

Assessment and Comparison of Sustainable Agriculture Approach Using a Combination of AHP and TOPSIS

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Abstract

Over the last decade, pressure on natural resources has increased due to population growth and the need for food security especially in developing countries. Excessive use of productive inputs increases the importance of sustainable agriculture to enhance the performance and reduce the environmental degradation. The present study was established on the basic model of agricultural sustainability as a consideration of three criteria including environmental, social and economic. Seventeen sub-indicators of sustainability were analyzed for the Ardebil province. According to the questionnaires and statistical yearbooks of Ardebil Agricultural Jihad Organization and Regional Water Authority the required data were collected in 1394. Determination of Value-Weighted index was accomplished using the Analytic Hierarchy Process (AHP). The relative importance of each sub-options (agricultural areas) were also categorized using TOPSIS technique. The results demonstrated that the environmental index with 0.443 relative weights had the highest impact and social criteria with 0.169 relative weights had the lowest effect on agricultural sustainability. The results indicated that Germi with 0.624 final values was the most suitable area and Sarein with 0.395 was the most inappropriate area from the aspect of agriculture sustainability.

Keywords: AHP, Ardabil, Environment, Sustainable Agriculture, TOPSIS

Introduction:

Sustainability, during the 70's decade was used rarely and only in the exploitation of forests, and forest resources (Mousavi and Akbari, 2011; Mousavi et al., 2011). Sustainability has become Today one of the most common terms in economic and social fields in general and specifically in environmental sciences . Increase awareness of the impact of human activities including agriculture on the environment and resource base caused that over the past decade, Over the past decade, concepts such as "sustainable development" and "sustainable agriculture" proposed by researchers and the necessity of changing economic, social and agricultural systems towards to sustainability be emphasized (Gupta, 1997). Sustainable development as development knows that solve the needs of the present without compromising the ability of future generations to meet their needs limit (Siwar et al., 2009). The basic concept of sustainable development by the World Commission on Environment and Development states "to ensure the needs of the present generation without compromising the ability of future generations to meet their needs (Xu et al., 2006). Therefore sustainable agriculture is agricultural for the benefit of human kind, more efficient use of resources and in harmony with the environment. In other words, sustainable agriculture must be ecologically appropriate, economically justified and socially desirable. Hence, I believe that sustainable agriculture seeks to achieve three general objectives "healthy agricultural economy", "maintaining rural society" and "environmental protection" (Korfmacher, 2000). In the agricultural sector, sustainability goals is include environmental maintaining or enhancing natural resources, human needs for food, economic viability and social welfare (Praneetvatakul, et al., 2001). Method the use of indices of sustainability in research different and depends on the goals of the study. Practical use of sustainability indicators at the level of provisions more widely available a few important things when designing the parameters, including: 1. easily be used by farmers. 2. have high accuracy and easily interpreted. 3. can be used in different scale from a small farm to a system of extensive farming took advantage of it. 4. Use them to guide decisions on new management. 5. To the extent that they are sensitive to environmental changes and the effects of good management practices and crop show on the environment. 6. make them understand the ecological relationships and processes (such as the relationship between biodiversity and pest population stability) used (Nicholls et al., 2004). Based on the material presented , in recent years one of the concerns of agricultural policy is agricultural production strategy based on a variety of purposes, including water resources management (water supply), increasing employment, reducing negative environmental impacts, sustainable agricultural development and self-sufficiency (Kohansal et al., 2015). Several studies have tried to assess the sustainability of agricultural that common theme of all these studies is the personification of economic, social and environmental sustainability, for example Dantsis et al (2010) assess and compare to sustainable agricultural using aggregate indicators of economic, social and environmental and theory of value multidimensional in Greece's. Liu and Zhang (2013) comprehensive assessment of economic, social and environmental in China's important agricultural region. Cauwenberg et al (2007), provided a framework and criteria to assess all aspects of sustainable economic, social and environmental applicable at farm level, regional, national and international. Pacini et al (2003) evaluated three farming systems, organic, compilation and conventional in a region in Italy with using indicators of environmental and economic sustainability. The results showed that the net profit Gifts of organic agricultural was more than conventional agricultural. But in the investigation of Alabdulkader, et al (2012) note, have to optimize cropping patterns with using mathematical programming in Saudi Arabia. In this study annual plan

objectives such as maximizing efficiency, reducing water consumption and efficient allocation of agricultural lands was considered among competing products. The results showed that the optimal crop pattern, program efficiency about 42/2 billion increased and water consumption about 53 percent reduced. Accordingly, the need for such research can be felt in Iran. Ardabil province with an area of 17952 square kilometers is 1.9 percent of the total area of the country. Ardabil province Such cold and mountainous areas of country and rainfall in an average of 250 to 600 mm per year has fluctuated in this province. Agricultural land area of Ardabil is 788,614 hectares, which is 37 percent water and 63 percent is rained. The share of value added of agriculture sector in GDP of about 20% while the average of this share in country is 30 percent (the Ministry of Agriculture 2015). Potato after wheat and rice, especially in Iran is the second-largest food crop. Ardabil province with 24 thousand hectares to cultivate this crop and the production of one-fifth of the country's potato production is an important pole. Due to strong demand for this product to the water, in the last two decades, in the plains of Ardabil are indiscriminate action is and is not allowed to dig wells (water sources Ardebil Regional Water Company, 1394). Also, due to strong demand for this glandular product to nutrients, indiscriminate use of chemical fertilizers in the form of plain takes place. Today, Because of the non-attention to the principles of sustainable agriculture, damage entered natural resources and environmental Ardabil Province. With limited water resources and the impact of climate change and because of continued drought and overuse of groundwater and subsidence in underground aquifers, agricultural of Ardabil province is faced with serious challenges. The total annual discharge of underground water resources approximately is 85/363 million cubic meters per year. The main factors that cause soil pollution is agricultural in Ardabil province as excessive use of pesticides and fertilizers, Wastewater and drainage water use in irrigation of agricultural lands and mismanaging the irrigation systems noted. Studies have shown that use of these substances in the context of land near rivers and declining water quality pollute Balykhlychai and Gharasoo rivers (provinces of Ardabil, 1391). Thus, the necessity of addressing the issue of sustainable agriculture and agricultural sustainability assessment indices in Ardabil Province, is of special importance. Therefore, detailed research is needed in this area. Research such as Constanta and Rahoveanu (2010) that combines two approaches in using (AHP and TOPSIS) in weighting indicators of sustainability, economic, social, environmental and seven areas of Romania and Min Wu (2007), used of AHP-TOPSIS to manage, and prioritize weighting of the criteria stated. The results of Studies suggested that the process of hierarchical decision-making model selection and priority criteria in error TOPSIS can reduce uncertainty. Therefore, in this study, using the standard indices integration of environmental, social and economic and technical multi-criteria decision (MCDM) to evaluate and compare the sustainability of agriculture in the province of Ardabil was used.

Methodology

Analytic Hierarchy Process (AHP) of the most comprehensive and the most common system is designed based on MCDM techniques. This technique allows formulation of issues has provided hierarchically and the possibility of considering various qualitative and quantitative criteria give to decision makers (Saaty, 2008). The first step in the method of AHP, created a decision tree with the selection criteria. The decision tree based on the overall stability of the integration of the three indicators of environmental, economic, social and their sub outlined obtained. After the breakdown of the hierarchy,

first main indicators are compared with each other two by two, Then, in each of them, the following parameters (sub- Criteria) are compared (Saaty, 1994).

The AHP methodology provides decision makers with a useful way of checking and improving consistency. The Consistency Criteria (CI) measures the degree of logical consistency among pair-wise comparisons. Consistency Index (CI) is defined as follows (Saaty, 1980):

$$C.I = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

n is the number of existing items in the judgment matrix problem. where

Consistency Ration (CR) indicates that the amount of allowed inconsistency (0.1 or 10%). Higher than 0.1 means that the comparisons are less consistent. Smaller than 0.1 means the comparisons are more consistent. CRs above 0.1 means the pair-wise comparison should be revisited or revised. The consistency ratio is calculated using the following formula:

$$C.R = \frac{CI}{RI} \quad (2)$$

The Random Criteria (RI) is the average CI value of randomly-generated comparison matrices using Saaty's preference scale. Table 1 shows the value of the RI for matrices of order (N) 1 to 15.

Table 1: Random Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

If the rate of incompatibility, is smaller than or equal to 0.1 ($IR \leq 0.1$). In paired comparisons, there is compatibility and analysis can be continued. Otherwise, decision makers must revise paired comparisons. In this study to measure the sustainability of agriculture and combine qualitative and quantitative data, the combination of AHP and TOPSIS approach was used. Preferred Approach Based on the similarity of responses of the ideal (TOPSIS) Another powerful methods in decision-making. This method is based on calculating the distance Options positive and negative ideal of the ideal solution based (Lin, 2010). In this method should be the decision matrix to a matrix "non Scale" by using the following formula becomes:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^J X_{ij}^2}}, j = 1, \dots, J ; i = 1, \dots, n. \quad (3)$$

This model proposed by Huang and Yun in 1981 that is one of the best multi-criteria decision-making models. This technique is based on the assumption that the choice should be closest to the positive ideal solution (best possible) and maximum distance from the negative ideal solution (worst) .The solve the problem with this method is as follows (Lin, 2010):

$$V = N * W_{n*n}$$

- N = calculation method non Scale Matrix Software
- W = calculated weight matrix with a weighting methods
- V = calculated weighted non Scale Matrix

V_j^+ = Positive ideal solution: the largest and the smallest value for a positive indicator for the amount of negative indicators, taking up of the best values of each indicator

V_j^- = The biggest positive ideal solution for the small-negative indicators and the most value for the positive indicators, to expression vector consists of the best values of each indicator

- Calculate the distance from every ideal option to have positive and negative

$$S_j^+ = \sqrt{\sum_{i=1}^n (v_{ij} - v_i^+)^2}, j = 1, \dots, J. \quad (4)$$

$$S_j^- = \sqrt{\sum_{i=1}^n (v_{ij} - v_i^-)^2}, j = 1, \dots, J. \quad (5)$$

- Determine the relative closeness to solve an ideal option

$$CL_i^* = \frac{d_i^-}{d_i^+ + d_i^-}, \quad 0 < CL_i^* < 1 \quad (6)$$

- Ranking based on the larger CL.

Research process generally involves determining the appropriate criteria and complete matrix of pairwise comparisons between them by experts, traced them the hierarchical structure of criteria and sub-criteria, gaining weight and rank criteria with AHP method with using regions are Topsis. That advantages and disadvantages of each method according to the combined approach is used for weighting and ranking (shih et al., 2007). In this paper, we present a hybrid multi-criteria evaluation method which integrates the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). It takes subjective judgments of decision makers into consideration. The criteria weights are calculated by using the AHP. Then rankings of the alternatives are determined by the TOPSIS method. Our method is used for evaluating the performance, from the sustainable agricultural point of view, of seven counties from the South Muntenia Region of Romania. The criteria taken into consideration are grouped under the concepts of sustainable agriculture in economic, social and environmental criteria. The proposed method enables the decision makers to understand better the whole evaluation process. It provides a more accurate, effective, and systematic decision support tool.

The present study, the kind of descriptive- analytical is an applied nature. Method of collecting is a survey data - library. In the process of analyzing the use of quantitative data and statistics, the expert's opinion have also been used. Selected individuals as a class and the proportional is taken from a random selection of people in this procedure should be strictly avoided. First, to give weight to sustainability indices, the index is composed of 30 questions for pair-wise comparison between specialists and experts versions of

Agriculture and Environmental organizations were collected and distributed. With using Expert choice software paired comparisons, the weight of each indicator and gives the selected sub was obtained. In this study, the first to design a model of sustainable agricultural and assessment, indicators have been developed (Table 2).

Table 2: The Hierarchy of Criteria and Sub-Criteria

Criteria	Sub- Criteria	Definition
environmental	Z1. Consumption Fertilize Z2. Consumption poisons Z3. Efficient irrigation systems Z4. Grain crop diversity Z5. Water balance Z6. Conservation tillage Z7. The electrical conductivity (EC) Z8. Observe crop rotation	Consumption per unit area (kg/ ha) Consumption per unit area (liters per hectare) The total area of land under modern irrigation Formula H- degree of diversity of crop plants Overuse of groundwater Reduced tillage and no tillage systems than covered land to total land area Percent of total arable land acreage saline lands Of the principles of crop rotation
Economic	E1. Risk E2. The dependence of farmers on state aid E3. The level of employment E4. The gross value of production E5. Wheat yield	Insurance of land to total land The dependence of farmers on state aid Proportion of the population employed in agriculture The average gross production value per hectare of arable land Yield per hectare (kg)
Social	S1. The literacy S2. population density S3. Education S4. Classes promote sustainability	The ratio of literate farmers to the farmers in each region The proportion of the total area The promoters of the population The number of classes to promote sustainability

Results and discussion

After completing the questionnaire, initially inconsistency rate every single questionnaires were obtained and questionnaires that inconsistency rate was greater than 0.1 were eliminated. 5 questionnaire at this stage due to the high rate of incompatibility was removed from the final analysis. Then geometric mean formula matrix comments by individuals merged into a single matrix. In the next step final matrix was entered to the Expert Choice software. And its weight was calculated for each criteria and sub criteria that is presented in Table 2.

After compilation and combination of pairwise comparisons were performed, according to the software output to the main index inconsistency rate was 0.02 (less than 0.1). And demonstrates the consistency of decision-making in the process of hierarchical analysis. Most indicators of environmental indicators, weighing was 0.443 and social weight was 0.169 has less impact on agricultural sustainability areas (Table 3).

Table 3: The AHP Calculated Weights

Criteria and SubCriteria	weight between the Criteria (%)	weight within the Criteria (%)	Weight (final Sub)
environmental	0.443		
Z1		0.158	0.069
Z2		0.158	0.069
Z3		0.145	0.064
Z4		0.111	0.049
Z5		0.122	0.054
Z6		0.111	0.049
Z7		0.065	0.028
Z8		0.130	0.057
Economic	0.387		
E1		0.148	0.057
E2		0.167	0.064
E3		0.195	0.075
E4		0.195	0.075
E5		0.295	0.114
Social	0.169		
S1		0.225	0.038
S2		0.100	0.016
S3		0.297	0.050
S4		0.337	0.063

According to the results in Figure 1 between environmental subs. Sub of fertilizers and pesticides consumption with relative weight of 0.158 per unit area, As well as Subsystems efficient irrigation with weight 0.145 utmost importance and the following weight of soil salinity indicator 0.065 was minimal role in agricultural sustainability. In other words, by reducing the use of fertilizers and pesticides, as well as increase the efficient use of modern irrigation systems due to increase the sustainability of agriculture.

Crop rotation and tillage Sub compliance with 0.111 weight in the evaluation of agricultural sustainability are equally important.

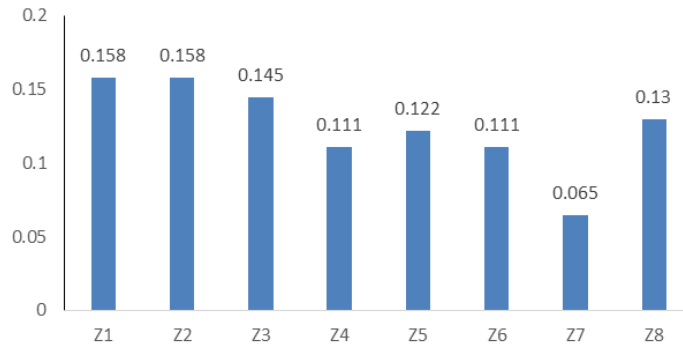


Fig1.The relative weight of environmental indices

Based on the economic stability of the Sub indicator of risk, farmers dependence on government aid, the level of employment, the gross value of agricultural production and production performance have been formed. Among The following economic indicators, the risk with weight 0.148 was the least important and the following crop production performance indicator weight is 0.295 allocated to the most important. Because of the increased production will also to increase the farmers' income, any strategy to increase production while ensuring environmental sustainability and health will ultimately help increase agricultural sustainability (Figure 2).

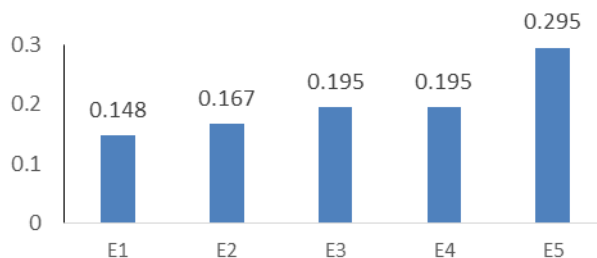


Fig2.The relative weight of economic indices

Among the social sub-index, propaganda Subclasses with the relative weight 0.377 have been the most important and population density, with weighing 0.001 have been minimal role in sustainable agriculture. The importance of propaganda subclasses means that the weakness of human resources Because of neglected to promote the education of beneficiaries of challenges seriously and empowering human resources by promoting new agricultural practices, agricultural development is one of the requirements

and continuous training farmers to improve plays a significant role agricultural sustainability. Integrating and using appropriate methods to promote the empowerment of human resources in agriculture and facilitate agitation and practices can be achieved higher levels of production in the province (Figure 3).

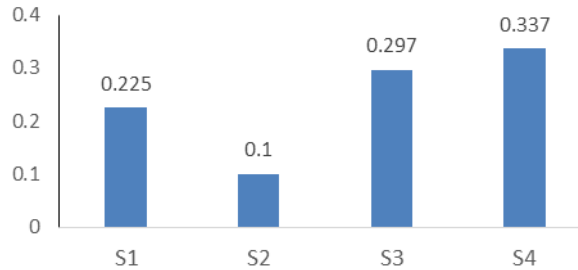


Fig3.The relative weight of social indices

Then, according to the weights derived from the previous and data related to each criterion, the ranking was done by TOPSIS. The decision matrix values, according to the relations explained, they were non-Scale. The decision matrix by multiplying the values of cells in Weight Index Scale, the Scale weighted decision matrix was obtained. Finally, using equation (5) S_i^- values and S_i^+ values was calculated. As well as revealing distance of both positive and negative for each ideal option, similarity indexes were calculated for each of the options that results are shown in Table 4 and Figure 4. Amount of similarity index between zero and one variable and the ideal option to be more similar, the similarity index value is closer to 1.

Table 4 Ranking agricultural sustainability townships Ardebil

City	S_i^+	S_i^-	Close to ideal solution	Rank
Ardabil	0.081	0.085	0.511	7
bilesavar	0.057	0.093	0.620	2
Pars abad	0.105	0.092	0.468	8
khalkhal	0.095	0.103	0.518	6
kousar	0.081	0.103	0.559	4
germi	0.063	0.106	0.624	1
Meshgin shahr	0.078	0.112	0.589	3
namin	0.083	0.097	0.540	5
nir	0.098	0.085	0.463	9
sarein	0.109	0.071	0.395	10

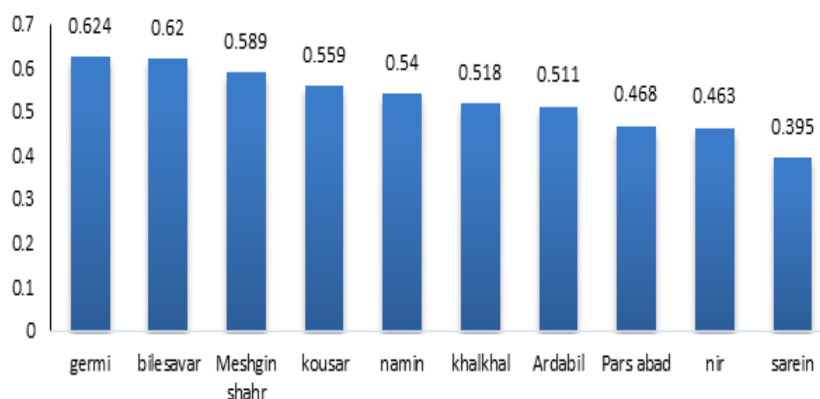


Fig.4. The TOPSIS ranking of the cities

The results suggest that Germe city with amount 0.624 have been best sustainability in agriculture and Sarein city with the weakest amount 0.395 agricultural sustainability in the city of the province is allocated. The main reasons for the favorable situation of the agricultural sustainability in the Germe city than other city can be having the maximum amount of conservation tillage indicator with 0.61. The amount this index is less than 0.31 in rest of the cities. It also Germe city has the best employment situation and insurance of agricultural land in the city is also notable. The low indicators of soil salinity, fertilizer and chemical pesticides is also important in this area. To determine the salinity of soil saturation extract electrical conductivity indicator was used. Most amount saline lands belonged to the city of Sarein with 0.3, Nir with salinity 0.2 and Pars Abad is Amount 0.049. Germe, Bilesuar and Meshkinshar Cities with 0.001 amount have less than percent saline lands are lowest. Other indicators is the indicator of amount of fertilizer and pesticide per unit area. This indicator is the smaller Indicates the more sustainable. Sustainability Criteria is calculated in relation to the use of chemical fertilizers (nitrogen, phosphate and potassium), the highest this index in the Parsabad city 191 kg per hectare and the city of Ardabil is 107 kg per hectare.

Conclusion

Due to environmental and climatic conditions prevailing in the Ardabil province should have any food production for sustainable agriculture depends on correct and rational use of resources of the province. Therefore, the need to address this issue in recent years and according to the standards and principles of sustainable agriculture and agricultural development has been emphasized. In this study, based on the model of agricultural sustainability to the following three objectives, indicators and sub-indicators were designed, 17 sustainability indicator for the city of Ardebil, Parsabad and Namin were analyzed. Based on the results of present study Namin city best stability and the Parsabad city were the weakest region in terms of agricultural sustainability. Developed and designed several models and indicators for measuring the sustainability of agricultural systems, is of particular importance. Therefore, it is suggested that future

studies in this area by adding other criteria for a more complete assessment of the areas used for agricultural sustainability. In order to inform farmers on sustainable agriculture, it is suggested that educational and extension programs not only focus to yield improvement per unit area, but also environmental issues and preservation of nature also must pay special attention.

References

- Alabdulkader, A. M., Al-Amoud, A. I., & Awad, F. S. (2012). Optimization of the cropping pattern in Saudi Arabia using a mathematical programming sector model. *Agricultural Economics/Zemledska Ekonomika*, 58(2).
- Ardabil Province Department of Agriculture. Census of 1390. Reports of the Ministry of Agriculture the city of Ardabil in 2016
- Dantsis, T., Douma, C., Giourga, C., Loumou, A., & Polychronaki, E. A. (2010). A methodological approach to assess and compare the sustainability level of agricultural plant production systems. *Ecological indicators*, 10(2), 256-263.
- Gupta, G. (1997). A curriculum in sustainable agriculture. *Journal of natural resources and life sciences education (USA)*. 26: 177-179.
- Kohansal, M. R., Etehad, S., and Akbari, S. M. (2015). Effects of rice cultivation restriction policy, Case study: Marvdasht city. *Advances in Environmental Biology*. 9 (4): 446-453.
- Korfmacher, K. S. (2000). Farmland preservation and sustainable agriculture: Grassroots and policy connections. *American journal of alternative agriculture*, 15(01), 37-43.
- Lin, H. T. (2010). Fuzzy application in service quality analysis: An empirical study. *Expert systems with Applications*, 37(1), 517-526.
- Liu, F., & Zhang, H. (2013). Novel methods to assess environmental, economic, and social sustainability of main agricultural regions in China. *Agronomy for sustainable development*, 33(3), 621-633.
- Min Wu.(2007). TOPSIS-AHP Simulation Model and Its Application to Supply Chain Management, *World Journal of Modeling and Simulation*. Vol 3 (3): 196-201.
- Mousavi, S. N. and Akbari, S. M. R. (2011). Estimated value of forest conservation in Iran: A case study of Fars Province. *African Journal of Agricultural Research*, 6(30): 6407-6411.
- Mousvi, S. N., Akbari, M., and Rezaie, M. (2011). Estimating the preservation and outdoor recreation values of Iran forests and forest parks. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 11(4), 551-558.
- Nicholls, C. I., Altieri, M. A., Dezanet, A., Lana, M., Feistauer, D., & Ouriques, M. (2004). A rapid, farmer-friendly agroecological method to estimate soil quality and crop health in vineyard systems. *Biodynamics*, 33-39.
- Pacini, C., Wossink, A., Giesen, G., Vazzana, C., & Huirne, R. (2003). Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems & Environment*, 95(1), 273-288.
- Praneetvatakul, S., Janekarnkij, P., Potchanasin, C., & Prayoonwong, K. (2001). Assessing the sustainability of agriculture: a case of Mae Chaem Catchment, northern Thailand. *Environment International*, 27(2), 103-109.

- Radulescu, C. Z., Rahoveanu, A. T., & Radulescu, M. (2010). A hybrid multi-criteria method for performance evaluation of romanian South Muntenia Region in context of sustainable agriculture. In International Conference on Applied Computer Science (ACS) (pp. 15-17).
- Saaty, T. L. (1994). Highlights and critical points in the theory and application of the analytic hierarchy process. *European Journal of operational research*, 74(3), 426-447.
- Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International journal of services sciences*, 1(1), 83-98.
- Saaty, T. L. (1980). *The Analytic Hierarchy Process*, McGraw-Hill, New York. There is no corresponding record for this reference.
- Shih, H. S., Shyur, H. J., & Lee, E. S. (2007). An extension of TOPSIS for group decision making. *Mathematical and Computer Modelling*, 45(7), 801-813.
- Siwar, C., Alam, M. M., Murad, M. W., & Al-Amin, A. Q. (2009). A review of the linkages between climate change, agricultural sustainability and poverty in Malaysia. *International Review of Business Research Papers*, 5(6), 309-321.
- Van Cauwenbergh, N., Biala, K., Biolders, C., Brouckaert, V., Franchois, L., Cidat, V. G., ... & Sauvenier, X. (2007). SAFE—A hierarchical framework for assessing the sustainability of agricultural systems. *Agriculture, ecosystems & environment*, 120(2), 229-242.
- water sources Ardebil Regional Water Company, 1394. Reports of the Ministry of Agriculture the city of Ardabil in 2016
- Wu, C. S., Lin, C. T., & Lee, C. (2010). Optimal marketing strategy: A decision-making with ANP and TOPSIS. *International Journal of Production Economics*, 127(1), 190-196.
- Xu, X., Hou, L., Lin, H., & Liu, W. (2006). Zoning of sustainable agricultural development in China. *Agricultural Systems*, 87(1), 38-62.