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A multi-criteria analysis to assess sustainable olive cultivation at the regional level: an application of the TOPSIS model

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Abstract

Rapid population growth and the industrial revolution have led to an increase in the demand for olive oil. On the other hand, the cost of olive oil imports and the less production of olive has forced the government to develop olive production through an olive localization project. Some economic, environmental, public, and private factors influence the localization of olive cultivation. Therefore, these criteria were evaluated using multi-criteria decision-making (MCDM) techniques. For this purpose, the TOPSIS model was applied to evaluate these criteria. Seventy-three percent of the sample (372) indicated that adaptation was successful. The results showed that land allocation, increase in income and improvement in employment were the most important factors, at the same time transforming industries and credit opportunities were less important factors for the adaptation of the olive production. In addition, the results of the model can be used by policy makers as a prerequisite tool for the development of olive production in new regions to reduce policy opportunity costs and reduce dependence on olive oil imports.

Keywords: Olive production, Adaption, MCDM, TOPSIS.

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Introduction

Over the past several years, olive cultivation in various parts of Iran has received considerable attention and support from state institutions. Large amounts of Iranian olive oil (approximately 90%) are imported every year. In order to reduce this quantity of imports, particular attention should be given to the adaptability of this product at regional level. Adaptability is a biological term. This means plant species can complete its life cycle and reproduce naturally in a new habitat with a specific climate. The choices between the various production options in olive growing depend on soil and climate factors, local culture and traditions, the availability of mechanization, water, labor, economic resources, the environment, the type of olives to produce (Giulio et al. 2017). Olive cultivation in any region requires experimental plants and proof of their performance. In other words, a variety can only be grown in the target area if it has a proven track record in the field. Fortunately, famous varieties of foreign and local olives have been planted and tested in experimental fields in many Iranian olive growing regions.

Most research studies carried out on olive trees in the world, dealing with the biological and physiological processes that occur during the growing cycle of trees, in relation to climate, water use, growth and production to improve the olive grove, farming practices and to achieve better productivity by reducing inputs and costs (Fernández-Escobar et al., 2012, Mohamad et al., 2014, Russo et al., 2015, Salomone et al., 2015, Tsarouhas et al., 2015, Pattara et al., 2016, Proietti et al., 2016, **Masmoudi,**2013). These research studies point out on localization during the cultivation but after the localization of the olives, it is necessary to consider the factors that influence the sustainability of this localization and cultivation on a regional scale. Growth of the olive tree is a complex phenomenon, governed by exogenous and endogenous factors. Sustainable olive cultivation requires multiple management and consideration of various aspects. Management strategies and practices must be implemented through available economic, political, environmental, and social instruments (Michalopoulos et al. 2020). Therefore, any kind of analysis of the sustainability of production and adaptation must examine economic, political, social, and environmental indicators. In order knowing what factors have the most impact and what factors should be strengthened, will help decision-makers to reduce their opportunity costs.

The government, through its financial assistance program, tried to encourage farmers to plant olive. The "Toba Project" is one of the most important programs of the Iranian Ministry of Agriculture; The Toba Project seeks to develop olive production. As this project is being implemented on a large scale in Golestan province, the present study aimed to propose and assess the degree of adaptation and localization of olive cultivation and to rank the economic, environmental and political factors that cause sustainable olive cultivation in this province. Golestan Province, with an area of 20,438 square kilometers (1.3% of the country), lies between latitudes 36 degrees 30 minutes to 38 degrees 8 minutes north and longitudes 53 degrees 51 minutes to 56 degrees 21 minutes east. The province of Golestan has 97,000 acres of olive growing. It is the country's leading province for the production of olive seedlings. There are 4160 producers. It is the fifth largest producer in the country. It has 14 factories for the extraction and processing of olive oil.

Sustainability olive cultivation should be taken into account in decision-making processes, especially in public policies both from a global and local viewpoint, however this needs a good knowledge of the olive tree in general and specifically the social-economics factors that made cultivation to be sustainable. So this study evaluates the most suitable criteria for the sustainability olive cultivation of olive production in Golesatn by means of the TOPSIS method. The results of this study will help policymakers to improve the weak factors and stabilize the substantial factors needed for sustainable development of olive production at the regional level. The results can help better management strategies with Toba project. In addition, the choice of the case study format for analyzing olive cultivation is aimed at supporting decision-making on investments in The Toba Project, the diagnosis of economic performance problems and quickly establishing a socioeconomic knowledge base on olive production in the north of Iran.

Materials and Methods

As a decision-making nowadays involves an ever-increasing amount of data, the attention of decision-makers must be distributed efficiently. This is all the more true for adaptation assessments, which are based on a multi-dimensional approach that includes economic, environmental and, agronomic perspectives. Many decision problems are made based on spatial and regional information, leading to site selection (Sánchez-Lozano et al., 2015, Zambelli et al., 2012, Miglieta, 2019).

The techniques of multi-criteria decision analysis allow us to approach the decision problems in a structured way and help in decision making (Bouyssou et al., 2002). The choice of the most appropriate MCDA method is not easy and is closely related to various aspects: the problem analysed, the ambiguity and vagueness of the data and information, the conflicts between criteria etc. (Simanaviciene and Ustinovicius, 2012, Greco et al., 2016). MCDA provides a comprehensive set of procedures, techniques, and algorithms that are useful for structuring decision problems and designing, evaluating, and prioritizing decision alternatives by combining factual information with value-based information (e.g., expert opinions) (Geneletti, 2010). The main techniques used in multi criteria decision making are WSM (Weighted Sum Model), WPM (Weighted Product Model), AHP (Analytic Hierarchy Process), ANP (Analytical Network Process) and, TOPSIS (Technique for the Order of Preference to the Ideal Solution) etc. (Nwokoagbara et al., 2015; Mardani et al., 2014). MCDM studies are used for various topics such as energy policy evaluation (Siksnelyte et al., 2019), technology selection (Al-Alawi et al., 2018; El-Aghourya et al., 2021), project selection (Mahdi et al., 2020), safety engineering (Mahdi et al., 2020), and energy planning (Lerche et al., 2020; Katal et al. 2018).

The TOPSIS method uses many attribute information, provides cardinal ranks, and works independently of qualification decisions. This method assumes that attribute values are numeric, move up and down (benefit or cost attribute), and are quantifiable for the same criteria (Asli & Kilic, 2022). The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), developed by Hwang and Yoon in 1981, is a technique based on the selection of distances to the positive and negative ideal solution (Chakraborty, 2022). The TOPSIS method is used to sort the alternatives according to specific criteria. The first step in this method is to create the decision matrix. In the second step, the decision matrix is normalized. In the third step, the decision matrix is weighted. In the fourth step, the ideal and negative ideal solutions are calculated. In the fifth step, the positive and negative ideal distances are calculated. Finally, in the sixth step, the relative scores of the individual alternatives are calculated (Dumanog & Ergul, 2010). The TOPSIS method can be computed applying the following steps (Hwang and Yoon, 1981; Chen et al., 2006):

Step 1: Obtaining the decision matrix. In this method, the decision matrix is evaluated, which contains i options and j indicators. The rows denote the decision points, and the columns show the factors (Eq. (1)).

$$D = \begin{bmatrix} x_{11} & x_{12} \ldots x_{1n} \ldots x_{1j} \\ x_{21} & x_{22} \ldots x_{2n} \ldots x_{2j} \\ x_{n1} & x_{n2} \ldots x_{nn} \ldots x_{jn} \\ .. & \\ . & \\ . & \\ x_{i1} & x_{i2} \ldots x_{in} \ldots x_{ij} \end{bmatrix} \quad (1)$$

In this matrix, the numerical value resulting from option i with indicator j, the indicator with positive utility is the profit index and the indicator with negative utility is the cost index.

Step 2: Normalization of the decision matrix. the scales in the decision matrix are unscaled. In this way, each of the values is divided by the size of the vector corresponding to the same index (i.e., the sum of the weights of the criteria is equal to one). As a result, normalized values are obtained using equation (2).

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}}} \quad (2)$$

Step 3: Weighting the normalized matrix, the decision matrix is actually an index and must be quantified. For this purpose, the decision maker determines a weight for each index. The set of weights (W) is multiplied by the normalized matrix from step 2.

$$W = (W_1, W_2, \ldots, W_j, \ldots, W_n) \qquad (3)$$

$$\sum_{j=1}^{n} W_j = 1$$

Step 4: Determine the positive ideal solution and the negative ideal solution values after constructing the weighted normalized decision matrix, the maximum values of each column are determined by equation (4) so that the positive ideal solution values are:

$$A^{+} = \left\{ \left(\max_i v_{ij} \middle| j \in J \right) \& \left(\min_i v_{ij} \middle| j \in J' \right) \middle| i \right\} = \left\{ v_1^{+}, v_2^{+}, \ldots, v_j^{+}, \ldots, v_n^{+} \right\} \qquad (4)$$

Then the minimum values for each column are determined by equation (5), the values are those of the negative ideal solution:

$$A^{-} = \left\{ \left(\min_i v_{ij} \middle| j \in J \right) \& \left(\max_i v_{ij} \middle| j \in J' \right) \middle| i \right\} = \left\{ v_1^{-}, v_2^{-}, \ldots, v_j^{-}, \ldots v_n^{-} \right\} \qquad (5)$$

J' refers to the cost index, and J to the profit index. The two virtual options created are the worst and the best solution.

Step 5: To obtain the size of the distances, the distance between each n-dimensional alternative is calculated by computing the Euclidean distance. Namely, the distance of option i to the positive and negative desirable options is calculated as follows:

$$S_i^{+} = \sqrt{\sum_{j}^{n} (v_{ij} - v_j^{+})^2} \qquad (6)$$

$$S_i^{-} = \sqrt{\sum_{j}^{n} (v_{ij} - v_j^{-})^2}$$

Step 6: Calculate the relative closeness to the ideal solution. This criterion is determined by the following formula. The distance between ideal and non-ideal points is used to calculate the relative proximity to an ideal solution according to equation (7).

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-} \tag{7}$$

Step 7: Ranking the options; finally the options are ranked. Using the descending order, the available options can be ranked according to the most important; the closer the value is to one, the better the solution (Magdalena & Brodny, 2022).

Results and Discussion

In this research, the Delphi approach was used to select the practical criteria for evaluating the sustainability of olive cultivation. These steps include the formation of the management team and the selection of the experts, the preparation of the questionnaire, the first sending to the experts, the verification, the re-sending as many times as necessary, the analysis, and finally, the report. In the first phase of the Delphi process, the desired questionnaire was prepared and a set of essential and influential criteria was drawn up in the form of a table and distributed by e-mail or in-person to the experts, who were asked to indicate their agreement or disagreement in the table. After collecting the questionnaires of the first phase, which took one month, the information was summarized, ordered and classified and tabulated in the format of the questionnaire of the second phase. It was taken into account that the criteria selected in the Delphi method have different importance and influence on the evaluation sustainability of olive cultivation, which is why the criteria had to be ranked. The selected criteria were ranked using the TOPSIS multi-criteria decision method.

From the surveys of farmers and owners of the olive groves studied, production and financial information were obtained over the last year (2022). We used a sample of 372 respondents whose statistical data are presented in Table 1. They are 38 agriculture students involved in olive production, 19 employees of an agricultural institution involved in olive cultivation, 14 researchers conducting research on olives and 301 farmers cultivating olives.

Table1- summary statistics of the sample

	Male	Female	Years of education	Students	Employees	Researchers	farmers
Number	253	119	12	38	19	14	301
Percentage	68	32		10.2	5.1	3.7	81

We asked respondents at the five Likert scale whether they believed olive production had been adapted at the regional level. As shown in Table 2, 73.2 percent of respondents indicated that adaptation has been successful in the general assessment of the adaptation of olive production in Golestan province.

Table2- General assessment of the adaption of olive cultivation

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Number	104	120	48	82	18
Percentage	28	32.2	13	22	4.8

The main criteria selected by the Delphi method are economic benefits (C1) with three sub-criteria such as increased income (C11), improved employment (C12) and transformation industries (C13), second, government support (C2) with two sub-criteria such as land allocation (C21), and loan facilities (C22); third, environmental factors (C3) with two sub-criteria such as soil quality (C31) and water supply (C32); and fourth, personal motivation (C4) with one sub-criteria, namely personal preferences (C41). All sub-criteria were asked at the five Likert scale ranging from absolutely excellent (A1), good (A2), average (A3), poor (A4), and very poor (A5), as shown in Table 3.

Table3- decision matrix for TOPSIS method

	A1	A2	A3	A4	A5
C11	21	33	66	78	174
C12	38	47	49	83	155
C13	158	115	50	17	32
C21	23	35	68	95	151
C22	45	49	116	57	105
C31	49	45	75	83	120
C32	45	63	70	99	95
C41	34	46	75	89	128

The normalized decision matrix is calculated by applying Eq. (2).

Table 4- normalized decision matrix

	A1	A2	A3	A4	A5
C11	0.0508	0.0762	0.1160	0.1298	0.1813
C12	0.0920	0.1085	0.0861	0.1381	0.1615
C13	0.3826	0.2656	0.0879	0.0283	0.0333
C21	0.0557	0.0808	0.1195	0.1581	0.1573
C22	0.1090	0.1132	0.2039	0.0948	0.1094
C31	0.1186	0.1039	0.1318	0.1381	0.1250
C32	0.1090	0.1455	0.1230	0.1647	0.0990
C41	0.0823	0.1062	0.1318	0.1481	0.1333

A weighted normalized decision matrix (Table 5) was then created by applying equation (3).

Table 5- weighted normalized decision matrix

	A1	A2	A3	A4	A5
C11	0.0102	0.0152	0.0232	0.0260	0.0363
C12	0.0184	0.0217	0.0172	0.0276	.0323
C13	0.0765	0.0531	0.0176	0.0057	0.0067
C21	0.0111	0.0162	0.0239	0.0316	0.0315
C22	0.0218	0.0226	0.0408	0.0190	0.0219
C31	0.0237	0.0208	0.0264	0.0276	0.0250
C32	0.0218	0.0291	0.0246	0.0329	0.0198
C41	0.0165	0.0212	0.0264	0.0296	0.0267

After creating the weighted normalized matrix, the maximum values of each column were determined using equation (4) and then the minimum values for each column were determined using equation (5) (Table 6).

Table 6- Ideal and Negative Ideal Solution Values

	A1	A2	A3	A4	A5
Positive	0.0102	0.0152	0.0172	0.0329	0.0362
Negative	0.0765	0.0531	.0408	0.0057	0.0067

Next, the positive and negative ideal distances for each sub-criteria were calculated using equation (6). Then the ideal and non-ideal point distances are used to calculate the relative closeness to the ideal solution using equation (7) (Table 7).

Table 7- The relative closeness to ideal solving solution

	S+	s-	C*
C11	0/0092	0/0862	0/9036
C12	0/0124	0/0778	0/8626
C13	0/0863	0/0232	0/2118
C21	0/0084	0/0849	0/9097
C22	0/0339	0/0658	0/6603
C31	0/0213	0/0697	0/7661
C32	0/0255	0/0689	0/7296
C41	0/0162	0/0762	0/8247

Finally, the ranking of the sub-criteria (income enhancement (C11), employment enhancement (C12), transformation industries (C13), land allocation (C21), credit facilities (C22), land quality (C31), water supply (C32) and personal preferences (C41)) was determined based on their relative proximity to ideal solution values (Table 8). The results show that the ranks of factors considered for evaluating olive cultivation adaptation are in the following order: Land Allocation (C21), Income Increase (C11), Employment Improvement (C12), Personal Preferences (C41), Soil Quality (C31), Water Supply (C32), Credit Opportunities (C22) and Transformation Industries (C13) from the highest to the lowest suitable alternative economic benefits, government support, environmental factors and personal motivation. The calculated relative proximity to the ideal solution results in the ranks.

Table 8- The ranking of sub-criteria through TOPSIS analysis.

	Rank	sub-criteria
C21	1	land assignment
C11	2	income increasing
C12	3	Employment
C41	4	personality preferences
C31	5	soil quality
C32	6	water facility
C22	7	facilities of loans
C13	8	transformation industries

Conclusion

It is important for every country needs to cater to crop adaptation and ensure food security. The evaluation after adaption in the olive sector, from the sustainability point of view of olive adaption in the region, is a complex and interesting feature. Farming systems and government support and olive oil industries, play a very important role in the future development of the sector in the next future. Especially in Iran, where olive oil chain is a pillar of agro-food business. In order to give a response to the need for policymakers and in order to help farms and olive oil industries to increase their competitiveness, this paper paid the way to support decisions, not only based on economic aspects but also capable to take into due consideration environmental and social implications.

This study presented the TOPSIS-based MCDM model to evaluate the yield of factors that lead to a sustainable localization of olive cultivation. According to this study, the proposed model identified important criteria using the Delphi method and classified alternatives using the TOPSIS method. Analysis results show that the ranking of criteria for olive production in Iran is as follows: Land Allocation, Income Increase, Employment Improvement, Personal Preferences, Soil Quality, Water Supply, Credit Opportunities and Transformation Industries.

The analysis conducted is important evidence as it underlines that MCDM approaches can easily address multidimensional decision-making issues in this area. Policy makers can support farmers and agricultural land can be used efficiently for this purpose. With these economic models, the goal of sustainable production, expressed in terms of decent work and economic growth, can be achieved.

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