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A Case Study of Zarand, Iran

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Abstract: Site selection and allocation of manufacturing and processing facilities are essential to sustainable economic productivity of a given product while preserving soil, the environment, and biodiversity. An essential criterion when evaluating various approaches to model land suitability for pistachio processing facilities is their adaptability to accommodate diverse perspectives and circumstances of managers and decision makers. Incorporating the concept of risk into the decision-making process stands as a significant research gap in modeling land suitability for pistachio processing facilities. This study presents a scenario-based multi-criteria decision-making system for modeling the land suitability of pistachio processing facilities. The model was implemented based on a stakeholder analysis as well as inclusion of a set of influential criteria and restrictions for an Iranian case study, which is among the top three producers. The weight of each criterion was determined based on the best-worst method (BWM) after the stakeholder analysis. Then, the ordered weighted averaging (OWA) model was used to prepare maps of spatial potential for building a pistachio processing factory in different decision-making scenarios, including very pessimistic, pessimistic, intermediate, optimistic, and very optimistic attitudes. Finally, the sensitivity analysis of very-high- and high-potential regions to changes in the weight of the effective criteria was evaluated and proved that the most important criteria were proximity to pistachio orchards, proximity to residential areas, proximity to the road network, and proximity to industrial areas. Overall, 327 km^2 of the study area was classified as restricted, meaning that they are not suitable locations for pistachio processing. The average estimated potential values based on the proposed model for very pessimistic, pessimistic, intermediate, optimistic, and very optimistic scenarios were 0.19, 0.47, 0.63, 0.78, and 0.97, respectively. The very-high-potential class covered 0, 0.41, 8.25, 39.64, and 99.78 percent of the study area based on these scenarios, respectively. The area of suitable regions for investment decreased by increasing risk aversion in decision making. The model was more sensitive to changes in the weights of proximity to residential areas, proximity to pistachio orchards, and proximity to transportation hubs. The proposed approach and the achieved findings could be of broader use to respective stakeholders and investors. Given the suitability of arid regions for planting pistachio and its relatively high profitability, the local authorities and decision makers can promote further expansion of the orchards, which can lead to better welfare of farmers and reducing rural-urban migration in the region.

Keywords: facilities' allocation assessment; GIS-MCDA; risk based; pistachio; sensitivity analysis

1. Introduction

The sustainable use and development of land are vital factors in economic growth [1–3]. One of the goals of land suitability and ultimately sustainable development programs is the selection and evaluation of different locations for the development of different uses [4–7]. This evaluation is an effective step for devising a sustainable development plan because by identifying and evaluating land suitability, development programs can be adapted to suit regional characteristics [8]. Optimal land use can help to achieve economic, social, ecological, and environmental efficiency for optimal use of land resources [9]. Therefore, it is necessary to determine suitability maps for different applications before development.

Industry can be considered the leading sector in regional economic development [10]. The location of manufacturing and processing facilities is of great importance for optimal land use, sustainable economic development, and increased productivity [11]. In other words, optimizing land use and determining optimal locations for the development of industrial areas can enhance sustainable development and reduce the waste of resources at the macro level. The feasibility of industrial development leads to cost reduction and the success of industrial units [12]. Conducting proper and appropriate feasibility studies, in addition to the economic impact on the performance of the industrial unit, will have social, environmental, cultural, and economic effects on the area of its construction.

Location selection for facilities is a multi-criteria decision-making problem. Determining the optimal location for the construction of facilities depends on a set of different factors, including accessibility and environmental, economic, social, etc., criteria [13,14]. Spatial decision making prevents decision makers from focusing on one criterion and losing sight of the others [15]. The integration of GIS and MCDA helps the decision maker to perform decision analysis functions such as location ranking [16]. GIS is used as a powerful and integrated tool for storing, manipulating, and analyzing industrial development criteria [17]. Considering that many criteria can affect location selection, the use of multi-criteria decision-making methods can facilitate the decision-making process by considering the key criteria [18–21].

The combination of GIS-MCDA has been used for various purposes such as the assessment of land suitability [11,22–25], renewable energy [26–29], vulnerability to natural hazards [30,31], socio-environmental resilience [32], agricultural management [33], habitat suitability [34], spatial modeling of migration [35], and urban management [1,36,37]. In past studies, various GIS-MCDA methods such as AHP, Fuzzy AHP, Fuzzy TOPSIS, ANP, VIKOR, ELECTRE, and PROMETHEE have been used for these applications. In some studies, GIS-MCDA capabilities were used in sustainable development of agriculture [38–40]. The focus of these studies has been on identifying and determining agricultural suitable land. In a number of other studies, attention has been paid to determining the optimal location for the development of agricultural product transformation facilities, which is one of the basic prerequisites for achieving sustainable development of agriculture. In addition, some studies used MCDA-based GIS to assess land suitability for the construction of facilities. Ramya and Devadas [10] used a hierarchical model combined with GIS to evaluate suitable locations for industrial development in the Tehri Garhwal district, India. Benaissa and Khalfallah [41] developed a model based on Delphi-AHP and GIS to assess land suitability for industrial activities to prevent land degradation in Bordj Bouarreridj, Algeria. Baghel [42] presented an integrated approach using GIS-based expert methods to prepare a mechanism for allocating land to industrial parks. The sites chosen for future industrial development were mostly near roads and railroads.

As a strategic product, pistachio is one of the most precious agricultural and medicinal products in the world [43]. Due to its high resistance to drought and salinity, it has been able to play a great role in improving the social and economic status of rural and urban areas in the central regions of Iran, especially the province of Kerman, which is facing many limitations in agricultural production [44]. Pistachio is called green gold thanks to its economic significance and holds a special, strategic place among horticultural products [45]. Therefore, it is highly regarded in Iran given its contribution to securing foreign currency, job creation, added value creation, and other economic aspects. Hard access to pistachio processing facilities in the province of Kerman has led orchardists to sell their products raw with low economic returns. Therefore, the development of pistachio processing facilities in suitable locations can boost the economic situation of these regions.

An essential criterion when evaluating various approaches to model land suitability for pistachio processing facilities is their adaptability to accommodate diverse perspectives and circumstances of managers and decision makers. Incorporating the concept of risk into the decision-making process stands as a significant research gap in modeling land suitability for pistachio processing facilities. Evaluating land suitability while considering the element of risk in decision making and the manager's specific approach and planning can be highly beneficial in allocating financial resources and time effectively to achieve sustainable development. The mental attitudes influencing decision making encompass a spectrum ranging from very optimistic and optimistic to neutral, pessimistic, and very pessimistic. Mapping the suitability of land for pistachio processing facilities holds great significance for each of these mental attitudes, aligning with sustainable development based on distinct timeframes and financial conditions. In optimistic and pessimistic mental attitudes, the level of risk in decision making is comparatively low and high, respectively. For instance, when financial and time constraints are absent, managers can incorporate the results derived from an optimistic outlook into their planning. Conversely, when faced with financial and time limitations, the results from a pessimistic perspective can inform their planning decisions.

This study aims to present a scenario-based multi-criteria decision-making system for measuring the spatial potential of pistachio processing facilities in the city of Zarand, the province of Kerman. A risk-based expert system based on GIS was used to achieve this goal. The advantage of this system is flexibility in creating different scenarios with an emphasis on decision-making risk.

The structure of the rest of the paper is as follows: In Section 2, the characteristics of the study area are described. In Section 3, the details of the data and methods used to model land suitability for pistachio processing facilities in different scenarios are stated. In Section 4, the results obtained from different implementations are presented. In Section 5, various dimensions of the method used and the results obtained in this study are discussed. Finally, the general conclusion of the study is presented in Section 6.

2. Study Area

The area studied in this research is the city of Zarand, located in the north of the province of Kerman, covering latitude 30°49′ N and longitude 56°34′ E. According to the latest census of the Iran Statistics Center in 2016, its population is 60,370. Zarand has a semi-desert climate with relatively hot summers and cold winters. Its average rainfall is 140 mm. The highest and lowest elevation of the studied area is 1608 and 3125 m above sea level, respectively. Recently, the entry of industry into the city of Zarand, as one of the less privileged areas of the province of Kerman, has been an effective step towards the all-round development of this city because economic enterprises have improved the cultural and economic infrastructure indicators of the region with a supportive view and in the form of fulfilling social responsibilities. The city covers over 43,000 hectares of pistachio orchards, of which 35,000 hectares have been harvested. Thanks to grafting, there are many pistachio varieties, the most famous of which are called Mumtaz, Ohadi, Kale Ghochi, Akbari, and Fandgi. Zarandi Mumtaz pistachio has the first rank in the world in terms of quality. In this city, a significant portion of the population consists of individuals engaged in farming, particularly those involved in pistachio-related occupations. Consequently, the establishment and enhancement of pistachio processing facilities can significantly contribute to elevating the quality of life for these residents. Considering that the pistachio processing facilities should not be far from the city due to easy access to the labor force and sales market, a buffer of 10 km from the border of the city of Zarand was assumed in this study. Figure 1 shows the geographic location of the study area.

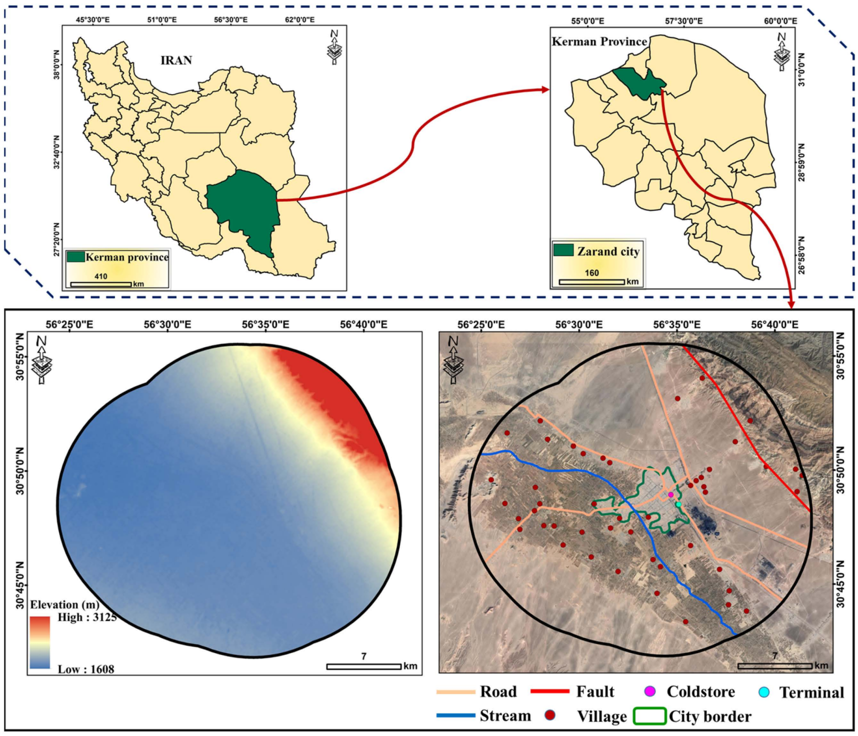

Figure 1. Geographical location of the study area.

3. Data and Methods

3.1. Data

Data collection is an integral yet time-consuming step in spatial potential assessment. The research data were obtained from various sources such as organizations and departments, satellite images, and statistical data. The primary data types included DEM data to obtain elevation and slope (https://earthexplorer.usgs.gov/ accessed on 24 August 2023), maps of urban and rural areas, gas and electricity lines, industrial areas, and coldstores (https://ncc.gov.ir/ accessed on 24 August 2023), a map of faults and landslide points (https://gsi.ir/ accessed on 24 August 2023), a map of pistachio orchards (https://www.maj.ir/ accessed on 24 August 2023), maps of the road network, a railway station, a terminal (https://www.mrud.ir/ accessed on 24 August 2023), and the stream network map (https://frw.ir/ accessed on 24 August 2023). Finally, after collecting the primary data layers, a spatial analysis was performed in ArcGIS to produce and analyze the information layers and prepare the criteria map according to their capabilities in each stage.

3.2. Methods

The flowchart of the main stages of the proposed method for spatial potential assessment of pistachio processing facilities is shown in Figure 2. The proposed method consists of five steps: (1) effective criteria were selected using the opinion of experts and specialists, and then, criteria and restriction maps were prepared using the spatial analysis; (2) Min and Max functions were used to standardize the values of the criteria map and Boolean logic was used to classify the study area into suitable and unsuitable classes; (3) using the

BWM method, the weight and importance of the criteria were calculated; (4) potential maps under different scenarios were prepared using the OWA model, and the OR operator was used for obtaining the maps of restrictions; and (5) finally, the sensitivity analysis of the area of classes with high and very high potential was performed by changing the weights of the criteria.

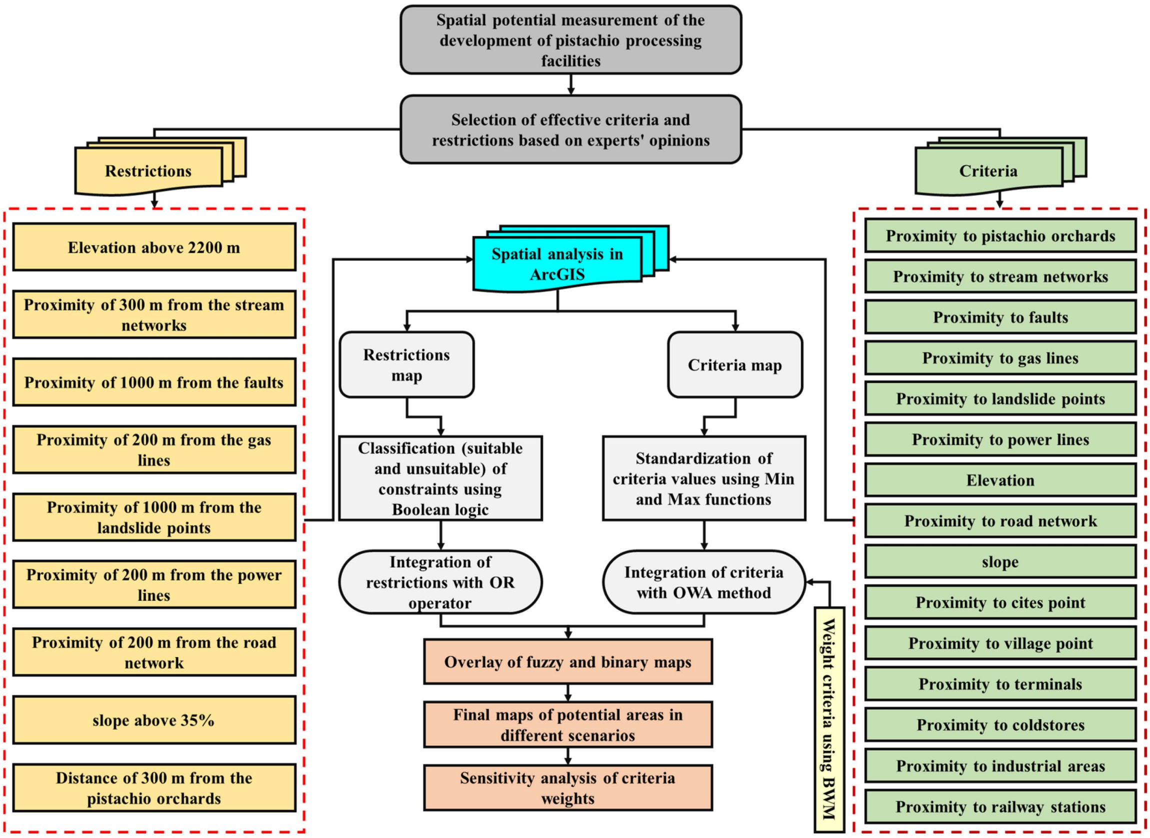

Figure 2. Flowchart of the main stages of the proposed method for spatial potential assessment of pistachio processing facilities.

3.2.1. Criteria and Restrictions

Choosing the suitable areas for measuring the spatial potential of the development of pistachio processing facilities is a multi-criteria decision-making process that requires careful consideration. The criteria were selected by interviewing experts and specialists and considering the social, geographical, and physical conditions of the study area. In this study, the opinions of 45 experts and specialists in the field of sustainable development, GIS, site selection, agriculture, and industrial facilities and places have been used. The selection criteria of these experts included practical and research experience, especially in relation to the location of transformation facilities.

Criteria were divided into two groups, namely restrictions and evaluation factors. Restrictions define areas that are not suitable for the development of pistachio processing facilities based on national and international standards. To determine such restricted areas, the study area was divided into suitable and unsuitable classes using Boolean logic. The evaluation factors were checked according to the suitable ranges for all possible locations. Finally, 15 spatial criteria and 9 restricted criteria were used here. Table 1 shows the list and description of criteria identified for the development of pistachio processing facilities in the study area.

Table 1. The list and description of criteria identified for the development of pistachio processing facilities in the study area.

Criteria	Description
Proximity to city and village	Pistachio processing facilities should not be far from urban and rural areas, as they host the workforce and central markets [46]. Therefore, location suitability increases as the proximity decreases. However, in order to reduce the negative effects that industrial areas may have on the urban environment, a proximity of less than 300 m from the city and 200 m from the village was considered a restriction.
Proximity to fault and landslide points	As the proximity to fault and landslide points increases, the location suitability increases since such events can cause serious damage [47]. Therefore, locations with a proximity of less than 1000 m were considered restricted areas.
Elevation and slope	The higher the slope and elevation, the higher the cost of energy transfer, construction, and equipment transport [28]. Therefore, a lower slope and elevation means higher suitability. Here, slopes over 35% and elevations over 2200 m were considered restricted areas.
Proximity to power transmission lines	Considering both easy access and cost saving [48], the lesser the proximity to the power grid, the higher the suitability. However, in order to reduce electrical hazards, areas with a proximity of less than 200 m were considered restricted areas.
Accessibility	Easy accessibility means higher investment opportunities and economic growth. In addition, the longer the proximity, the higher the transportation costs and production time [49].
Proximity to stream network	Being too close to water bodies can cause flooding hazards and economic loss [50]. According to the regulations of Iran's Environment and Forestry Organization, a proximity of less than 300 m from rivers was considered a restriction.
Proximity to coldstores	Proximity to coldstores is very important given their necessity for maintaining product properties and quality and increasing added value [41].
Proximity to pistachio orchards	A fundamental criterion in determining a suitable location for pistachio processing facilities is proximity to pistachio orchards [10,42]. Still, a proximity of less than 300 m was considered a restriction to prevent possible damage to pistachio orchards.
Proximity to industrial areas	Given the existence of suitable infrastructure, access to raw materials and equipment, and access to technology in industrial areas, the shorter the proximity, the higher the suitability [51].

3.2.2. Standardization of Criteria Values

To evaluate the location suitability, it is necessary to convert different indicators into one unit for the sake of comparison. The criteria may have a positive or negative relationship with the purpose of the research. Positive criteria indicate that higher values are preferred, such as proximity to fault and proximity to landslide points, whereas in negative criteria, lower values are preferred, such as proximity to gas lines and proximity to road networks. Therefore, the minimum (Equation (1)) and maximum (Equation (2)) methods, respectively, were used to standardize these (positive and negative) criteria.

$$Negative = \frac{C_j^{max} - C_{ij}}{C_j^{max} - C_j^{min}} \tag{1}$$

$$Positive = \frac{C_{ij} - C_j^{min}}{C_j^{max} - C_j^{min}} \tag{2}$$

where C_j^{min} and C_j^{max} are the minimum and maximum values of the jth criterion, respectively, and C_{ij} is the value of the ith position relative to the jth criterion [52,53].

3.2.3. Criteria Weight Calculation

The pairwise comparisons used by the expert are intended to reveal the relative preferences of m options or actions in situations where it is not possible to assign values to such options or actions based on specific criteria [54]. For example, under the method based on a relative scale, in the AHP, which was first introduced by Saaty [55], weights are derived through a pairwise comparison of criteria, and scores are derived through a pairwise comparison of options based on criteria. The main challenge in the pairwise comparison method is the lack of compatibility of the matrices, which often occurs in practice. Rezaei [56] states that inconsistencies occur for various reasons, including changes/corrections in expert opinions, and the order in which comparisons are made. Moreover, inconsistencies may lead to the loss of validity in previously used methods. For this purpose, Rezaei [56] introduced BWM. The BWM method is based on the assumption that decisions are generally evaluated based on the best and worst options, and other options are scored or weighted accordingly. As a result, instead of a pairwise comparison of all indicators, it is enough to compare all indicators with the best (most important) and worst (least important) ones [57]. When we have n indices, the total number of pairwise comparisons is n^2. Here, the nth comparisons are also avoided because the comparison of each index is with itself and $a_{ij} = 1$, and so the remaining comparisons become equal to $n(n-1)$ [28]. There are two types of comparisons in pairwise comparisons: reference comparison and secondary comparison. Reference comparison a_{ij} is a comparison where option or criterion i is the best or j is the worst indicator. Meanwhile, comparison aij is regarded as a secondary comparison if neither i nor j are the best or the worst elements and $aij \geq 1$. As a result, in the BWM method, the total number of comparisons is equal to $2n - 3$ [56]. The following are the steps of the BWM method [58]:

Step 1: Specify the set of decision criteria.
Step 2: Determine the best (most preferred or most important) and worst (least important or weakest) criteria.
Step 3: The preference of the best criteria over other criteria and also the preference of other criteria over the worst criteria are determined by assigning numbers 1 to 9. This best-to-others vector can be written as Equation (3):

$$A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn}) \tag{3}$$

where a_{Bn} represents the preference degree of the criterion j compared to the worst criterion (B), and a_{BB} is equal to one. This others-to-worst vector can be written as Equation (4):

$$a_w = (a_{1w}, a_{2w}, \ldots, a_{nw})^T \tag{4}$$

where a_{jW} represents the preference degree of the criterion j compared to the worst criterion (W), and a_{WW} is equal to one.
Step 4: Calculating optimal criteria weights.

To determine the optimal values, the weight assigned to each $\frac{w_B}{w_j}$ and $\frac{w_j}{w_w}$ pair must yield $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_w} = a_{jw}$. To satisfy these conditions for all js, the solution must have the lowest maximum absolute value for $\frac{w_j}{w_w} = a_{jw}$ and $\left|\frac{w_j}{w_w} = a_{jw}\right|$ differences for all criteria. Considering the non-negativity restrictions and weight normality, the problem can be modeled as Equation (5):

$$\begin{gathered} min\overset{max}{j} \left\{ \left|\frac{\omega_B}{\omega_j} - a_{Bj}\right| . \left|\frac{\omega_j}{\omega_W} - a_{jW}\right| \right\} \\ s.t \\ \sum_{j=1}^{n} w_j = 1 \\ w_j \geq 0.\ for\ all\ j \end{gathered} \tag{5}$$

The value of the compatibility rate in the best-worst method can be calculated using the value of ξ and the compatibility index, through Equation (6):

$$Consistency\ Ratio = \frac{\xi}{Consistency\ index} \tag{6}$$

where ξ represents the compatibility ratio. Consistency values close to 1 indicate less consistent and stable comparisons, whereas those close to 0 indicate more consistency and stability in the comparisons. Table 2 shows the compatibility index values:

Table 2. Compatibility index values concerning the priority of the best criterion over the worst criterion.

a_{BW}	1	2	3	4	5	6	7	8	9
$CI\ (max\xi)$	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

3.2.4. Land Suitability Modeling under Different Scenarios

In this study, the OWA method was used to model land suitability for the development of pistachio processing facilities in different scenarios. In past studies, this method was used in various applications such as potential of renewable energies [4,28], vulnerability and resilience [15,59], and modeling the physical growth of cities [60]. OWA is a multi-criteria integration operator developed by Yager [61]. This method has two types of weights [62]; one is a criterion weight and the other is an order weight. The criterion weight shows the relative importance of one criterion over another criterion and is the same for all its cells in an information layer. But the order weights are in the form of a set, the number of which is equal to the number of criteria layers. For each cell in the final raster layer, there is an ordered set of weights. These weights are obtained from the cell values of the existing criterion layers, which are arranged in descending order.

Since the set of sequential weights is $V = [v_1, v_2, \ldots, v_n]$, with $v_j \in [0,1]$ for $j = 1,2,3,\ldots,n$ and $\sum_{i=1}^{n} v = 1$, the OWA operator is defined as Equation (7):

$$OWA_i = \sum_{j=1}^{n} \left(\frac{u_j v_j}{\sum_{j=1}^{n} u_j v_j} \right) z_{ij} \tag{7}$$

where z_{ij} is the value of the i^{th} cell according to the j^{th} criterion, u_j is the weight of the j^{th} criterion, which is according to the relationship between the j^{th} criterion and decision-maker priorities, and v_j is the order weight [63]. An important feature of the OWA operator is that, unlike many other aggregate operators, multiple answers can be created based on the mental characteristics of the decision maker by using a decision matrix [64]. The most important difference between this operator and other aggregation operators is that OWA provides the possibility of flexible aggregation in a range between minimum and maximum, and takes into account the level of risk-taking/risk-aversion of the decision maker [65]. Considering the sensitivity of decision making in high-risk and stressful jobs such as investing, OWA yields more accurate and logical results [66]. This is because it is possible to calculate the weight of each option and its ranking by considering different degrees of optimism for decision makers to determine the best option.

Ordinal weights are associated with tradeoffs and risk taking. The numbers obtained from these two concepts are between zero and one [67]. The riskiness value indicates how similar this operator (obtained from the conceptual quantifier) is to the logical OR operator. The closer this number is to 1, the more risk-taking it is. The risk taking of this operator is because it is like the set community operator and places the maximum number of input map pixels in the output map. This action causes the maximum values to appear in the output map, while not all criteria play a role in creating the final map. The unsuitable locations, which cause risk in decision making, are then identified. The tradeoff value can be expressed as the size of the dispersion of order weights. The tradeoff maximum is for when the order weights are equally distributed among the criteria. A tradeoff value of 0 indicates non-tradeoff and a tradeoff value of 1 indicates a complete tradeoff [68]. Equations (8) and (9), respectively, show how to calculate risk and tradeoff.

$$ORness = \sum_{j=1}^{n} \left(\frac{n-j}{n-1} \right) \lambda_j,\ 1 \leq ORness\ \leq 0 \quad (8)$$

$$TRADE - OFF = 1 - \sqrt{\frac{n \sum_j (\lambda_j - 1/n)^2}{n-1}} \quad (9)$$

where n is the number of criteria, j is the order of the criteria that are sorted in descending order, and λ_j is the order weight of the j^{th} criterion [64].

In this study, land suitability maps for the development of pistachio processing facilities for the study area were prepared in very pessimistic, pessimistic, intermediate, optimistic, and very optimistic scenarios based on the OWA method. The land suitability value obtained from the OWA method in each scenario ranges from 0 (low land suitability) to 1 (high land suitability). Also, land suitability maps for the construction of pistachio processing facilities in five classes (very low (0–0.2), low (0.2–0.4), moderate (0.4–0.6), high (0.6–0.8), and very high (1–0.8)) were classified. Then, the area of each class was calculated in different scenarios.

3.2.5. Sensitivity Analysis

There are different methods to perform the sensitivity analysis of the weight of the criteria. One of the most used methods of a sensitivity analysis is the method of changing each input factor to observe its effect on the output. This method is known as the OAT method [69]. In this method, any change in output is clearly due to a change in a criterion. By changing one criterion, all other criteria can be kept constant and the results can be compared [70].

In the OAT method, there are three common methods for analyzing the sensitivity of criteria: (1) changing criteria weights, (2) changing criteria values, and (3) changing relative importance of criteria [71]. In this study, changing the weight of criteria was used in order to identify criteria that are sensitive to weight change and to quantify changes in the priority of criteria. In this method, the user must define three parameters: the main change criterion, range of percent change, and increment of percent change. The main change criterion is the criterion whose weight will change in current executions. The range of percent change can be a limited set of discrete percentage changes from the main weights of the criteria. In this method, one interval can be used for all criteria or a different interval can be used for each criterion. The increment of the percent change parameter also expresses the percentage by which the weight of each criterion changes, which should not exceed the percentage change range [72]. After changing the weight of the main variable criterion according to the increase in the percentage change, the weights of other criteria are also changed to establish the condition that the total weight of the criteria must be equal to one [4].

4. Results

The weight of the effective criteria in determining the optimal location for the construction of pistachio processing factories is shown in Table 3. The consistency rate of the determined weights for different criteria was 0.003, which shows the high consistency of experts in determining the weight of these criteria. The criteria of proximity to pistachio orchards and proximity to gas lines had the highest and lowest weights. Proximity to pistachio orchards, proximity to the city and village, proximity to the road network, and proximity to facilities had a higher weight than other criteria. The weights of elevation and slope criteria were 0.05 and 0.06, respectively. The influence of the impact type of all the criteria on determining optimal locations was minimal, except for the proximity to faults and proximity to landslide points.

Table 3. Weight of effective criteria calculated using the AHP method.

Criteria	Weight	Type of Impact
Proximity to city	0.12	Minimum
Elevation	0.05	Minimum
Proximity to faults	0.04	Maximum
Proximity to gas lines	0.02	Minimum
Proximity to landslide points	0.04	Maximum
Proximity to pistachio orchards	0.16	Minimum
Proximity to power lines	0.03	Minimum
Proximity to railway stations	0.05	Minimum
Proximity to stream networks	0.04	Minimum
Proximity to road networks	0.10	Minimum
Proximity to industrial areas	0.09	Minimum
Slope	0.06	Minimum
Proximity to coldstores	0.03	Minimum
Proximity to terminals	0.07	Minimum
Proximity to village points	0.10	Minimum

Maps of the criteria used in this study are shown in Figure 3. Spatial distribution of values of effective criteria in determining land suitability for the development of pistachio processing facilities is heterogeneous and different from each other. The least spatial changes in the studied area are related to the criteria of elevation and slope. According to these criteria, the areas located in the northeast of the studied area have a lower suitability than other areas for the construction of pistachio processing facilities. The areas located in the southwest of the study area have a higher suitability than other areas, especially the north and southeast of the study area, due to being located at a greater proximity to landslide points. In terms of criteria of proximity to a fault, proximity to pistachio orchards, proximity to stream networks, and proximity to gas lines, the north and northeast regions have a lower ratio than other regions. The spatial changes that are of proximity to the city, proximity to the village, proximity to coldstores, proximity to terminals, proximity to industrial areas, and proximity to landslide points are radial. But the spatial adjustments of the proximity to stream networks, proximity to road networks, proximity to gas and electricity lines, and proximity to pistachio orchards are linear. The city of Zarand has been studied in the center of the region; therefore, in terms of many criteria such as access to the urban area, coldstores, a terminal, industrial areas, etc., the central areas have a higher proportion than other areas. The values of the criteria are variable between zero and one. So, a value of one (red color) indicates a high potential and a value of zero (blue color) indicates a low potential for the establishment of pistachio processing facilities. The visual examination of the maps shows that the central parts of the study area are more suitable locations in terms of most of the effective criteria.

Some parts of the study area fall into the restricted category; that is, they are not suitable for the construction of a pistachio processing industry factory. Figure 4 shows the map of restrictions. Almost 33% of the studied area is considered as a restricted area with existing pistachio garden lands. In terms of slope and elevation, respectively, 3.6% and 5% of the studied area are classified in the restriction class. In terms of fault and landslide criteria, some of the areas located in the east, northeast, and north of the study area are classified as restriction classes. The development of pistachio processing facilities in these areas is limited in terms of safety against natural hazards. Also, 5.84% of the area under study is located within 300 m of the waterway network, which is one of the geographical limitations in the development of transformation facilities due to the risk of flooding. In total, 5.5, 2.48, and 5.75% of the area of the studied area are defined as restrictions due to being within the boundaries of the road and gas and power lines. According to different criteria, more than 60% of the study area is classified as restricted.

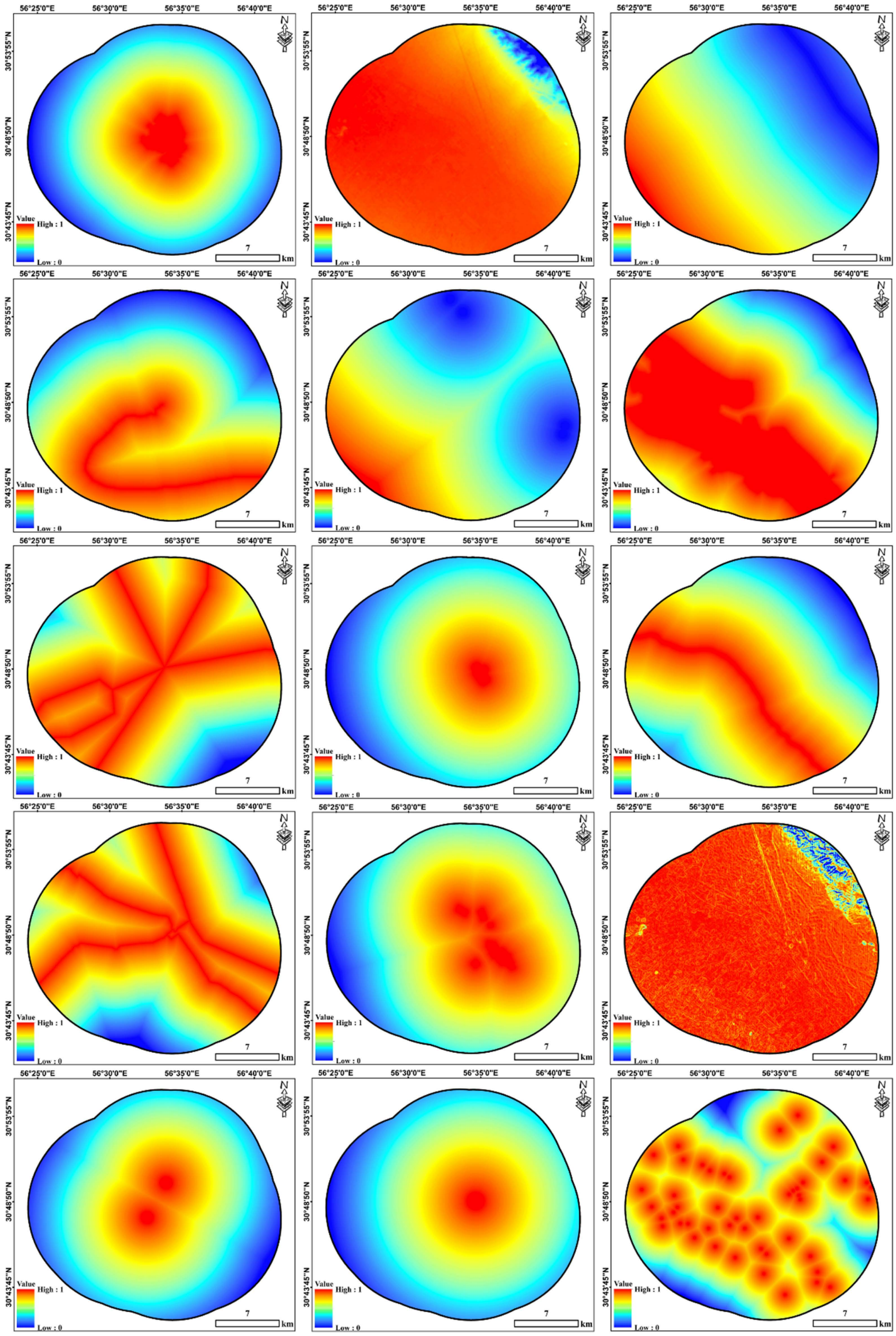

Figure 3. Standardized map of criteria (from left to right); proximity to city, elevation, proximity to faults, proximity to gas lines, proximity to landslide points, proximity to pistachio orchards, proximity to power lines, proximity to railway stations, proximity to stream networks, proximity to road networks, proximity to industrial areas, slope, proximity to coldstores, proximity to terminals, proximity to villages.

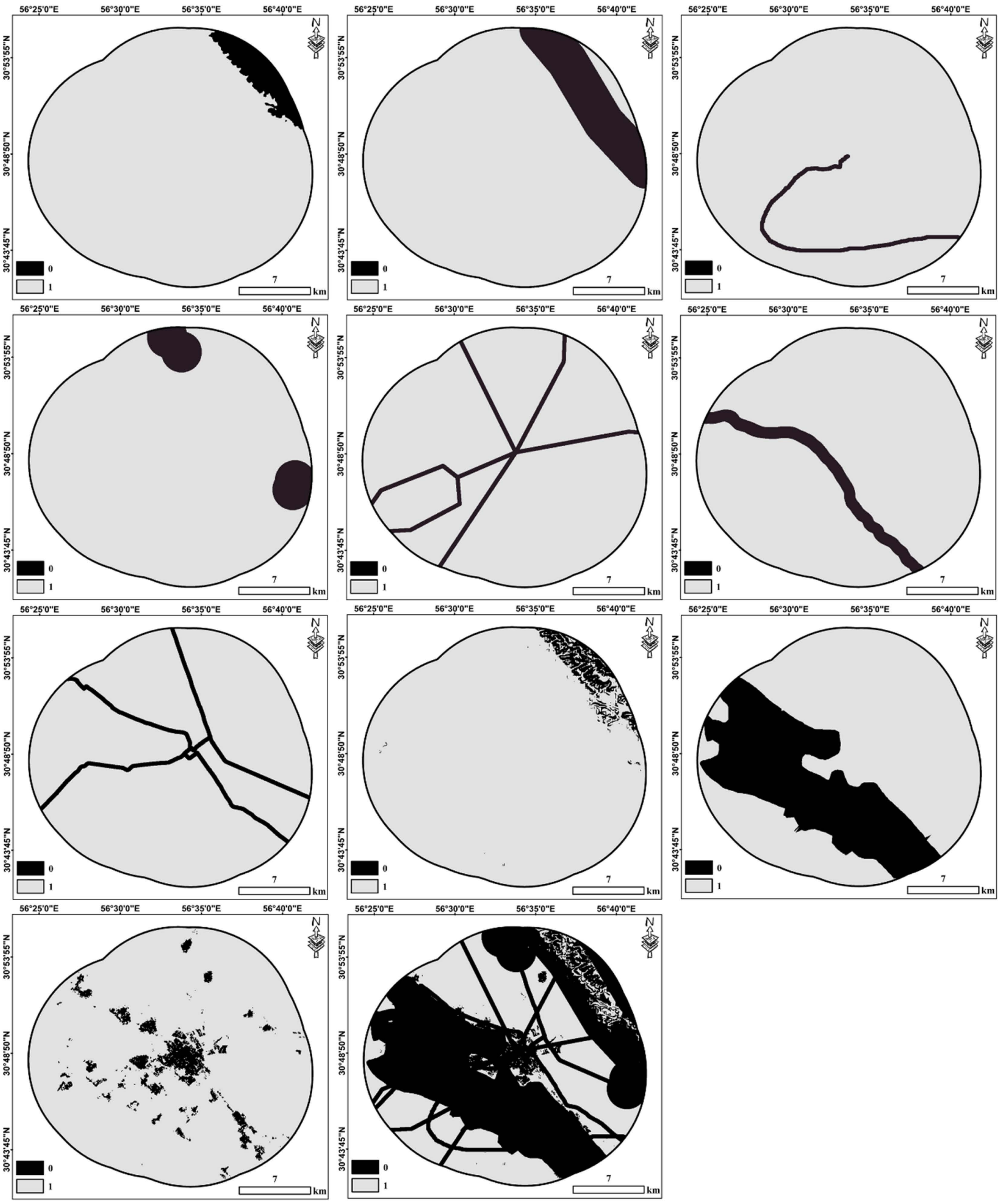

Figure 4. Maps of restrictions for the establishment of pistachio processing facilities (from left to right); elevation above 2200 m, proximity of 1000 m from faults, proximity of 200 m from gas lines, proximity of 1000 m from landslide points, proximity of 200 m from power lines, proximity of 300 m from stream networks, proximity of 200 m from road networks, slope above 35%, proximity of 300 m from pistachio orchards, proximity of 300 m from city, and 200 m from village; total restrictions for the establishment of pistachio processing facilities.

The potential maps for the construction of pistachio processing factories in different risk scenarios in decision making obtained from the OWA model are shown in Figure 5. With the increase in the degree of risk scenarios, the amount of areas with high potential and suitability for the construction of pistachio packaging factories increases. In the very pessimistic scenario map, many areas in the study area have potential values less than 0.5, while in the very optimistic scenario, almost the entire study area has potential values above 0.5. Due to the proximity to urban area, industrial areas, coldstores, a terminal, etc., the potential of the central areas in the study area is higher than the peripheral areas. But the difference between central and peripheral areas in very pessimistic scenarios is higher than in optimistic and very optimistic scenarios.

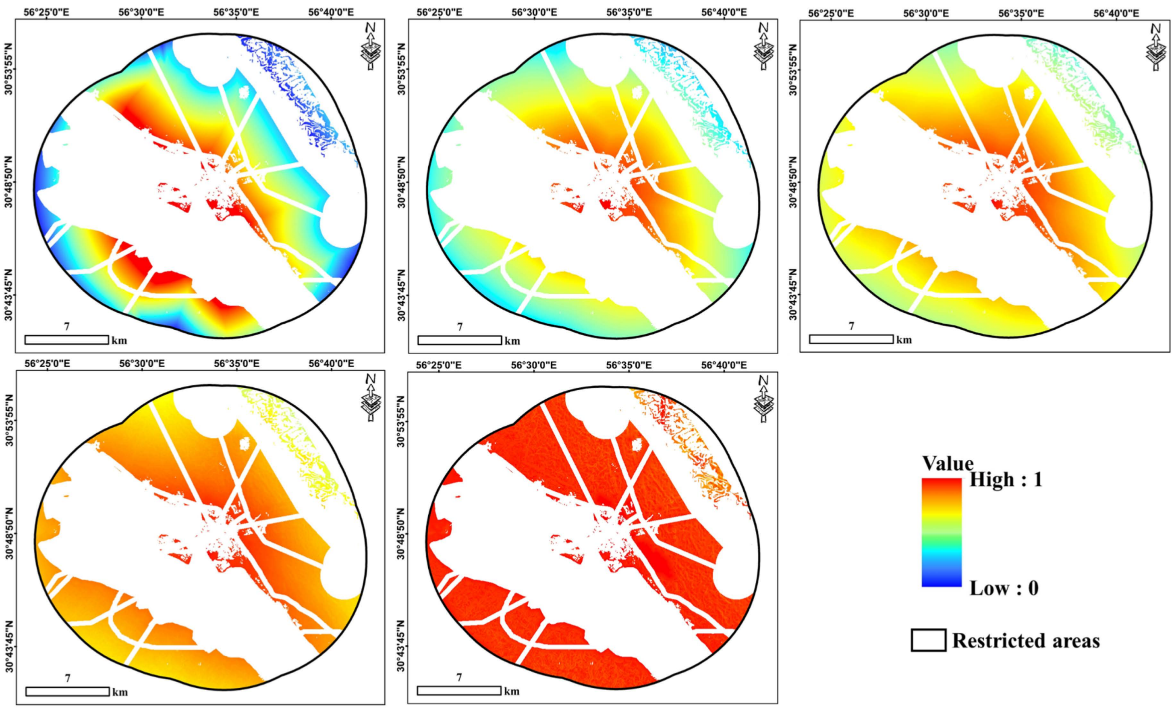

Figure 5. Potential maps for the construction of pistachio processing factories in different decision-making risk scenarios (from left to right; very pessimistic, pessimistic, intermediate, optimistic, and very optimistic).

The suitability values of the statistical parameters of the potential maps in different decision-making risk scenarios are shown in Table 4. The average values in very pessimistic, pessimistic, intermediate, optimistic, and very optimistic scenarios are 0.19, 0.47, 0.63, 0.78, and 0.97, respectively. These results show that with the increase in the degree of optimism, the amount of potential and suitability increases. The standard deviation values of these maps for very pessimistic, pessimistic, intermediate, optimistic, and very optimistic scenarios were 0.09, 0.13, 0.10, 0.07, and 0.02, respectively. The standard deviation values show that the maps based on pessimistic and intermediate scenarios have the highest heterogeneity of potential values. The range of changes in potential values calculated for the pixels of the study area in the very optimistic scenario was 0.26, which is less than in other scenarios. This value was 0.55, 0.66, 0.58, and 0.45 for very pessimistic, pessimistic, intermediate, and optimistic scenarios, respectively.

Table 4. Statistical parameters of risk scenarios.

	Min	Max	Mean	STD
Very pessimistic	0.01	0.56	0.19	0.09
Pessimistic	0.18	0.84	0.47	0.13
Intermediate	0.33	0.91	0.63	0.10
Optimistic	0.51	0.96	0.78	0.07
Very optimistic	0.74	1	0.97	0.02

Classified potential maps in different risk-based decision-making scenarios are shown in Figure 6. The spatial distribution of different potential classes varies in different decision scenarios. In the very pessimistic scenario, the potential map includes very low, low, and medium classes. Based on this scenario, only a small and limited area of the central areas of the study area has medium potential, which is located in the center of the study area. In the pessimistic scenario, the study area is classified into low-, medium-, high-, and very-high-potential classes. The obtained map based on this scenario for the study area has a very low class. Areas with low potential are marginal areas of the study area and areas with very high potential also cover a small part of the center of the study area. In other scenarios, the area of regions with high- and very-high-potential classes increases by increasing the degree of risk and optimism in decision making. In the optimistic scenario, the entire study area is classified into two classes of high and very high potential. Based on the very optimistic scenario, the entire study area was classified in a very high class. In other words, for the risk-taking investor, the entire study area, except for the restricted areas, is suitable for the development and construction of a pistachio processing factory.

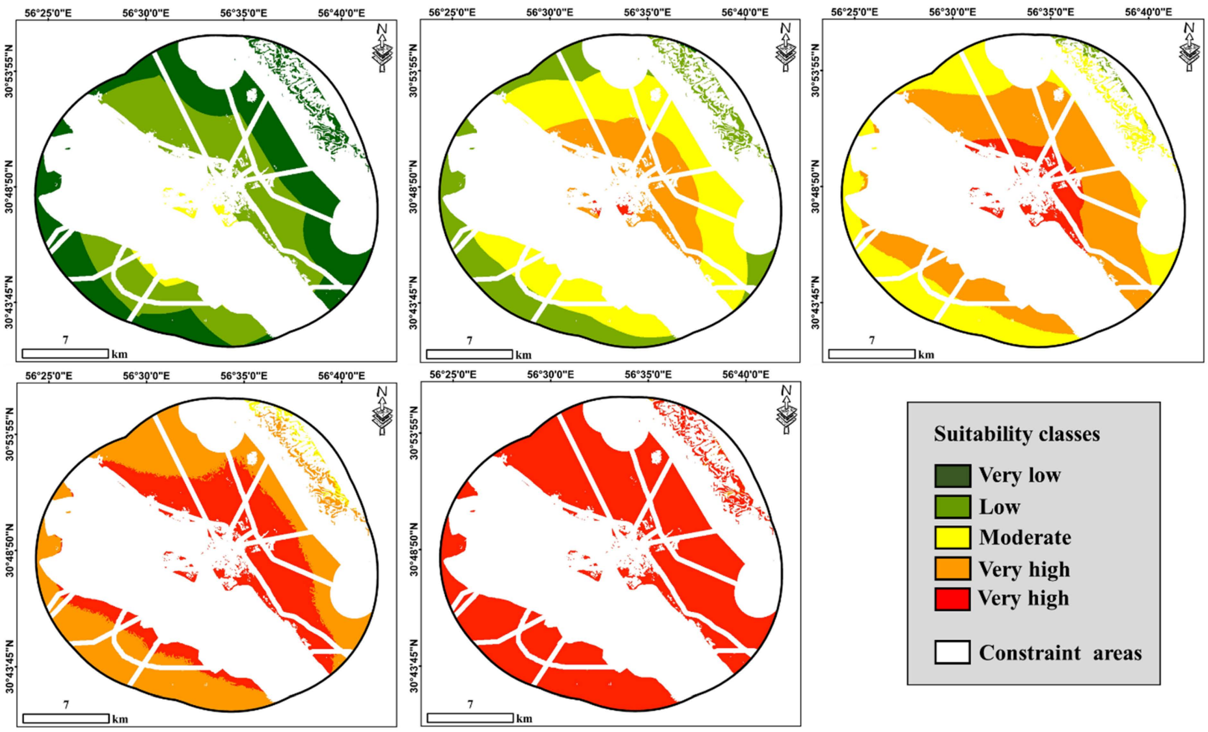

Figure 6. Suitability maps for the establishment of pistachio processing facilities in different risk scenarios (from left to right); very pessimistic, pessimistic, intermediate, optimistic, and very optimistic.

The area coverage percentage in the potential map classes under different risk scenarios is shown in Table 5. Here, 53.1% and 0.15% of the study area were classified in the very-low-potential class under the very pessimistic and pessimistic scenarios, respectively. The rest of the scenarios had no very-low-potential class. The coverage percentages of the high-potential class under very pessimistic, pessimistic, intermediate, optimistic, and very optimistic scenarios were 0, 19.47, 59.54, 54.76, and 0.22%, respectively. These values for the very high class under these scenarios were 0, 0.41, 8.25, 39.64, and 99.78 percent, respectively. With the increase in the degree of risk aversion, the number of suitable areas decreased.

The sensitivity analysis results of the percentage of areas with high and very high suitability are shown in Figure 7. These values are highly sensitive to the change in the criteria of proximity to the city, proximity to pistachio orchards, and proximity to road networks. By increasing the weight of these criteria, the percentage of areas with high and very high suitability increased significantly. Additionally, increasing the weights of the criteria for the distance from pistachio gardens, distance from cold storage, and distance from the road network up to 0.6 results in a significant increase in the percentage of areas with high and very high potential. For weights higher than 0.6, the changes in the percentage of these classes are limited. The percentage of areas with a high and very high suitability degree had a low sensitivity to the change in the weight of proximity to gas and power lines and proximity to terminals. Increasing the weight of proximity to a fault, slope, elevation, and proximity to stream networks caused a decrease in the percentage of areas with high and very high suitability. Increasing the weight of the fault distance criterion up to 0.4 leads to a noticeable reduction in the percentage of areas with high and very high potential.

Table 5. Coverage percentage of different classes under different risk scenarios.

	Very Low	Low	Moderate	High	Very High
Very pessimistic	53.10	45.13	1.77	0.00	0.00
Pessimistic	0.15	31.13	48.85	19.47	0.41
Intermediate	0.00	0.99	36.17	54.59	8.25
Optimistic	0.00	0.00	1.59	58.76	39.64
Very optimistic	0.00	0.00	0.00	0.22	99.78

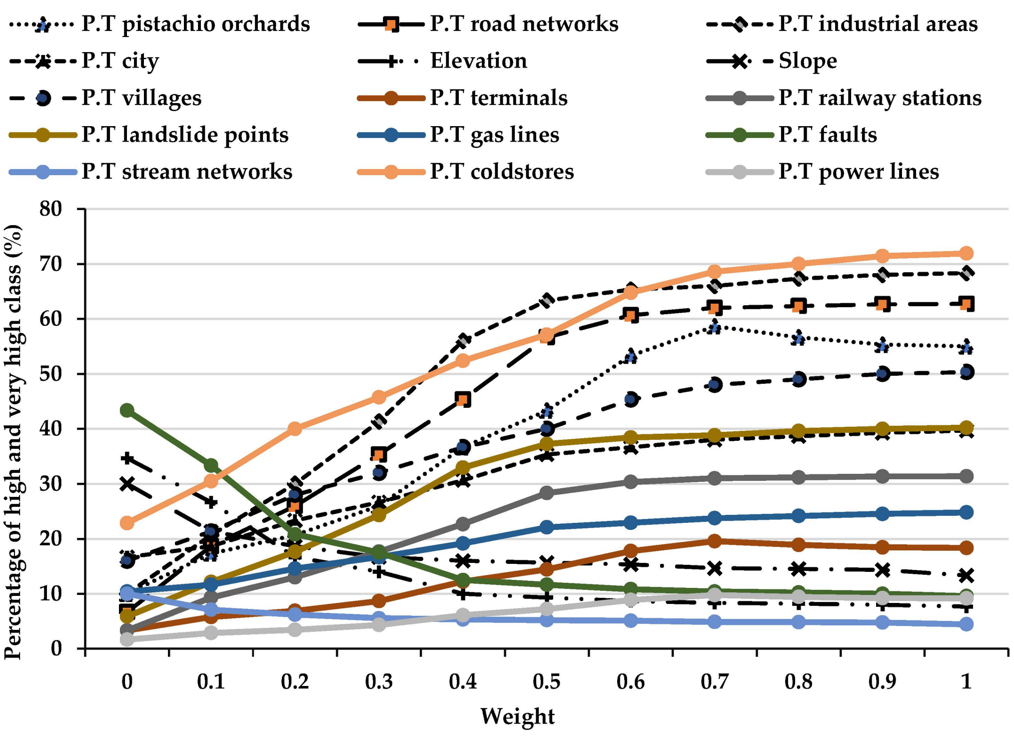

Figure 7. Sensitivity analysis of the percentage of areas with high and very high suitability to changes in criteria weights (Note: P.T (proximity to)).

5. Discussion

Determining the optimal location for the establishment of horticultural and agricultural product processing facilities is of great importance. A suitable location can prevent future economic, environmental, etc., costs and is a major effective factor in achieving local and regional sustainable development [10]. This study was the first attempt to determine potential and optimal locations for the development of pistachio processing facilities. In several previous studies, the optimal measurement potential was evaluated for some other industries such as healthcare [73,74], coffee [75], photovoltaics [76], steel [77], and compost food waste [78,79].

Determining the optimal location for the development of pistachio processing facilities is inherently a spatial decision and depends on various criteria, including economic, accessibility, and environmental criteria. Therefore, in this study, a GIS-MCDA model was used to assess the potential of different areas for the development of pistachio processing facilities. The accuracy and efficiency of GIS-MCDA models depend on the selected effective criteria, criterion weights, and the efficiency of aggregation models [80]. These criteria must enjoy certain conditions such as comprehensiveness and compatibility and can be selected from previous studies and expert opinions. Due to a shortage of studies on the topic addressed here, this study used the opinion of experts for this purpose.

The accuracy of criteria weights has a direct effect on the accuracy of the final model output. The methods of determining criteria weights can be divided into data-based, knowledge-based, and integrated methods [58]. Data-based methods are useful when information and past events are available [81]. This study employed the best-worst method, which falls into the knowledge-based category. In this method, experts determine the criteria weights. Considering that there is a difference of opinion among experts regarding the validity of different criteria, it is vital to calculate the compatibility rate. The condition for the acceptance of the weight calculated for different criteria based on the best-worst method is an acceptable compatibility rate [56]. Some of the advantages of the best-worst method are (i) generating more reliable criteria results, (ii) requiring less original pairwise comparison information, and (iii) smoothly fusing with other methodologies to manipulate uncertain information in the decision process [82].

In this study, the OWA model was used to aggregate the standardized values as well as the weights of the criteria. This method is more flexible than other methods such as WLC. The output and results of the OWA model can be used by a wide range of stakeholders, including managers, planners, and investors. Stakeholders with pessimistic attitudes are usually more strict in determining the optimal locations. Therefore, in this case, the selected locations must have suitable conditions in terms of a large number of effective criteria, whereas for optimistic stakeholders, a location can be optimal if it has suitable conditions in terms of a small number of effective criteria. In the OWA model, the ORness parameter regulates the degree of optimism and pessimism. Therefore, by changing the value of this parameter, it can produce different results that are suitable for stakeholders with different attitudes. The results of ORness = 0 are suitable for very pessimistic stakeholders and the results of ORness = 1 are suitable for very optimistic stakeholders. The OWA model has been used in several previous studies on measuring the potential of renewable energies [4,26,83], vulnerability and resilience [15,80], assessment of land suitability [84], and modeling the physical growth of cities [60].

For areas where there are pistachio processing facilities, the method proposed in this study can be used to evaluate the suitability of the existing situation and suggest new optimal areas. In some past studies, the outputs of GIS-MCDA models have been used to evaluate existing uses in an area such as restaurants [85]. However, the accuracy and uncertainty of the results of these models should be considered. In this study, the uncertainty caused by changing the weight of the criteria was investigated. The output of the model has a high sensitivity to the change in the weight of some criteria, such as the proximity to coldstores and the proximity to industrial areas, and a low sensitivity to the change in the weight of some other criteria, such as the proximity to power lines and proximity to stream networks. However, the efficiency of aggregation models is also effective on the accuracy and uncertainty of the final results of GIS-MCDA models, which is recommended to be paid attention to in future studies. Also, the use of algorithms based on artificial intelligence in modeling and analyses can also reduce uncertainty [86–90].

6. Conclusions

Measuring the spatial potential of processing facilities can be of great importance. The city of Zarand, Kerman, is one of the hubs of pistachio production in the world. This highlights the importance of determining the optimal location for the development of pistachio processing factories in this region. Different investors have different mental attitudes. Some of them are risk-taking and some are risk-averse. Therefore, it is of great importance to present the results of such spatial potential assessments based on different intellectual scenarios of investors. Including the concept of risk in the decision-making process is an important research gap in assessing land suitability for the development of pistachio processing facilities. This study presented for the first time a multi-criteria decision-making system based on risk in making decisions for the development of pistachio processing facilities. In this study, a scenario-based multi-criteria decision-making system was presented for measuring the spatial potential of developing pistachio processing factories. This system can prepare potential maps based on the attitude of different groups of investors, including very pessimistic, pessimistic, intermediate, optimistic, and very optimistic. Then, the OWA model was used to develop pistachio processing facilities in different decision-making scenarios. The research results showed that the effective criteria considering location selection have different weights. Proximity to pistachio orchards and proximity to gas transmission lines had the highest and lowest weights, respectively. With the increase in the degree of risk taking by investors, suitable locations increase. The results of the proposed system can be useful and practical for a wide range of stakeholders, including investors, managers, planners, and policy makers with different intellectual attitudes and risk tolerance. One of the remaining gaps in this study is the evaluation of uncertainty caused by different sources in the final result. It is suggested to use large-group decision-making methods in future studies to reduce the uncertainty in weights due to a low number of experts. Also, the development and use of a scenario to evaluate the accuracy of suitability maps for the establishment of pistachio processing facilities can be considered in future studies. Future studies can also use the system proposed in this study to flexibly locate suitable locations for different facilities based on different stakeholder attitudes.

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Abbreviations

GIS	Geographic Information System
MCDA	Multi-criteria Decision Analysis
OWA	Ordered Weighted Averaging
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	VlseKriterijumska Optimizcija I Kaompromisno Resenje
ANP	Analytical Network Process
ELECTRE	Elimination and Choice Translating Reality
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
DEM	Digital Elevation Model
BWM	Best-Worst Method
OAT	One-At-a-Time

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