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Agriculture, climate change and sustainability in Iran: Application of numerical taxonomy method and Panel-VAR

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ABSTRACT
The purpose of the paper is twofold. Firstly, through the Taxonomic Method, we construct a composite indicator, called the Index of Sustainable (IS), and analyze the provinces of Iran from 2011 to 2018, according to 9 variables. Secondly, the Granger-causality test for panel data is implemented in order to verify the causal relationship among the IS, climate change and agricultural production. In other words, we test which of the three analyzed variables turns out to be the causetive variable and which, instead, turns out to be the effect variable. This analysis provides a wide overview on how the provinces rank according to the IS and its three crucial pillars, i.e. environmental, economic and social. Moreover, important causality relationships among the IS, climate changes (approximated by mean annual temperature and mean annual precipitation) and agricultural production (approximated by wheat and barley production) are identified. The results showed that Khuzestan, Isfahan and Fars provinces have the highest average sustainability index during 2011-2018. Generally, the provinces which are in a better position in terms of agricultural and industrial production, are also in a more favorable position in terms of sustainability than other provinces. The results also showed that there is a significant causal relationship between agricultural productions, climatic variables of temperature, precipitation and stability index among the studied provinces.

Keywords: Sustainability, Agriculture, Climate change; Taxonomic method; Panel VAR.
Article type: Research Article.

INTRODUCTION
Various economic sectors, including agriculture, forestry, water and tourism industry, energy, and even the financial and insurance markets, are affected by climate change (Tol 2002, Hope 2005, Kemfert 2009). But it should be noted that climate is the main determinant of location, sources of production and productivity of agricultural activities. Therefore, due to the greater effectiveness of this part of climate change compared to other sectors, it is expected that the production of agricultural products will be limited (Labell *et al.* 2008). On the other hand, the continuous growth of the population on the planet and the increase of agricultural activities lead to destructive and negative effects such as the phenomenon of climate change. Therefore, it can be stated that this phenomenon is also affected by human activities and there is an interactional relationship between them (Mendelsohn & Dinar 1999). Concerns are growing worldwide about the negative impact of climate change on people's livelihoods in developing countries (Bala *et al.* 2014). Therefore, in order to achieve sustainability, it is necessary to use production resources and tools in different economic sectors in the best possible way (Yaghobi & Sedighi 2016). Global climate change and the over-pressure of human activities on non-renewable natural resources have led to the issue of sustainability being addressed by policymakers. In addition, these changes can make the yield of the agricultural sector vulnerable (Gliesman 2015*;* Nelson *et al.* 2009). The agricultural sector is one of the most important sectors of the economy, which is more affected by climate change than other economic sectors, and agricultural activities are directly affected by climate change. But these effects of climate change on agricultural yield vary between different countries and different crops (Agovino *et al.* 2017).

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Many regions can benefit from these climate-related changes (cold countries with rising temperatures; Stokes & Howden 2010). Other countries may experience great damage in this sector (reduced yield, water stress, and increased variability in yield). Increasing temperatures can have both positive and negative effects on agricultural yield, depending on the situation and location of countries. In addition, increased rainfall may lead to increased soil moisture in hot and dry countries and, in contrast, in countries with high water levels. But the agricultural sector can also help climate change by reducing greenhouse gases and carbon sequestration while maintaining food production. Of course, these effects depend on the type of agricultural activity. In this regard, we can mention sustainable agriculture. Sustainable agriculture is a type of agricultural system that emphasizes long-term yield stability with minimum impact on the environment (Yaghobi & Sedighi 2016). Therefore in order to achieve sustainable agriculture, it is necessary to identify the indicators of sustainable agriculture and make an accurate assessment of the agricultural status in order to assess the sustainability or instability of agriculture according to the principles and criteria of sustainable agriculture. Three issues are very important for sustainability in agriculture. The first issue is adequate income, especially among low-income people. The second issue is the ability to access and consume food. This means that more and accessible food must be produced and made available to the public through increased production and improved marketing. The third issue is the protection and improvement of natural resources. Therefore, sustainable agriculture is a type of agriculture that is in the interests of human beings, is more efficient in using resources and is in balance with the environment. In other words, sustainable agriculture must be ecologically appropriate, economically justifiable, and socially desirable. Therefore, it is generally believed that sustainable agriculture seeks to achieve the three general goals of a healthy agricultural economy, the preservation of rural communities and the preservation of the environment (Porzand & Bakhshodeh 2012). According to what was stated, this study seeks to calculate a composite index of sustainability for different provinces of Iran. This composite index is created by considering economic, social and environmental variables. The hypotheses are tested in the following. These assumptions can be expressed as follows. There is a causal relationship between climate change and the composite sustainability index. Conventional agricultural activity has a negative causal relationship with the composite sustainability index. Climate change is likely to have a negative impact on agricultural activity, and ultimately agricultural activity will have a negative effect on climate change. For this purpose, it will be important to examine the interrelationships between climate change and sustainability and agricultural production. Today, there is a need to quantify many qualitative aspects of sustainability. But sustainability is a concept and cannot be measured directly (Cornelissen *et al.* 2001). Therefore, appropriate indicators should be selected that can determine the amount and durability of sustainability. A review of previous studies shows that several methods have been used to combine indicators to achieve an overall index. These include algebraic and linear summation of indicators (Hayati, 1985), conjunctive analysis (Sydorovych and Wossimk, 2008), comprehensive data analysis (De Koeijer *et al.* 2002; Abay *et al.* 2003; Bosetti & Locatelli; 2006; Sauer & Abdallah2007), estimating the value of resources, money can be a strong intermediary for composition (Mitchell 1996; Rannings & Wiggering 1997) and fuzzy set theory (Cornelissen *et al.* 2001). A review of previous studies shows that in recent years, several studies in the country have evaluated sustainability, including those of Hadipour *et al.* (2019), Dehghan & Falsafian (2018), Akbarian ronizi (2018), Amirzadeh moradabadi *et al.* (2018), Amini & Nouri (2015). The aforementioned studies have used algebraic and linear methods of indicators and comprehensive data analysis in order to combine indicators to achieve a general index in Iran. Numerous studies have been conducted on the factors affecting agricultural sustainability, among which we can mention the study of Manafi mollayosefi *et al.* (2018), Sanaei *et al.* (2018) and Fallah-Alipor *et al.* (2019). In these studies, environmental, economic and social indicators have priority. Also, among the economic sub-criteria, the improvement of productivity and yield, among the social sub-criteria, food production and security, and finally, among the environmental sub-criteria, the protection of water resources have priority. Foreign studies in the area of sustainability include those conducted by Liu & Zhang (2015), Chalise *et al.* (2017), Ochuodho *et al.* (2016), Vista *et al.* (2014), and Dudo & Cakmak (2011). In these studies, the effects of climate change on sectors related to the agricultural sector were analyzed by a computable general equilibrium model. Wasaq & Parafiniuk (2015), Rockstrom *et al.* (2017), Latruffe *et al.* (2016), Dong *et al.* (2015) and Stattman & Mol (2014) also covered subjects such as sustainable agricultural development, indicators and their requirements and they explored how managers can actually apply adaptive strategies in development. Domestic research has paid less attention to various aspects of sustainability (such as economic, social and environmental criteria). Therefore, in this study, an attempt has been made to first calculate the aggregated sustainability index for the provinces of Iran based on economic, social and environmental criteria using numerical taxonomic method. Then, different provinces are ranked on the value of the desired index based on the index calculated during different years.

MATERIALS AND METHODS

Various models have been so far developed to understand the relationship between the three basic principles of sustainable development, the first of which is expressed in three interconnected circles. This model of sustainability is designed to better understand the relationship and connection of humans with the three main environmental, economic, and social elements, as well as to consider the balance between them, and enable researchers to make a dynamic assessment of each of these areas.

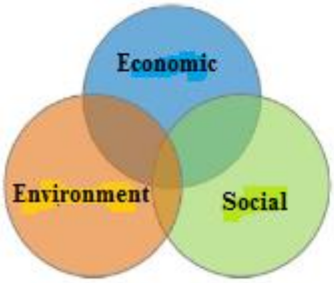


Fig. 1. Sustainable development in the interconnected model

In the second model, social and economic development has been shown as inter-systems and points out that the economy is in the context of society and all sectors of the economy need human relations and they include a wide range of relationships for those who balance goods and services in society. In contrast, society is a place where the basic needs of human beings are met.

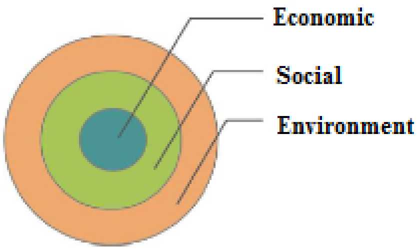


Fig. 2. Sustainable development in a concentric circle model

In a centralized model that defines the environment and the economy within a community, in order to better understand our relationship between the three main areas that consist sustainable development, it expresses their independence and connection in some way and it points to the fact that we, as social and economic beings, are in a physical environment. In contrast, the interconnected model is for our understanding of the nature of each of these areas (Manyong & Degand 1997). So, in this study, each of the indicators was measured by the variables presented in Table 1, which can ultimately achieve the index of sustainable development through taxonomy.In the present study, two variables of GDP and unemployment rate were used to show the economic index. Although GDP does not represent a sufficient condition for sustainability, it is the basis of economic growth. Because this concept has evolved over time. According to the World Commission on Environment and Development (WECD 2007), sustainable development is defined as a development that meets the needs of the present, without being able to meet the needs of future generations and itself. Therefore, it can be said that the concept of sustainable development resolves the conflict between economic growth and environmental protection. Unemployment rate is another representative of the economic index. Employment variables are important indicators of sustainability. In addition to helping prevent the risk of poverty, employment is also a social issue. Because higher incomes improve health and education (Betcherman 2015). Three variables have been proposed in relation to the social index. The first variable is the component of adult participation in learning. Learning can mean practicing, studying or reading. It can also mean training, mentoring or coaching. Therefore, it develops people's skills, knowledge, ability or understanding. Therefore, the issue of education can be considered as one of the main pillars of sustainable development. However, the gender employment gap component seems to be related to the economic index but it should be noted that it is mainly a social issue (Dong *et al.* 2015). Women's participation in the labor market has increased in recent years. But there is still a gap between the participation of men and women. Such that total cost of women's employment in 2013 is estimated at € 370 billion, which is only 2.8% of the EU's gross domestic product. The latest variable in the social index is for young people who are not studying or working. This component points to young people between the ages of 15 and 29, which is one of the most important concerns of policymakers because they can severely jeopardize sustainable economic development. After the elderly, this generation of people is at risk from the labor market and social deprivation.

Table 1. List of variables for each pillar and their sign.

	Code	**Economic Indicators**
Composite Index of Sustainability	Ec_1	GDP (% of total GDP)
	Ec_2	Unemployment Rate (Percentage)
	Ec3	Agricultural Value Added (% of GDP of Province)
		Social Indicators
	So_1	Adult participation in learning (Percentage)
	So_2	Gender employment gap (Percentage)
	So_3	Young people neither in employment nor in education and training by sex (Percentage)
		Environmental Indicators
	En_1	Forest (Percentage)
	En_2	Desertification (Percentage)
	En_3	Areas under environmental protection (Percentage)

Environmental performance is a very important and compound indicator that covers land, climate and sea issues and with that, we can achieve environmental efficiency and protect it. Today, in cities, the existence of environmental pollution such as water pollution, noise pollution, destruction of resources and its unfavorable operation is an example of environmental and environmental instability. Therefore, it should be noted that the capital or resources of that city remain the same or at least constant. In the present study, three components of forest area and desertification and areas under environmental protection represent the performance of the environment. Because the earth is an important natural resource and studying its topics can be considered as the starting point for studying environmental economics.

Taxonomic method for calculating the sustainability index

In order to examine the differences between the provinces in terms of sustainability, it is necessary to rank different regions as a composite index that is a criterion for development. Notably, this comprehensive analysis will be closer to reality. One of the methods of grading areas in terms of development is taxonomic analysis. Taxonomic analysis is used for various categories in the sciences. Its special specie is numerical taxonomy that, according to the definition, numerical evaluation of similarities between taxonomic units and grading those elements are related to taxonomic groups. This method was first proposed by Anderson (1763), and it was proposed in 1968 as a tool for classification and the degree of development between different nations. This method is an excellent method of grading, classifying and comparing different areas according to their degree of development and modernity.

The process of prioritizing provinces based on sustainability using socio-economic indicators is:

Step 1: Using socio-economic indicators such as GDP per capita, a k×n matrix is formed (n is the number of provinces and k is the number of variables) and based on this, the standard matrix is obtained as follows:

$$\bar{y}_{i0} = \frac{\sum_{i=1}^{n} y_{ij}}{n} \quad i = 1,2,...,k \quad j = 1,2,...,n$$

$$s_{i0}^2 = \frac{\sum_{j=1}^{n} (y_{ij}^2 - \bar{y})^2}{n} \qquad \textbf{(1)}$$

$$z_{ij} = \frac{y_{ij} - y_{i0}}{s_{i0}}$$

where, yij is the i-th index for the j-th province, $\bar{y}_{i0}$ is the mean and s_{i0}^2 represents the standard deviation of the indices. z_{ij} denotes the standard matrix elements as follows:

$$z = \begin{vmatrix} z_{11} & z_{12} & \cdots & z_{1k} \\ z_{21} & z_{22} & \cdots & z_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nk} \end{vmatrix} \quad \textbf{(2)}$$

Step 2: In this step, the matrix of distances, each of whose elements (Dab) is the distance of the variables of the two provinces a and b, is calculated as follows:

$$D_{ab} = \sqrt{\sum_{i=1}^{k} (Z_{ai} - Z_{bi})^2} \quad \textbf{(3)}$$

where Zai = Zbi and the main diameter elements are zero.

Step 3: In this step, in each row of the matrix of distances, we select the smallest number and form a matrix whose one column is the provinces and the other column is the smallest distance of the variables of the provinces.

Step 4: Using the step 3 matrix, we obtain the mean and standard deviation of the shortest distance:

$$\bar{d} = \frac{\sum_{j=1}^{n} d_j}{n} \qquad s_d^2 = \frac{\sum_{j=1}^{n} (d_j - \bar{d})^2}{n} \quad \textbf{(4)}$$

To make the confidence interval (-α) is a percentage for the dj variable, the upper bound will be $\bar{d} + 2s_d$ and the lower bound will be $\bar{d} - 2s_d$. Provinces for which the dj value is at a confident interval are classified as homogeneous provinces in a group, and other provinces are eliminated.

Step 5: The province that is significantly different from the others is eliminated and the previous steps are repeated (if the province is not removed from the set, you can go to the next step).

Step 6: The new matrix is rewritten after deleting some provinces and the standardized matrix is obtained from it. In the standard matrix we find the largest value for each column and call it the ideal value or zmax. After finding the ideal value for each component, the value of cj (market attraction) for each province is calculated as follows:

$$c_j = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_{i,\max})^2} \quad \textbf{(5)}$$

The smaller the cj, the higher the market capability. The mean value and standard deviation will be as follows:

$$\bar{c} = \frac{\sum_{j=1}^{n} c_j}{n}$$

$$s_c^2 = \frac{\sum_{j=1}^{n} (c_j - \bar{c})^2}{n} \quad \textbf{(6)}$$

Based on the above values, the optimal limit of the market attraction (*c) is obtained as follows:

$$c^* = \bar{c} + 2s_c \quad \textbf{(7)}$$

Step 7: Finally, the criterion of significance factor according to which the provinces can be prioritized, is obtained from the following relation:

$$F_i = \frac{c_j}{c^*} \quad \textbf{(8)}$$

where, Fi is the criterion for prioritizing provinces in terms of sustainability indicators and cj is an example of sustainability index. This index is between 0 and 1 (Agovino *et al.* 2019). If the sustainability index is closer to zero, the province is with *high performance*, and if it is close to one, the province is with *low performance*.

After establishing the data matrix and standardizing this matrix, to distinguish homogeneous from heterogeneous regions, the distance of the provinces was calculated according to the sum of the indicators. Then a symmetric matrix of distances between provinces was formed and the shortest distance between them was obtained and the distance of homogeneity of provinces was determined. According to the upper and lower limits obtained in the year under review and the column values of the minimum distances, it was determined that Tehran province is above the upper threshold and is heterogeneous compared to other provinces. Therefore, the mentioned province was eliminated and the analysis continued with 30 other provinces. Despite the public perception and contrary to the results of most studies conducted in recent years, Tehran province does not have a suitable position in terms of sustainable development and needs more attention from officials in this field. It should be noted that in many metropolitan areas, excessive migration can lead to issues such as housing, marginalization, unemployment, land use change, noise pollution, water pollution, high traffic and land density. Therefore, considering these issues and problems of heterogeneity and elimination of a province such as Tehran province in terms of socio-economic and economic environmental sustainability, it is completely in line with expectations and it is logical because the existing context no longer meets the needs and expectations of the population. After performing the above steps, a new standard matrix was formed with the elimination of Tehran province and the composite index of the degree of development was calculated.

Vector auto-regression panel (VAR panel) model

According to the study of Abrigo & Love (2015) and Love & Zicchino (2006), the vector auto-regression model (VAR) in the form of data panel has been used to test causal relationships, impulse response functions and variance decompositions between the studied variables. This model is a combination of the conventional vector auto-regression model, where all variables in this system are endogenous, with data panel method. The summary form of econometrics is as follows:

$$X_{it} = \Gamma(L)X_{it} + u_i + \varepsilon_{it} \quad \textbf{(9)}$$

where X_{it} is a vector of the variables under study and $\Gamma(L)$ is a multi-term matrix with a interruption operator in the form of $\Gamma(L) = \Gamma_1(L^1) + \Gamma_2(L^2) + \cdots + \Gamma_P(L^P)$. u_i is a vector of specific (individual) effects of countries and ϵ_{it} is a vector of disruption components (Roodman, 2009).

In dynamic panels, the estimators of constant effects are not compatible due to the correlation between the fixed effects and random effects due to the presence of interruptions of the dependent variable on the right side of the equation. To resolve the problem of orthodontic deviation or data difference, the forward mean data (Helmert process) is used. Thus, by transforming all the variables of the model to a deviation from the forward mean data, the constant effects are eliminated. If the values of the desired series are in the form of $X_{it} = (X_{it}^1, X_{it}^2, ..., X_{it}^M)'$ and the future values of X_{it}^m are part of this vector, the mean of them is obtained as $\bar{x}_{it}^m = \sum_{s=t+1}^{T_i} x_{is}^m / (T_i - t)$ where, T_i is the last period of the available data for the series of countries i and t also represents the time. Orthogonal deviation of disruption components $\bar{\varepsilon}_{it}^m$ is also obtained in the same way. So we have:

$$\tilde{x}_{it}^m = \delta_{it}(x_{it}^m - \bar{x}_{it}^m) \quad \textbf{(10)}$$

$$\tilde{\varepsilon}_{it}^m = \delta_{it}(\varepsilon_{it}^m - \bar{\varepsilon}_{it}^m) \quad \textbf{(11)}$$

where $\delta_{it} = \sqrt{(T_i - t)/T_i - t + 1)}$. It should be noted that for the latest data available, this transform is incalculable, because the value of the next data is not available to obtain the forward mean. The transformed form of Equation (3) is in the following form:

$$\tilde{X}_{it} = \Gamma(L)\tilde{X}_{it} + \tilde{\varepsilon}_{it} \quad \textbf{(12)}$$

where:

$$\tilde{X}_{it} = (\tilde{x}^1_{it}, \tilde{x}^2_{it}, ..., \tilde{x}^M_{it})'$$

$$\tilde{\varepsilon}_{it} = (\tilde{\varepsilon}^1_{it}, \tilde{\varepsilon}^2_{it}, ..., \tilde{\varepsilon}^M_{it})'$$

If the disruption components of the relationship (6) are not correlated and have a constant variance, the transformed error sentences must have similar properties therefore, this transform does not create the problem of variance inequality and serial correlation. In addition, this method allows estimator interruptions to be used as tools and coefficients to be estimated using the generalized moment method (GMM) (Roodman 2009; Arellano & Bover1995). After estimating all the coefficients using the Panel-VAR method, like the VAR method in the time series data, the Impulse Response Functions (IRFs) and Variance Decompositions (VDCs) can be estimated. Instantaneous impulse response functions show the response of endogenous variables over time to shocks to each of the system variables. The variance decompositions also shows the contribution of each variable to the changes of other variables over time.

RESULTS AND DISCUSSION

In this section, first, the descriptive information of the variables in each of the economic, social and environmental indicators is examined. It should be noted that all variables are calculated as a percentage to be sufficient for other stages of analysis. Table 2 includes statistical features such as mean, standard deviation and coefficient of variation. As observed, the highest mean is related to the variable of adult participation in learning and the lowest mean is related to the five variables of GDP, forest area, desertification and areas under environmental protection. In addition, the desertification variable with standard deviation of 6.28 and the two variables of unemployment rate and unemployment rate of 15 to 29 years equal to 2.91 have the highest and lowest standard deviation during the studied years, respectively. Based on the results during the study period, the coefficient of variation of energy consumption is 1.94, which has the highest coefficient of variation. In contrast, the lowest variation coefficient for the variable of adult participation in learning was obtained at 0.9.

Table 2. Summary statistics of variables used in the first step of empirical analysis.

variable	Average	Standard Deviation	CV
Ec_1	3.22	4.30	1.33
Ec_2	11.78	2.91	0.24
Ec3	1.25	2.35	0.15
So_1	48.30	4.58	0.09
So_2	25	5.04	0.20
So_3	11.78	2.91	0.24
En_1	3.22	3.33	1.03
En_2	3.22	6.28	1.94
En_3	3.25	6.15	1.90

The results related to the calculation of the composite sustainability index have been reported in Table 3 exhibiting that among the studied provinces, Khuzestan, Isfahan, Fars, with the average sustainability index of 0.610, 0.632, and 0.655 have the highest average sustainability index during 2011-2018. Also, the study of the average status of variables such as GDP, forest rate, women's participation rate and learning during the study period indicates a better situation in terms of sustainability. So that the average variable of GDP for Khuzestan province is equal to 15.17%, which is better than other provinces. The variable of women's participation and adult learning rates for this province is equal to 19.58% and 8.53%. As mentioned before, the average sustainability index for Isfahan province during the study period has been equal to 0.632. According to the extracted statistics, the average forest area in this province is equal to 8.01% and the participation rate of women is equal to 15.18%. Also, the study of the sustainability of Fars province during the period 2011-2018 shows that this province has the average contribution of gross domestic product of this province from the country gross domestic product equal to 5.16 %

and the average variables of forest area, women's participation rate and unemployment rate for this province are respectively 7.70%, 17.88% and 9.85%. The provinces of Hormozgan and Sistan and Baluchestan have the lowest average sustainability index of respectively 0.875 and 0.882. The sustainability index of these provinces have fluctuated between 0.715 and 0.890 during the years 2011-2018. So that the annual variation rates of these indices for Sistan and Baluchestan province is equal to -0.086% and for Hormozgan province is estimated at 0.012 %. In addition, according to Table 4, these provinces are not in a favorable position in terms of economic, social and environmental indicators. In other words, the participation of Sistan and Baluchestan Province in the Iran's GDP is less than one %. On the other hand, in terms of environment, the share of this province of the country's forests is 0.10 %. The average variables of adult learning and the unemployment rate in this province are 2.57% and 10.36%, respectively. Economically, the average share of Hormozgan province in the Iran's GDP is 0.58 %. In addition, in terms of environment, 0.11% of the country's forests is in this province. The average of women's participation rate, adult learning and unemployment rate for Hormozgan are 8.83%, 2.56% and 9.54%, respectively.

Table 3. Average Sustainability Index of Provinces in Iran during 2011-2018.

Province	Sustainability index	Rank	min	max	Average annual change
Alborz	0.680	4	0.618	0.785	-0.006
Kerman	0.755	10	0.679	0.832	-0.009
Sistan	0.882	30	0.861	0.978	-0.086
Elam	0.812	18	0.618	0.886	-0.313
Ardbil	0.799	13	0.700	0.877	-0.009
Esfahan	0.632	2	0.404	0.896	0.002
Boshehr	0.838	22	0.767	0.878	0.007
Khuzestan	0.610	1	0.385	0.878	0.068
Khorasan Jonobi	0.811	17	0.752	0.896	-0.161
Khorasan Razavi	0.869	27	0.519	0.893	-0.041
Fars	0.655	3	0.525	0.867	-0.188
Azerbaijan Gharbi	0.834	20	0.739	0.959	0.014
Zanjan	0.855	24	0.777	0.967	0.010
Azerbaijan Sharghi	0.767	11	0.673	0.854	0.011
Semnan	0.710	6	0.587	0.838	0.023
Chaharmahal	0.796	15	0.707	0.947	-0.008
Ghazvin	0.873	28	0.732	0.992	0.017
Ghom	0.868	26	0.758	0.937	0.012
Kordestan	0.837	21	0.732	0.978	0.014
Mazandaran	0.714	8	0.630	0.781	0.005
Kermanshah	0.839	23	0.721	0.905	0.013
Kohgiluyeh-Boyer Ahamd	0.817	19	0.666	0.896	0.019
Golestan	0.803	16	0.715	0.912	0.005
Gilan	0.776	12	0.721	0.830	0.002
Lorestan	0.696	5	0.597	0.840	-0.084
Hamedan	0.795	14	0.718	0.883	-0.007
Markazi	0.864	25	0.752	0.933	0.004
Yazd	0.720	9	0.760	0.906	-0.009
Hormozgan	0.875	29	0.763	0.934	0.012
Khorasan Shomali	0.712	7	0.693	0.765	-0.234

The sustainability indices for each provinces have been shown in Fig. 3 according to their geographical location. As can be seen, the northern and central provinces of Iran have more desirable status than the border provinces in terms of sustainability. Therefore, the weather conditions and access to water resources seem to be effective in achieving a higher sustainability index. Tehran Province has been removed during the indexing process, which was shown in white in the Fig. 3. Khuzestan Province, despite having about 4% of the total area of the country and more than 30% of the total surface water of the country, has the highest sustainability index. There are five important rivers in this province, in addition to the lakes behind the dams and numerous wetlands, including Shadgan and Hur al-Azim. In addition, agriculture is of special importance in the whole region of Khuzestan, especially in the plains. Wheat, barley, rice, sugarcane, dates and citrus are the main agricultural products in this province. After agriculture, animal husbandry and fisheries are also important in this province. Sustainability index of Alborz province was 0.680 with the average annual growth of -0.006. The average annual changes in this index can indicate an improvement in the situation of this province over time. The index of Khuzestan and Isfahan provinces with the positive average annual changes shows that despite gaining the first and second place in the development and stability of these provinces, their sustainability has decreased over time. Sustainability index of Sistan and Baluchestan Province is equal to 0.882. This province has an unfavorable situation compared to other provinces of the country. However, the average change in the sustainability index of this province is negative and indicates an improvement in the economic, social and environmental situation of this province during the period under review. The sustainability index of Mazandaran Province is 0.714, which puts this province in the eighth place in the country in terms of stability. Among the central provinces of Iran, Ghom Province with an average forest rate of 0.47%, average gender employment gap of 10.45%, average adult learning equal to 0.33%, average unemployment rate of 11.32% and finally, with an average GDP of 0.94% compared to Ghazvin Province is in a higher position. Therefore, due to the weak situation of Ghazvin Province in each of the components, it can be concluded that it has unfavorable conditions compared to Ghom.

Table 4. Average social, economic and environmental variables of provinces in Iran during 2011-2018.

Province	Ec_1		Ec_2		So_1		So_2		En_1	
	CV	Average	CV	Average	CV	Average	CV	Average	CV	Average
Alborz	0.06	4.64	0.22	9.19	0.14	6.29	0.29	17.63	0.53	6.96
Kerman	0.06	2.44	0.15	13.31	0.26	8.27	0.41	15.13	0.44	4.65
Sistan	0.06	0.52	0.13	10.36	0.36	2.57	0.38	8.74	0.38	0.10
Elam	0.09	1.36	0.15	11.08	0.24	2.56	0.34	11.89	0.22	2.48
Ardbil	0.95	2.06	0.47	9.41	1.39	3.32	0.31	13.18	1.68	3.52
Esfahan	0.14	6.00	0.14	9.34	0.32	1.25	0.38	18.74	0.22	8.01
Bushehr	0.39	1.09	0.11	10.66	0.58	0.82	0.31	11.02	0.81	1.19
Khuzestan	0.07	15.17	0.21	12.03	0.40	8.53	0.37	19.58	0.21	8.76
Khorasan Jonobi	0.13	1.54	0.20	13.58	0.22	0.81	0.34	12.13	0.26	2.50
Khorasan Razavi	0.05	0.89	0.18	11.90	0.13	7.58	0.39	9.27	0.02	0.41
Fars	0.13	5.16	0.23	9.85	0.16	2.00	0.34	17.88	0.24	7.70
Azerbaijan Gharbi	0.20	1.21	0.13	9.16	0.13	8.53	0.36	11.78	0.22	2.22
Zanjan	0.08	0.97	0.10	9.71	0.22	1.14	0.42	10.76	0.33	0.79
Azerbaijan Sharghi	0.07	2.29	0.16	9.55	0.42	0.21	0.35	14.17	0.17	4.17
Semnan	0.13	4.35	0.13	13.22	0.13	13.11	0.42	16.62	0.13	5.70
Chaharmahal	0.06	1.67	0.23	11.36	0.32	4.51	0.34	12.61	0.19	2.89
Ghazvin	0.09	0.65	0.09	14.68	0.37	1.30	0.33	9.18	1.31	0.30
Ghom	0.06	0.94	0.10	11.32	0.33	1.18	0.32	10.45	2.50	0.47
Kordestan	0.06	1.18	0.14	12.71	0.27	4.18	0.41	11.44	0.18	1.87
Mazandaran	0.06	3.36	0.22	10.13	0.43	4.94	0.37	15.98	0.10	5.02
Kermanshah	0.07	0.99	0.17	10.16	0.11	2.45	0.35	10.94	0.17	0.81
Kohgiluyeh-Boyer Ahamd	0.26	1.23	0.12	14.89	0.24	1.56	0.53	11.79	0.20	2.27
Golestan	0.09	1.55	0.21	9.90	0.36	2.13	0.43	12.58	0.16	2.78
Gilan	0.08	2.22	0.16	12.93	0.19	2.99	0.32	13.30	0.11	3.87
Lorestan	0.05	4.51	0.15	9.65	0.35	3.63	0.34	17.04	0.25	5.78
Hamedan	0.08	1.97	0.18	16.44	0.31	2.55	0.34	12.81	0.15	3.08
Markazi	0.57	0.97	0.18	16.20	0.51	0.91	0.41	10.59	3.39	0.49
Yazd	0.07	2.88	0.17	12.62	0.26	3.09	0.47	15.18	0.20	4.69
Hormozgan	0.08	0.58	0.27	9.54	1.04	2.56	0.39	8.83	3.13	0.11
Khorasan Shomali	0.12	3.45	0.27	11.32	0.39	0.80	0.40	16.18	0.38	5.27

Isfahan Province with over 500000 hectares of the Iran's cultivated lands is one of the other provinces in Iran that has a more favorable situation in terms of sustainability index. This province, having the first rank in the yield of various products such as wheat, barley, paddy, potatoes, onions, cotton and apple is one of the top provinces in terms of agriculture. It also has significant capabilities in various industries such as basic metals production, coke production, petroleum products and textiles, non-metallic mineral industries, recycling industries, medical instrument manufacturing industries, precision and optics, metal fabric manufacturing industries and furniture production industries.

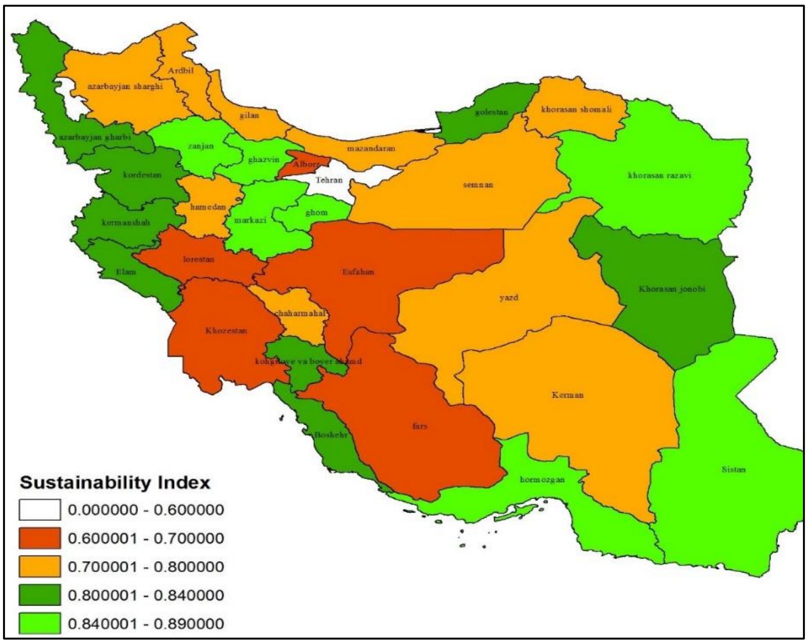


Fig. 3. Map of distribution of Sustainability index in Iran.

The sustainability situation of provinces such as Semnan, Yazd and Kerman indicates that the sustainability cannot be attributed only to the climatic conditions of the regions. Notably, most of the variables used in this study depend on Socio-economic data and depend on economic management in the provinces and the level of government attention. On the other hand, the unsustainable situation of provinces such as Azerbaijan, Kermanshah, Kurdistan and Ardabil related to weakness in management methods and the type of utilization of facilities and it is not limited to the weakness of environmental strength and unfavorable soil and climate. Among the border provinces of Iran, seven provinces including Kermanshah, West Azerbaijan, Hormozgan, Golestan, South Khorasan and Bushehr are in the semi-optimal range of sustainability. The Sistan and Baluchestan, Khorasan Razavi and Hormozgan provinces are in the undesirable range due to the bad situation of the studied variables.

In the second step of analysis, the causal relationship between variables was investigated based on the panel auto-regression approach (PVAR). Table 5 shows a significant causal relationship between agricultural productions, climatic variables of temperature, precipitation and sustainability index among the studied provinces. The results of the stability condition in Fig. 4 depict that the eigenvalues calculated for the estimated models provide the stability condition in our model.

Table 5. Summary of Granger-causality test.

Test	causality	Chi2
Agricultural production→Sustainability	**Yes**	66.81 (0.00)
Temperature→Sustainability	**Yes**	18.14 (0.00)
Precipitation→Sustainability	**Yes**	8.53 (0.01)
Temperature→ Agricultural production	**Yes**	16.79 (0.00)
Precipitation→ Agricultural production	**Yes**	6.41 (0.04)
Sustainability → Agricultural production	**Yes**	123.76 (0.00)
Agricultural production→ Precipitation	**Yes**	25.97 (0.00)
Agricultural production→ Temperature	**Yes**	10.07 (0.00)

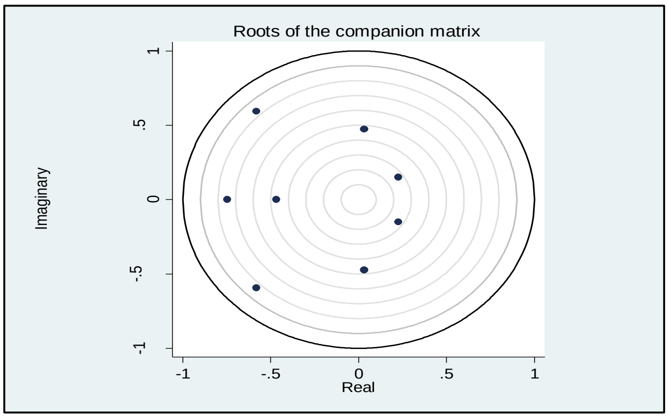
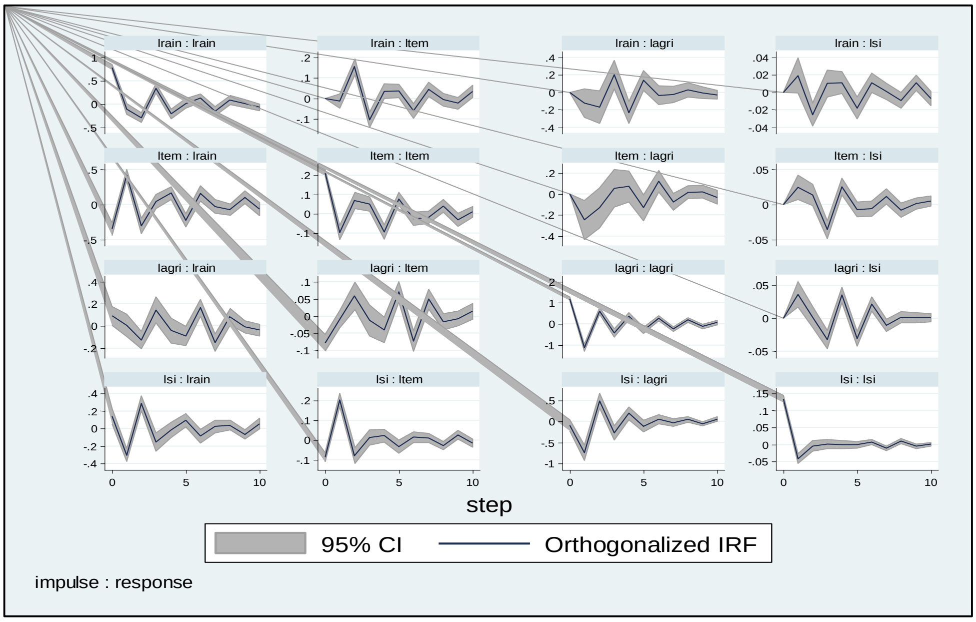


Fig. 4. VAR system stability condition check.

In order to investigate the effect of agricultural production, climatic variables on the sustainability index of the Iran provinces. Fig. 2 depicts the results of impulse response functions. In more detail, these figures indicate the effect of a change in each variables on itself and other variables. As observed, the effect of a unit change on agricultural production has a positive and increasing effect on the sustainability index of the Iran provinces. Then the effect is negative and eventually disappears in less than 7 periods. Similar results have been obtained for the temperature and precipitation variables. According to Fig. 5, the effect of a change on the temperature variable on the sustainability index has been associated with fluctuations. So that, at the beginning of the period, its effect is positive and increasing and then its effect is decreasing, and after about 7 periods, the effect of one momentum unit on temperature on sustainability will disappear. The reaction of the variable of sustainability to the momentum on precipitation in the early periods has been positive and increasing, and then it decreases and becomes negative, and these fluctuations are observed during the period.



The results of estimating the variance decompositions in Table 6 indicate that for sustainability, among the variables, at the beginning of the period under review, the share of self-variables in explaining sustainability is more than other variables and the explanatory power of other variables is very small. In the next period, this share gradually decreases to about 70%. In addition, the share of agricultural production and climatic variables of temperature and precipitation is more than 13%, 8% and 7%, respectively. This finding suggests that agricultural production plays a more important role than climate variables to determine the sustainability of the provinces. At the end of the period, the share of sustainability variable reaches 52% and the share of agricultural production in explaining the sustainability index reaches 22%. In addition, the share of climatic variables is estimated to be below 15% at the end of the period. This finding shows that agricultural production has a more important role than climate variables. Results indicate the decisive effect of the development of the agricultural sub-sector in the sustainability of the country's provinces. The study of the historical trend of economic development of countries shows that most developed countries have chosen agriculture as an infrastructure sector of their economic development and by using the abundant capacities of this sector, in addition to providing appropriate inputs for the growth of other Departments to develop other departments as well (Gliessman 2015). Therefore, agricultural development in the context of rural development, while providing the possibility of optimal use of water and soil resources and human resources located in rural areas, will also have undeniable effects on creating a proper economic structure and the desired national development trend.

Table 6. Variance Decomposition of Sustainability Index (VAR)

Equation	Year	Variables			
		Precipitation	Temperature	Agricultural Production	Sustainability Index
Sustainability Index	3	0.05	0.03	0.06	0.86
	5	0.07	0.08	0.13	0.72
	7	0.07	0.09	0.17	0.67
	9	0.09	0.10	0.17	0.64
	11	0.10	0.11	0.18	0.61
	13	0.13	0.11	0.19	0.57
	15	0.14	0.12	0.22	0.52

CONCLUSION

In the present study, the provinces are first ranked based on a composite sustainable index consisting of three dimensions: environmental, economic and social. This method has allowed us to cope with multidimensional set of indicators to be aggregated into a unique composite indicator that can improve our understanding of the complex concepts such as supporting the sustainable agricultural development and environmental protection. Khuzestan, Isfahan and Fars provinces have the highest average sustainability index during 2011-2018. The results show that the provinces that are in a better position in terms of agricultural and industrial production, are also in a more favorable position in terms of sustainability than other provinces. In other words, one can hope for the role of agricultural and industrial development in achieving sustainability. There is a clear evidence that agricultural productivity growth responds to research and development efforts. The importance of strengthening the public sector research for agricultural development has been well recognized. It is also now well acknowledged that the target of agricultural R & D has to embrace the twofold goal of agricultural productivity and the environmental performance which accompanies agricultural production. In addition, the border provinces of the country and the provinces that do not have favorable conditions in terms of environmental indicators such as temperature, rainfall and access to water, have a lower stability index. Border areas have special characteristics that due to their proximity to foreign countries and the geographical and political conditions prevailing in them that, if not addressed, it will have a negative impact on the development and security of these areas. In addition, in order to promote adaptation strategies to achieve sustainable agriculture, causal relationships between the combined sustainability index, climate change and agricultural products among the provinces during the mentioned years were examined. The results show a causal relationship between climate change (temperature and precipitation) and agricultural production among the studied provinces. In fact, too much rain could rot the crop, and too much sun could be associated with periods of drought that would ruin the crop (Porter & Gawith 1999; Nelson *et al.* 2009; Ciscar *et al.* 2011; Maleksaeidi & Karami 2012; Ignaciuk & Mason-D'Croz 2014; Gliessman 2015). Although rises in temperature can have both positive and negative effects on crop yields (see Section 1), in general, rises in temperature have been found to reduce yields and quality of many crops, as cereal and feed grains (Smith *et al.* 1996, Adams *et al.* 1998). Furthermore, an increase in frequency of unusually hot nights is found to be damaging to most crops and particularly observed for rice yields (Welch *et al.* 2010; Wassmann *et al.* 2009). As a result, there is the need for the Iranian provinces to improve climate change adaptation strategies into their agricultural policies in order to reduce unsustainable agricultural practices. Possible strategy is to focus on improving the conserving soil and water in natural systems to alleviate the effect of droughts and to prevent floods, soil erosion and desertification. In addition, Agri-Climate-Environmental payments can play an important role in introducing or maintaining agricultural practices that contribute to mitigating climate change or favoring adaptation to climate change. These agricultural practices must be compatible with the protection and improvement of the environment, the landscape and its characteristics, natural resources, soil and genetic diversity.

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