Iran, the reduction of crop imports, and aggravation of drought in 2008 – the negative trend of the technical indicator in agricultural sustainability index confirms this finding. These reasons are strong evidence for the decrease in domestic crop production and the resulting loss of food security in these years. The purchasing

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Table 3. Results the Aggregate Household rural Food Security Index (AHFSI) in Iran and province.

Province	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
East Azar	87.22	88.94	91.06	89.13	88.17	87.13	88.87	90.83	89.64	90.23	91.4	89.32
Weat Azar	86.62	87.83	89.97	89.37	87.67	87.32	87.67	87.2	88.04	89.55	89.05	88.20
Ardebil	86.51	87.05	89.27	89.06	88.28	88.06	89.21	89.28	89.65	90.23	90.8	88.85
Esfahan	86.14	87.23	89.24	88.85	87.66	86.85	88.65	89.35	89.67	90.32	90.65	88.60
Ilam	83.14	84.43	85.55	84.48	82.91	80.3	81.33	81.02	82.96	83.32	84.36	83.07
Boushehr	81.55	83.92	86.16	85.02	82.35	82.21	83.33	81.28	80.19	83.97	84.012	83.09
Tehran	87.06	88.88	91.65	89.46	88.31	88.21	89.4	91.52	91.63	91.67	91.75	89.95
Chaharmahal	84.15	86.99	88.35	88.22	87.42	85.,21	87.26	87.41	88.24	87.33	87.65	87.30
South khorasan	81.45	84.42	83.74	83.42	82.56	82.22	82.65	82.25	82.6	82.94	83.65	82.90
Khorasan Razavi	87.15	88.85	90.84	89.45	88.76	87.25	88.75	89.45	90.7	91.02	91.25	89.40
North khorasan	85.01	86.52	87.25	85.54	84.54	83.32	83.75	84.54	84.65	85.65	85.95	85.15
khozestan	86.1	87.78	89.7	87.38	86.83	85.31	86.97	86.56	87.97	87.84	89.55	87.45
zanjan	86.55	87.52	89.72	88.82	87.48	86.34	87.48	88.57	89.11	90.2	90.25	88.36
semnan	85.4	86.53	89.57	87.88	86.05	85.25	87.82	88.5	89.12	90.22	90.36	87.88
Sistan and balochestan	80.25	82.56	85.57	83.18	80.54	76.36	78.42	79.02	84.83	85.76	83.36	82.07
Fars	87.02	89.88	91.74	88.48	87.76	86.87	87.62	89.48	90.05	90.08	91.25	89.11
Gazvin	87	88.26	91.2	90.13	88.23	87.11	89.55	90.51	91.32	91.53	93.25	89.82
Qom	87.54	88.36	90.47	89.47	88.23	88.21	89.04	90.31	89.26	90.02	90.26	89.19
Kordestan	84.64	84.86	85.74	84.57	83.75	82.6	80.74	83.56	84.73	85.93	86.25	84.30
Kerman	86.41	87.23	89.46	88.22	87.5	86.32	87.56	87.22	88.52	89.82	90.56	88.07
Kermanshah	85.35	87.22	89.44	87.19	86.43	86.22	87.45	87.1	88.01	88.06	87.78	87.29
Kohkiloye &boyer	83.55	85.66	86.67	84.2	82.94	80.26	81.48	85.7	84.77	85.45	86.25	84.26
Golestan	86.85	87.46	90.39	88.08	87.82	86.07	87.22	87.32	90.68	90.59	90.65	88.46
Gilan	86.95	88.62	90.48	89.11	88.83	87.67	88.82	89,68	90,16	90,92	90.87	88.91
Lorestan	83.11	84.67	86.76	84.65	83.79	82.56	84.35	83.24	84.81	85.94	85.24	84.46
Mazandaran	87.65	89.77	91.62	89.38	88.21	87.26	88.58	89.93	90.69	90.89	91.02	89.54
Markazi	86.88	88.91	91.91	89.7	87.46	85.1	88.82	89,54	89.77	90.43	90.56	88.95
Hormozgan	81.38	84.54	85.62	83.49	81.48	79.27	79.35	81.25	84.53	85.8	84.75	82.86
Hamedan	87.15	89	91.23	89.55	87.59	86.29	87.43	89.48	90.57	91.09	90.65	8909
Yazd	86.05	88.18	90.41	89.34	88.76	86.52	88.97	88.22	89.55	89.96	90.02	88.72
Iran	85.12	87.06	89.02	87.49	86.27	84.98	86.28	86.78	87.80	88.47	88.78	87.15

Source: Research findings

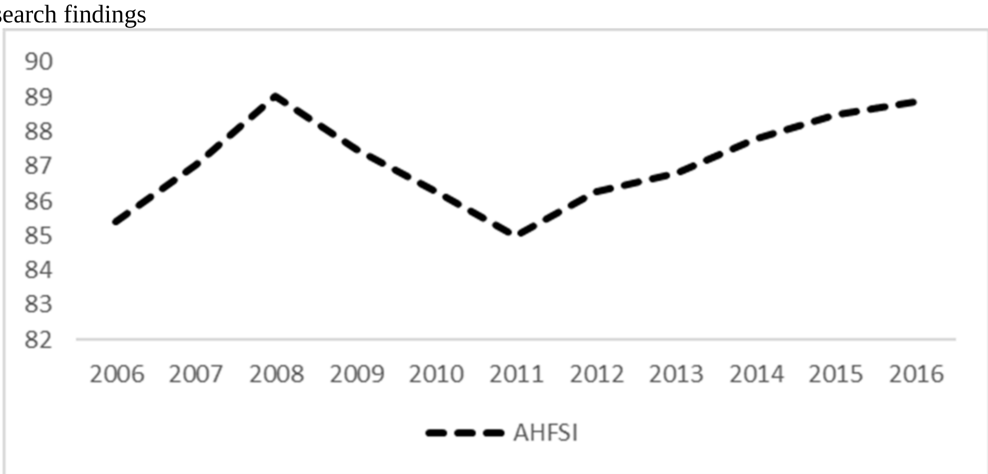

Figure 1. Average food security index of rural households in Iran over the period of 2006-2016.

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Table 4. Results the Composite Sustainable Agriculture Index (I_{CSA}) in Iran and provinces.

Province	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
East Azar	0.508	0.497	0.514	0.561	0.619	0.677	0.686	0.672	0.775	0.747	0.866	0.626
Weat Azar	0.456	0.405	0.408	0.447	0.452	0.533	0.508	0.570	0.578	0.678	0.662	0.518
Ardebil	0.451	0.380	0.479	0.454	0.504	0.563	0.504	0.586	0.588	0.594	0.643	0.522
Esfahan	0.521	0.538	0.516	0.566	0.475	0.483	0.565	0.576	0.606	0.626	0.578	0.550
Ilam	0.446	0.470	0.402	0.527	0.405	0.434	0.486	0.389	0.509	0.616	0.628	0.483
Boushehr	0.384	0.429	0.471	0.495	0.470	0.540	0.518	0.472	0.529	0.533	0.521	0.487
Tehran	0.413	0.454	0.518	0.487	0.609	0.554	0.621	0.594	0.659	0.725	0.740	0.564
Chaharmahal	0.418	0.448	0.415	0.474	0.379	0.435	0.511	0.432	0.504	0.523	0.630	0.470
South khorasan	0.272	0.283	0.327	0.316	0.408	0.426	0.346	0.361	0.445	0.457	0.482	0.375
Khorasan Razavi	0.467	0.537	0.595	0.555	0.615	0.645	0.659	0.702	0.786	0.825	0.865	0.659
North khorasan	0.312	0.343	0.480	0.473	0.490	0.494	0.530	0.564	0.520	0.533	0.599	0.485
khozestan	0.503	0.526	0.467	0.541	0.636	0.566	0.538	0.639	0.604	0.699	0.726	0.586
zanjan	0.367	0.416	0.408	0.503	0.487	0.567	0.523	0.668	0.712	0.609	0.616	0.534
semnan	0.393	0.409	0.456	0.449	0.448	0.419	0.520	0.428	0.520	0.540	0.580	0.469
Sistan and balochestan	0.223	0.246	0.294	0.294	0.460	0.321	0.327	0.402	0.415	0.423	0.430	0.349
Fars	0.487	0.503	0.520	0.679	0.742	0.668	0.714	0.808	0.748	0.772	0.873	0.683
Gazvin	0.415	0.444	0.428	0.481	0.497	0.455	0.474	0.557	0.601	0.668	0.651	0.516
Qom	0.347	0.430	0.434	0.474	0.523	0.493	0.523	0.526	0.526	0.605	0.607	0.499
Kordestan	0.464	0.451	0.410	0.469	0.562	0.469	0.499	0.534	0.509	0.531	0.645	0.504
Kerman	0.441	0.509	0.541	0.490	0.547	0.462	0.598	0.546	0.617	0.737	0.828	0.574
Kermanshah	0.441	0.471	0.484	0.474	0.564	0.589	0.506	0.574	0.447	0.526	0.553	0.512
Kohkiloye &boyer	0.444	0.467	0.487	0.470	0.429	0.545	0.525	0.491	0.449	0.616	0.606	0.503
Golestan	0.403	0.441	0.499	0.508	0.453	0.508	0.537	0.567	0.668	0.649	0.743	0.543
Gilan	0.496	0.432	0.458	0.465	0.518	0.469	0.449	0.557	0.524	0.587	0.637	0.508
Lorestan	0.379	0.400	0.424	0.390	0.450	0.455	0.498	0.491	0.547	0.587	0.614	0.476
Mazandaran	0.500	0.533	0.600	0.512	0.601	0.553	0.542	0.686	0.727	0.708	0.763	0.611
Markazi	0.452	0.475	0.401	0.498	0.437	0.456	0.531	0.464	0.584	0.645	0.749	0.517
Hormozgan	0.338	0.345	0.346	0.401	0.322	0.368	0.389	0.406	0.446	0.494	0.513	0.397
Hamedan	0.448	0.419	0.506	0.554	0.501	0.555	0.578	0.501	0.658	0.690	0.674	0.553
Yazd	0.353	0.413	0.471	0.456	0.514	0.516	0.583	0.562	0.560	0.555	0.588	0.506
Iran	0.418	0.437	0.459	0.482	0.504	0.507	0.526	0.544	0.579	0.617	0.654	0.521

Source: Research findings.

power of households has been improved since 2011 due to the subsidy reforms. The improved purchasing power was directed towards the purchase of food items. Also, the calorie intake self-sufficiency coefficient of the households was improved to 67.5 percent in 2011, which was higher than the previous years. This, in turn, has improved the food security of the households.

Agricultural Sustainability Index

Results for the opposite sustainable agriculture index in Iran show that (Table 4) with the average score of 0.521, this index is at the moderate level of sustainability and it has had an ascending trend from 0.41 to 0.65 over the studied years. Figure 2 illustrates the trend of agricultural sustainability in Iran in terms of social, environmental, economic, technical and political indicators, as well as the composite sustainability index. The positive trend and higher value of economic indicator versus other indicators in Figure 2 can be related to the fact that the five-year development programs of Iran gives a priority to economic goals. In spite of its vital role in sustainability, the environmental indicator is ranked after the economic and social indicators, which can be attributed to its underestimation by the officials of the agricultural sectors. However, this indicator has been improved since 2009 owing to such

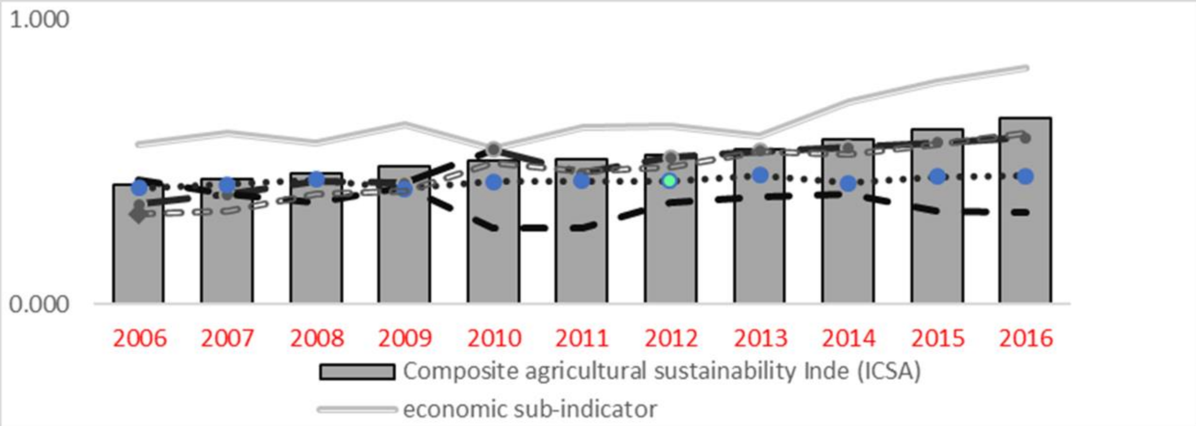

Figure 2. The variations of Composite Agricultural Sustainability Dimensions (I_{CSA}) in Iran over the period of 2006-2016. (Source: Research findings).

measures as the use of modern irrigation systems to curb excessive use of water in agriculture, optimal use of fertilizers and pesticides, and enhancement of local agronomical diversity index. The negative trend of the technical indicator can be associated with the variations in crop acreages and the reduced level of rain-fed farming due to the lower precipitation in recent years. A closer look at the political indicators shows that even when foreign exchange conditions have been in favor of the agricultural sector's production, this indicator has been lowly sustainable.

Cartographic Analysis of Food Security and Agricultural Sustainability

To better display the results, the geographical distribution of food security index and agricultural sustainability in 2006 and 2016 was estimated by GIS software as depicted in Figures 3 and 4. In 2006, the lowest food security and agricultural sustainability were related to the Provinces of Sistan and Baluchestan, South Khorasan, Hormozgan, and Bushehr located at the lowest level. In 2016, these provinces were still in the lowest level of food security and agricultural sustainability in spite of some improvements. In 2006, the highest food security was observed in the Provinces of Tehran, Mazandaran, and Guilan and they retained their food security level over the studied 11-year period. Furthermore, food security was improved in the Provinces of Qazvin, Khorasan Razavi, East Azerbaijan, West Azerbaijan, Markazi, and Fars in 2016, shifting these provinces to the first level of food security. The highest agricultural sustainability level was observed in the Provinces of East Azerbaijan, Khuzestan, Mazandaran, Fars, and Khorasan Razavi in 2006, and this did not change until 2016 except for Khuzestan Province that shifted to a lower level and Kerman Province that shifted to a higher level of sustainability.

The comparison of Figures 3 and 4 lead us to the conclusion that the provinces that are the hubs of agricultural and food production and are at better levels in terms of sustainability enjoy higher food security. Food security is higher in rural areas of the northern, northwestern, and central parts of Iran compared to those of the southern part. This may be associated with more optimal sustainability of agriculture. The southern and southeastern regions of Iran are struggling with lower agricultural sustainability, which can be explained by a look at the different aspects of crop production and consumption management. This lower agricultural sustainability can be attributed to factors such as the non-optimal use of chemical fertilizers and pesticides, the

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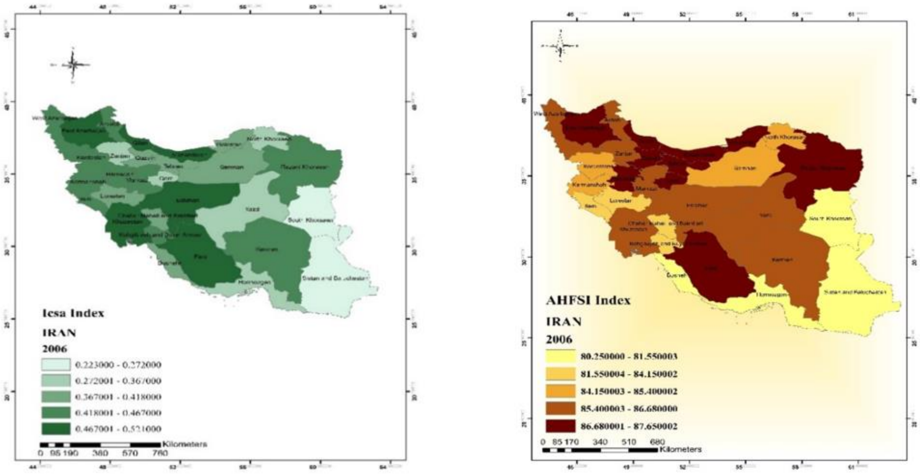

Figure 3. Spatial map of food security and agricultural sustainability in 2006.

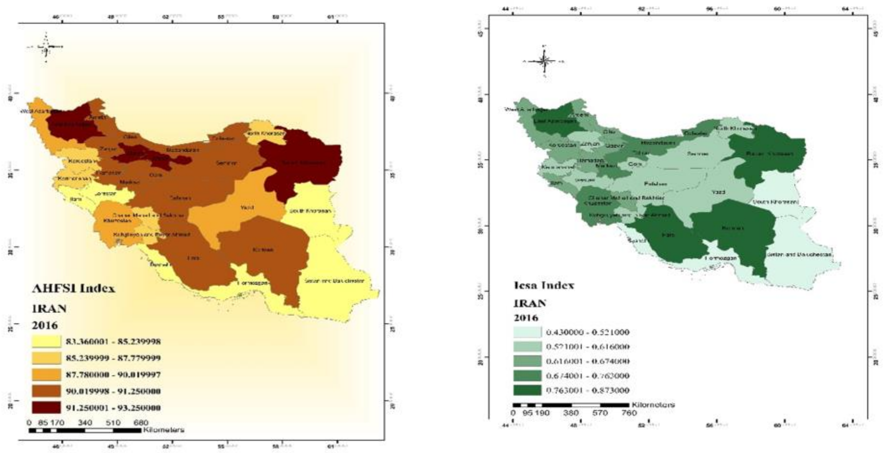

Figure 4. Spatial map of food security and agricultural sustainability in 2016.

loss of soil fertility, lower index of agronomical diversity, lower rural income *vs.* urban income, the loss of water reserves, and inattention to informing farmers about sustainable agriculture. Results of Spatial Panel Econometrics Model.

The spatial panel econometrics model was employed to figure out to what extent food security of rural households in a certain province was influenced by the food security of the neighboring regions (other provinces) and to what extent it was influenced by agricultural sustainability and economic factors of that province and the neighboring provinces. Before the spatial econometrics model is estimated, we need to test the spatial dependence and autocorrelation between the error terms. According to Table 2, Moran's I statistic confirms the presence of spatial autocorrelation and LM Error and LM Lag tests confirm the presence of spatial dependence. Given that LMLag_Robust is significant but LMError_Robust is insignificant, the spatial dependence is of the sort of spatial lag and mixed Spatial Autoregressive model (SAR) should be used to make estimations. Also, the results of the Wald test revealed that the SAR model was more preferred for model fitting. Afterward, we applied the Hausman test to select between fixed or random effects model. The results of this test refuted fixed effects against random effects. Therefore, the research model was estimated as a SAR with a random effects model whose results are presented in Table 2.

Model estimation indicates that spatial autoregressive coefficient (ρ) is positive and statistically significant. In fact, the significance of this coefficient shows the presence of spatial dependence among the observations, and its positiveness shows that food security in adjacent areas influences food security of the local area desirably. This coefficient is estimated to be 0.237, which means that 1% higher food security in adjacent areas results in 0.237% higher food security in the local area.

The composite agricultural sustainability index affects food security of rural households positively and significantly such that, if all other factors are assumed constant, 1% increase in I_{CSAit} would improve food security index by 0.043%. Due to their greater self-subsistence, rural households are affected by crop production in their own province, and crop production fluctuations impact food security of rural households. Thus, enhancement of the agricultural sustainability level via improving economic, social, environmental, technical and political sub-indicators will raise food security index of households.

Also, it is evident from the results about the economic variables affecting food security of rural households that household annual Income (PIN) influences food security index of rural households positively and significantly such that 1% higher PIN results in 0.073% higher food security index. People in rural areas are suffering from low income and lower quality of nutrition, so, the increase in income can improve their purchasing power and their ability to satisfy their food requirements. This, in turn, can be effective in improving their livelihood and food security. We found that Food Price Index (FPI) affects food security index of rural households negatively and significantly such that 1% higher FPI entails 0.053% loss in food security index. The price fluctuations of food items, especially staple commodities, affect consumers' behavior remarkably. The increase in food price, especially when the incomes do not grow proportionately, impairs food availability to households, negatively affecting their food security. The positive effect of household income and the negative impact of price index increase on food security have been supported by Dithmer and Abdulai (2017), Applanaidua *et al*. (2014). The Gini coefficient affects rural food security index negatively and significantly. If the Gini coefficient is increased at 1%, food security index will decrease at 0.062%. Suitable income distribution across the society, especially in rural areas, plays a vital role in purchasing power and people's capability for food supply, and highly unequal income distribution pushes rural areas towards unstable food security. Salem and Majaverian (2017), also, reported the negative impact of the Gini coefficient on food security. The effect of Population growth (POP) was negative and significant on food security index of rural households such that 1% higher POP causes 0.035% loss in food security. As the population grows, individuals in bigger households versus smaller households are exposed to a higher risk of nutrition intake in that the likelihood to receive the minimum energy requirement for everyday activities and to establish food security is decreased. On the other hand, given the lower income level of rural areas compared to urban areas and the lower capability of bigger family heads to satisfy the food requirement of the respective family, this variable is more likely to hurt food security in rural areas than in urban areas. The negative effect of population on food security has been reported by Salem and Mojaverian (2017) and Applanaidua *et al*. (2014), too.

The main application of the Spatial Autoregressive model (SAR) is to examine spatial spillovers that are calculated as the direct and indirect effects of the change in each independent variable on the dependent variable. The results of overall, direct, and indirect effects are shown in Table 5.

It was found that the effect of spatial spillovers of agricultural sustainability is

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Table 5. Results of direct, indirect and overall effects.

Variable	Direct effect			Indirect effect			Overall effect		
	Coefficient	Z-statistic	P-value[a]	Coefficient	Z-statistic	P-value[a]	Coefficient	Z-statistic	P-value[a]
log I_{CSAit}	0.043	2.26	0.024	0.0131	1.86	0.052	0.056	2.18	0.030
log *GINI*	-0.064	-2.70	0.007	-0.0182	-2.17	0.030	-0.082	-2.76	0.006
log POP_{it}	-0.0355	-2.57	0.010	-0.0103	-1.98	0.048	-0.045	-2.57	0.010
log *PIN*	0.075	4.64	0.000	0.0219	2.74	0.006	0.097	4.75	0.000
log *FPI*	-0.054	-2.88	0.004	-0.0157	-2.14	0.033	-0.0701	-2.90	0.004

[a] Significance at P< 0.05, Source: Research findings.

positive and significant on the food security index. Results for intra-provincial spillovers indicate that when agricultural sustainability index of a certain province is increased by 1%, the food security index of that province is directly improved by 0.043%, and intra-provincial spillovers show that 1% variations in agricultural sustainability index in other provinces indirectly changes the food security index of a province by 0.0131%. Finally, if the agricultural sustainability index of all provinces is increased by 1%, the food security index of the province *i* will be increased by 0.056%. Also, the direct and indirect effects of the variables of population growth, the Gini coefficient, food price index, and household annual income were significant on rural households in each province and the adjacent provinces, but it should be noted that the significant effect of income was positive, while it was negative for other variables.

CONCLUSIONS

Overall, the results of spatial effect of agricultural sustainability on food security of rural households in Iran indicated that food security of households in a local area (a province) is influenced by food security of the adjacent areas (other provinces). Additionally, the effect of spatial spillovers of agricultural sustainability is positive and significant on the food security index such that regions enjoying improvement in the agricultural sustainability in a certain period enjoy improvement in the food security too, and the rural households in provinces with higher agricultural sustainability are at a more suitable state of food security. Thus, given the positive effect of agricultural sustainability on food security, it is imperative to first assess the state of agricultural sustainability in a region so as to understand the strengths and weaknesses of different parameters and dimensions of agricultural sustainability. Then, the policymakers of the agricultural sector can make decisions to develop sustainable farming. For example, with investment in seeds production infrastructure (technology incorporation into rain-fed farming and production of high-quality seeds), fertilizers and pesticides (optimal use of chemical fertilizers and pesticides at the farm level), identification of locally-compatible plant species in order to increase agronomical diversity index, optimal management of agricultural water resources, and appropriate farming practices, measures can be taken to increase sustainable production as a prerequisite for the establishment of sustainable food security. Also, given the significant effect of economic variables on food security, it is imperative to adopt supportive policies, like low-interest loans and credits with long repayment period to help rural people started small businesses in order to increase their income. With respect to price supports, the government can improve the efficiency and quality of the crops and encourage more farmers to produce high-quality, healthy, and nutritious crops by applying good price supports such as timely and optimal adoption of guaranteed price policy, timely purchase of

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crops, and purchase price categorization in terms of production quality. Furthermore, agricultural crops should be imported as per a plan only to adjust the market of stable foods at an appropriate time. Eventually, income distribution across rural areas should be amended to allow sustainable supply of food in these regions.

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Dimensions of Sustainability of Farming Practices in the North China Plain Case Study from Ninja County of Shandong Province, PR China. *Agr. Ecos. Env.*, **105**: 507– 522.

تأثیر پایداری کشاورزی بر امنیت غذایی خانوارهای روستایی در ایران

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چکیده

با توجه به رشد جمعیت و کاهش ظرفیت‌های زیست محیطی طبیعت برای تولید مواد غذایی، امروزه دستیابی به امنیت غذایی بسیار دشوارتر از دهه‌های پیش است. برای رفع این بحران، توسعه کشاورزی پایدار در بهبود امنیت غذایی نقش بسزایی خواهد داشت. هدف این مطالعه بررسی اثرات فضایی پایداری کشاورزی بر امنیت غذایی خانوارهای روستایی در ۳۰ استان ایران طی دوره زمانی۲۰۰۶ تا ۲۰۱۶ است. بدین منظور ابتدا سطح کلی پایداری کشاورزی با استفاده از یک شاخص ترکیبی پایدار کشاورزی(I_{CSA}) و وزن‌دهی سنجه‌ها بر اساس روش تحلیل سلسله مراتبی (*AHP*) محاسبه گردید. از شاخص کلی امنیت غذایی خانوار (AHFSI) برای تعیین وضعیت امنیت غذایی خانوارهای روستایی استفاده شد و میزان اثرگذاری پایداری کشاورزی بر امنیت غذایی خانوارهای روستایی در کنار سایر عوامل موثر، با استفاده از مدل خودرگرسیونی فضایی(SAR) با داده‌های پنلی مورد بررسی قرار گرفت. نتایج نشان داد اثرات سرریزهای فضایی پایداری کشاورزی بر شاخص امنیت غذایی مثبت و معنی‌داری است: یک درصد افزایش در شاخص پایداری کشاورزی هر استان، باعث ۰.۰۴۳ درصد افزایش امنیت غذایی در همان استان به طور مستقیم می‌شود و یک درصد افزایش در شاخص پایداری کشاورزی در سایر استان‌ها ، باعث افزایش۰.۰۱۳۱ درصد شاخص امنیت غذایی به طور غیر مستقیم می‌شود. از اینرو، با توجه یه تأثیر مثبت پایداری کشاورزی بر امنیت غذایی لازم است متولیان،بخش کشاورزی با سرمایه‌گذاری بر روی زیرساخت‌های تولید در استان‌های مختلف ایران اقدامات خود را به سمت افزایش تولید پایدار که مقدمه‌ای برای استقرار امنیت غذایی پایدار است، پیش ببرند.

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