The Use of Multi-Criteria Decision Analysis (MCDA) and Geographic Information System (GIS) in Selection of Greenhouse Site Location: The Case of Aydin Region in Türkiye

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Abstract: The aim of this study was to determine the most suitable areas for greenhouse sites and the suitability of the sample sites in Aydin region by using Geographic Information System (GIS) and Multi-Criteria Decision Analysis methods. For this purpose, in line with the literature researches and expert opinions, five main location selection criteria (topography, soil, climate, water and economy) and two separate location selection constraints (land use capability class and distance from the surface water resources) were considered. In addition, 160 sample sites were selected from existing greenhouse sites in the study area through purposeful sampling method and their suitability was questioned. The scoring and pairwise comparison methods used in the Analytical Hierarchy Process (AHP) method were preferred for weighting the evaluation criteria. In the review, according to all criteria and constraints, it was determined that 2.4% of the study area was "most suitable", 33.4% was "suitable", 31.4% was "moderately suitable", 0.7% was "slightly suitable", 29.6% was "unsuitable", and 2.5% was "out of evaluation" area. In addition, it was determined that 1.9% of the sample sites selected were "most suitable", 10.1% were "suitable", 0.6% were "moderately suitable", and 87.3% were "unsuitable". According to these results, it was understood that the lands in the study area were not generally suitable for the greenhouse site in terms of the distance from the surface water resources and the land use capability class. In addition, recommendations have been made for realizing more comprehensively the selection of suitable places for greenhouse production and other agricultural production areas in both study area and other fields.

Keywords: Location selection, AHP, G-MCDA

Örtüalti İşletme Yeri Seçiminde Coğrafi Bilgi Sistemi (Cbs) Ve Çok Ölçütlü Karar Analizinin (Çöka) Kullanimi: Türkiye Aydin Yöresi Örneği

Öz: *Bu araştırmada, Coğrafi Bilgi Sistemleri (CBS) ve Çok Ölçütlü Karar Analizi yöntemleri kullanılarak, Aydın yöresinde örtüaltı işletme yerleri için en uygun alanların ve örnek işletme yerlerinin uygunluk durumunun belirlenmesi amaçlanmıştır. Bu amaçla, literatür araştırmaları ve uzman görüşleri doğrultusunda, beş ana yer seçimi ölçütü (topoğrafya, toprak, iklim, su ve ekonomi) ve iki ayrı yer seçimi kısıtı (arazi kullanım kabiliyet sınıfı ve yerüstü su kaynaklarına uzaklık) dikkate alınmıştır. Ayrıca, araştırma alanında gayeli örnekleme yöntemiyle mevcut örtüaltı işletmelerden 160 adet örnek işletme seçilerek uygunluğu sorgulanmıştır. Değerlendirme ölçütlerinin ağırlıklandırılması için Analitik Hiyerarşi Prosesi (AHP) yönteminde kullanılan puanlanma ve ikili karşılaştırma metotları tercih edilmiştir. Yapılan sorgulamada, tüm ölçütlere ve kısıtlara göre araştırma alanının %2.4'ünün "en uygun", %33.4'ünün "uygun", %31.4'ünün "orta uygun" %0.7'sinin "az uygun" ve %29.6'sının "uygun olmayan" ve %2.5'inin "değerlendirme dışı" alanlar olduğu belirlenmiştir. Ayrıca, seçilen örnek işletmelerin %1.9'u "en uygun", %10.1'i "uygun", %0.6'sının "orta uygun" ve %87.3'ü ise "uygun olmayan" olarak saptanmıştır. Bu sonuçlara göre, araştırma alanındaki arazilerin genelinin örtüaltı işletme yeri için yerüstü su kaynaklarına uzaklık ve arazi kullanım kabiliyet sınıfı bakımından uygun olmadığı anlaşılmıştır. Ayrıca, gerek araştırma alanı ve gerekse diğer alanlarda örtüaltı üretiminin yanısıra diğer tarımsal üretim alanları için uygun yer seçiminin daha kapsamlı olarak gerçekleştirilmesine yönelik öneriler geliştirilmiştir.*

Anahtar kelimeler: *Yer seçimi, AHP, C-ÇÖKA*

INTRODUCTION

The rate of current natural resources in the world to meet the needs of the rapidly growing population is crucial for human beings to maintain their life under optimum conditions. While the world population is increasing at an average rate of 1.09 (Anonymous, 2019a), main resources such as water and soil are regressing in terms of quantity as well as quality due to the effect of the factors such as industrialization, unplanned and unprogrammed urbanization and pollution depending on this population growth rate.

The use of technology in agricultural production may vary depending on the ecology and socioeconomic status of the producers. The ecological factors are climate and geography starting primarily with soil. Technologies that will make economic contributions to the agricultural sector should not be imported products. The production of technologies suitable for the structure and conditions specific to each ecology requires the establishment of capital-intensive industries.

Greenhouse cultivation is one of the application areas where labor and capital are used mostly per unit area. Although

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greenhouse agriculture is important in terms of economic development, many serious problems experienced in the sectors ranging from procurement of raw material to marketing issues have made the attempts inconclusive. Therefore, although there are sufficient opportunities in Turkey, the greenhouse sector could not reach the desired level. Along with the increase utilization of the geothermal energy and modern agricultural techniques in the widespread use of this sector, suitable sites where cultivation can be made are needed to develop and support the sector.

The goal in planning greenhouse sites is to reduce heat losses and to make maximum use of the winter sun. Generally, these enterprises are also planned for off-season production. Climate and environmental conditions should also be taken into account in planning suitable greenhouse structures. Greenhouse site selection and positioning are extremely important to provide ideal environmental conditions. The reason is that the site location and positioning affect the heating costs, the amount of labor, plant diseases, and economic success of the enterprise.

This study was conducted to determine the greenhouse site locations in Aydin province. The results obtained from the study allow to question the location of the existing facilities in the area and to determine the locations of new greenhouse sites to be established.

Location Selection Process

Location selection is the process of determining where an enterprise will be located. Since the location selection is a long-term and strategic decision that affects the competitive power of the enterprise, it is hard and costly to change it. The main objectives in site location selection are listed as meeting the business requirements, increasing efficiency and performance, and providing cost advantage (Ayanoğlu, 2005; Eleren, 2006).

In the past, site location selection was almost entirely based on economic and technical criteria. Today, it appears as an extremely complex structure. It is known that selection criteria should also meet a set of social and environmental requirements imposed by legislation and government regulations. Site location selection process emerges as a multi-criteria decision problem involving a complex set of factors including social, technical, environmental, and political problems (Rikalovic et al., 2014).

The suitability of the agricultural site location will not only help to reduce costs in operating activities and increase profits but it is also vitally important in terms of sustainability. However, since there is no specific decision making mechanism in Turkey, the site selection process is conducted with the operators' own knowledge and physical facilities. This situation causes problems arising from incorrect location selection process. These problems are generally unsuitable places in terms of geographical locations such as climate, topographic conditions, soil, land condition, water, transportation, labor supply, proximity to electricity and natural energy resources. These problems due to location selection cause additional costs in the enterprises to solve problems varying from raw material procurement, transportation, and marketing to the other infrastructure problems. Enterprise site selection has an extremely complex structure due to the presence of more than one criterion in the evaluation of the decision process and the need for consensus among these criteria, which can be in contrast to each other. Many methods and techniques are used to solve such complex problems (Malczewski, 1999a; Yüksel, 2004; Deri, 2015).

GIS-MCDA (G-MCDA) Solution For Greenhouse Site Selection

Since spatial decision problems are heavily based on geographical data, MCDA can be implemented by integrating into GIS (G-MCDA). G-MCDA is the evaluation of data with and without location reference together for a final decision. G-MCDA is the use of location referenced data and the arrangement and selection of the priorities of decision makers and data and alternatives within a certain decision rule. In the most general terms, G-MCDA operations are composed of the steps of defining the problems, determining the criteria and normalizing the criteria layers, weighting the criteria and decision analysis (Malczewski, 1999b). G-MCDA allows data collection, storage, organization and analysis operations with the facilities provided by GIS and integration of geographical data and preferences of decision makers with the facilities provided by MCDA for the final decision (Malczewski, 1999a; Öztürk, 2009).

In a study conducted in Samsun province and its districts, the suitable cultivation periods to make greenhouse cultivation economically were determined with GIS. Conditioning requirements were investigated using the climate and digital elevation model with geographical information systems as advantageous and disadvantageous on district basis. The most suitable economic cultivation period was determined to be April-November period (Cemek, 2005a).

In the study conducted by Sönmez and Sarı (2006), remote sensing and geographic information systems were used in the development of greenhouse database. For this purpose, a database was prepared containing information about field, location and other features by examining the satellite images of the greenhouses in computer environment. In this context, the presence of 3547 ha greenhouse reported in city center of Antalya was determined as 2783.0 ha with this method.

In a study conducted in Iran, multi-criteria decision methods were used in greenhouse site selection. In the study, the pairwise comparison methods in determining the relative weights between the criteria and ANP and COPRAS-G method for emphasizing the interdependent relationships were preferred. The factors used in determining the greenhouse sites are labor, government, environment, physical condition, regional economy and raw materials. Greenhouse site selection criteria and their weighting were determined by the sector experts. The selection was made from six criteria and five alternative locations in line with the expert opinions. According to the results of the analysis, the most important criteria were determined as government, environment and physical condition (Rezaeiniya et al., 2012).

In a study by Marucci et al. (2014), planning of the greenhouse energy need in Italy was performed using the geographic information system. In the study, the annual artificial energy need was determined for certain threshold values in heating the polyethylene covered greenhouse. The study was conducted in two greenhouses and the times when the temperature in the greenhouse fell below a certain threshold were determined. In the greenhouse, the annual energy need for the threshold values of the air temperatures of 10, 12 and 14 °C was calculated. The most suitable areas for greenhouse activities were classified for the availability of natural energy in Italy.

In a study conducted in Iran, fuzzy ANP approach was used in greenhouse site selection application. In determining the weights of the criteria that are effective in greenhouse site selection, they preferred triangular fuzzy numbers to represent the subjective two-way comparisons of the experts' decisions. In the study, seven criteria and eighteen sub-criteria were used in the greenhouse site selection and selection was made from five alternatives. The criteria were listed as government (government policy), labor (access to labor and labor cost), physical conditions (land cost, construction cost and expanding greenhouse), environmental conditions (soil, water and topography), raw material (raw material prices, access to raw material), special conditions (road, electricity, fuel and access to market) and greenhouse type (vegetable, plant and flower and mushroom greenhouse). It was stated in the analyses that the most effective criteria among all criteria used for selection of greenhouse site location was the government policy, which was followed by the land cost (Rezaeiniya et al., 2014).

In the study conducted by Kouchaksaraei et al. (2015) in Iran about the glass greenhouse site selection, SWARA and COPRAS methods from MCDA methods were used. SWARA in the evaluation of criteria and COPRAS method in the evaluation of alternatives were shown on a sample application. In the application, evaluation of the criteria and calculation of weights were performed by experts. In the application, selection was made from four alternatives using three criteria and fourteen sub-criteria. In conclusion, the most suitable alternative was selected from the listed alternatives.

In a study conducted to determine potential of the greenhouse cultivation, suitable areas were determined by considering the solar radiation and sunshine duration factors. In the study, by considering the greenhouse potential in Turkey, eleven provinces where the cultivation is made at the highest rate were selected and the effect of production areas and production varieties of these cities based on solar radiation and sunshine duration was examined. It was stated that the daily radiation value required in greenhouse cultivation was sufficient in Antalya and Mersin provinces while it was insufficient in Mugla, Adana, Izmir and Hatay provinces. It was stated that Samsun province, which is another prominent province in greenhouse cultivation, fell behind these provinces in terms of sunshine and radiation value. In conclusion, it was stated that in the greenhouse where cultivation is wanted throughout the year, the solar radiation and sunshine duration should be met artificially in regions where they cannot be met naturally (Öz, 2017).

In another study, Saltuk and Altun (2018) determined if lower Euphrates region is suitable for greenhouse site selection by considering its climate conditions and production capacities using GIS and MCDA methods. In the study, the criteria of climate, soil, wind, altitude, slope, aspect, and distance to rivers and lakes were considered. The effect classes of the criteria used in the greenhouse site selection and their weights were determined by ranking and scoring, respectively. Then, by matching the criteria, the eligibility maps of Sanliurfa, Kilis, Adiyaman and Gaziantep provinces were evaluated in three categories (suitable, partially suitable and not suitable). It was determined that 13.23% of the study area was suitable, 45.38% was partially suitable and 41.39% was not suitable. It was stated that the most suitable areas for greenhouse cultivation were Adiyaman and Sanliurfa provinces.

In the site selection of a new greenhouse enterprise, it was pointed out that criteria such as location of the enterprise (courtyard) with respect to the land, topographic and soil conditions, energy and water resources, sun and prevailing winds, environmental effects and legal regulations should be considered (Balaban and Şen, 1988).

MATERIAL AND METHODS

Material

This study was carried out to determine the suitable greenhouse site locations based on G-MCDA in Aydin region. Aydın is generally known as an agriculture and tourism city. In addition to the presence of geothermal resources in Aydın province, which has a temparature climate in West

Anatolia Region, also through the supports made by the Ministry, greenhouse agriculture activities have been accelerated. Aydın is one of the provinces with the highest geothermal greenhouse potential. Aydın province is one of the most important provinces in terms of both climate factors and geothermal energy resources (Yıldız, 2010; Tunçbilek ve Yılmaz, 2021). In the study, ArcGIS 10.6.1 software 3D Analyst, Conversion Tools, Data Management Tools and Spatial Analyst modules from basic geographic information system software allowing spatial inquiry were used. In addition, AHP method from MCDA techniques and Super Decision software in the analysis of this method were used (ESRİ, 2013; Yıldırım and Önder, 2015; Malczewski and Rinner, 2015; Anonymous, 2019b).

All data used in the study were converted into a common coordinate system in order for the analysis to give correct results. In this conversion, WGS 1984 Datum and UTM projection Zone 35 Coordinate system were used. Coordinate conversion of the data were made with ArcGIS software.

Figure 1 Study area

In the study area, 160 sample greenhouse sites were selected from a total of 441 existing greenhouse sites from 17 districts of Aydin province using purposeful sampling method (Aydin Provincial Directorate of Agriculture and Forestry, 2019). In the selection of these sites, certain criteria such as district-based distribution of the existing sites in a way to represent the study area, transportation facilities and soil characteristics were taken into consideration (Arıkan, 2013). Figure 1 shows the study area.

In this study, Turkish State Meteorology Service (TSMS), data provided by General Directorate of Meteorology, State Hydraulic Works, General Directorate of Rural Services, Landscape Architecture and Agrology and Plant Nutrition Department of the faculty of Agriculture in ADU were used in order to determine the greenhouse site areas suitable for Aydin province (KHGM, 2001; Anonymous, 2019c; Anonymous, 2023; TSMS, 2019; TSMS, 2023).

Method

In the study, regulating and preparing the criteria determining the greenhouse site locations were performed within a process. In this process, each criterion was prepared as a GIS layer. In the preparation of these layers, conversion tools, surface, distance, proximity, interpolation, reclass and zonal histogram analysis modules were used.

The analysis results obtained from the greenhouse site selection survey were evaluated and visualized in seven categories including “Out of evaluation”, “Not suitable” (0), “Least Suitable” (1), “Slightly Suitable” (2), “Moderately suitable” (3), “Suitable” (4) and “Most suitable” (5). Classification intervals and scores of the predicted evaluation criteria are given in Table 1 and defined separately below. And class scores for the constraints were specified as “0” (not suitable) and “1” (most suitable).

Site Selection Criteria

The factors that are effective in the decision making of greenhouse site selection can be gathered under two groups as environmental factors and structural factors. Environmental factors are listed as light, temperature, wind, moisture, energy, water, proximity to the market, and proximity to electricity and heating resources (Yüksel and Yüksel, 2012; FAO, 2013). The structural factors are the greenhouse enterprise type, structure type, width and length, height, roof type and slope, plant type to be grown, foundation depth, cover material, purlin length, rafter spacing, long axis direction and the status of other structures (Yüksel, 2004). By considering these factors, site selection process is completed.

In this study, topography (slope, aspect and altitude), soil (LUCC, erosion and depth), climate (solar radiation, sunshine duration, temperature and wind), water (distance to surface water resources) and economy (proximity to the surface water resources, proximity to wholesale locations, proximity to highways, proximity to residential centers and settlements) evaluation criteria were taken into account. In the study, factors like protected areas, ownership status, plant and tree properties desired to be grown, environmental requests, ground water resources, water quality, labor opportunities, heat sources, heating and construction costs, etc. were not taken into account.

Table 1. Classification intervals and scores of the evaluation criteria predicted in greenhouse site selection in the study area.

Evaluation criteria – Main criteria	Evaluation criteria – Sub criteria	Classification range	Class score	References
1) Topography	Slope (%)	<2	5	Çelebi (1973); FAO (1974); Benites ve Friedrich (2000); Yüksel (2004); Dorren ve Rey (2004); Castilla ve Baeza (2013); Güney (2013); MEGEP (2015); Anonymous (2019d)
		2-5	4	
		5-15	3	
		15-60	2	
		60-80	1	
		>80	1	
	Aspect	Flat	5	Zabeltitz (2011); Yüksel ve Yüksel (2012).
		South	5	
		Southwest	4	
		Southeast	4	
		West	3	
		East	2	
		Northwest	1	
		Northeast	1	
		North	1	
	Altitude (m)	<200	5	Zabeltitz (2011); Castilla (2013); Sezer ve Başkaya (2014); Yaslıoğlu (2014)
		200-400	4	
		400-600	3	
		600-800	2	
		>800	1	
2) Soil	Land Use Capability Class(LUCC)	1st Class	5	Alkan (1977); Sönmez vd. (2007) Tarım ve Köyişleri Bakanlığı (2008); Yüksel ve Yüksel (2012)
		2nd Class	4	
		3rd Class	3	
		4th Class	2	
		5th Class	1	
		6th Class	1	
		7th Class	1	
		8th Class	0	
		Other	0	
	Erosion	1st Degree (slight)	5	Yüksel (2004)
		2nd Degree (moderate)	3	
		3rd Degree (severe)	2	
		4th Degree (extreme)	1	
		Other	0	
	Depth	Deep	5	Yüksel ve Yüksel (2012)
		Medium deep	4	
		Shallow	3	
		Very Shallow	2	
		Lithosolic	1	
		Other	0	

Evaluation criteria – Main criteria	Evaluation criteria – Sub criteria	Classification range	Class score	References
3) Climate	Solar radiation ($kWhm^{-2}d^{-1}$)	<2.1	1	Elsner vd. (2000); Yüksel (2004); FAO (2013) Cemek vd. (2006); Zabeltitz (2011);
		2.1-2.2	3	
		2.2-2.3	4	
		>2.3	5	
	Sunshine duration (hour)	<300	1	Baytorun vd. (2000); Cemek vd. (2006)
		300-350	3	
		350-400	4	
		>400	5	
	Temperature (^{0}C)	<5	3	Elsner vd. (2000); Cemek (2005b); Castilla ve Hernandez (2007); Zabeltitz (2011); Sezer ve Başkaya (2014); Çaylı ve Temizkan (2018)
		5-10	4	
		>10	5	
	Wind (ms^{-1})	<2	3	TSE (1997); Yüksel (2004); FAO (2013)
		2-3	5	
		>3	1	
4) Water	Distance from the surface water resources (m)	<2000	0	Turkish Official Gazette (2004); Tomar (2009); Sönmez ve Demir (2011); Turkish Official Gazette (2017);
		>2000	5	
5) Economy	Proximity from the surface water resources (m)	<2000	0	Alkan (1977); Yüksel (2004); Rorabaugh (2012)
		2000-3000	5	
		>3000	1	
	Proximity to wholesale locations (m)	<10 000	5	Yüksel (2004)
		10 000-20 000	4	
		20 000-30 000	3	
		30 000-40 000	2	
		>40 000	1	
	Proximity to highways (m)	<1 000	1	Yüksel (2004); Rorabaugh (2012); Castilla (2013)
		1 000-5 000	5	
		5 000-10 000	3	
		>10 000	2	
	Proximity to residential centers (m)	<1 000	5	Yüksel (2004); Rorabaugh (2012); Castilla (2013)
		1 000-5 000	4	
		5 000-10 000	3	
		10 000-15 000	2	
		>15 000	1	
	Proximity to settlements (m)	<1000	5	Zabeltitz (2011); Rorabaugh (2012); Yüksel ve Yüksel (2012); Castilla (2013); Castilla ve Baeza (2013)
		1000-5000	4	
		5000-10 000	3	
		10 000-15 000	2	
		>15 000	1	

Site Selection Constraints

In order to remove the areas that were not suitable for greenhouse site selection in the study area, two separate constraints including "Land Use Capability Class" and "Distance to Surface Water Resources" were taken as basis. Class scores for the constraints were specified as "0" (not suitable) and "1" (most suitable). The class intervals and scores predicted for these constraints are given in Table 2 and defined separately below

Table 2. Classification intervals and scores of the constraints predicted in greenhouse site selection in the study area

Evaluation criteria	Class	Score
1) Land Use Capability Class (LUCC)	Other	0
	1st Class	0
	2nd Class	0
	3rd Class	1
	4th Class	1
	5th Class	0
	6th Class	1
	7th Class	1
	8th Class	0
2) Surface Water Resources Protection Area	≤2000 m	0
	>2000 m	1

Normalization of Criterion Layers

In this study, layer values should be in the same measurement unit in order to synthesize the criterion layers together with their weights. This happens by normalizing the criterion layers. In the study, all layers were normalized according to the value range method and the result was ensured to take values between 0-1 (Malczewski and Rinner, 2015). The normalization process was performed with the Map Algebra Raster Calculator tool of Spatial Analyst Tools module (Huisman, and de By, 2009).

Weighting of criterion layers

In the determination of the relative weight values showing the relative importance of the criterion layers, scoring and paired comparison methods were used. In this study, weight values of the main and sub-criteria were determined with a survey study for the formation of pair-wise comparison matrices and the fitness values of the sub-criteria were determined by the scoring method. The survey study was conducted through face-to-face interviews with 12 academic staff members working in Faculty of Agriculture of Aydin Adnan Menderes University. At this stage, consensus was obtained by taking the geometrical mean of the values indicating the relative importance of personal judgments of each decision maker in terms of pairwise comparison method and a similar study was also applied by Saaty (1980) and Kurc (2018). Figure 2 shows the screenshot showing the hierarchy structure of greenhouse site selection.

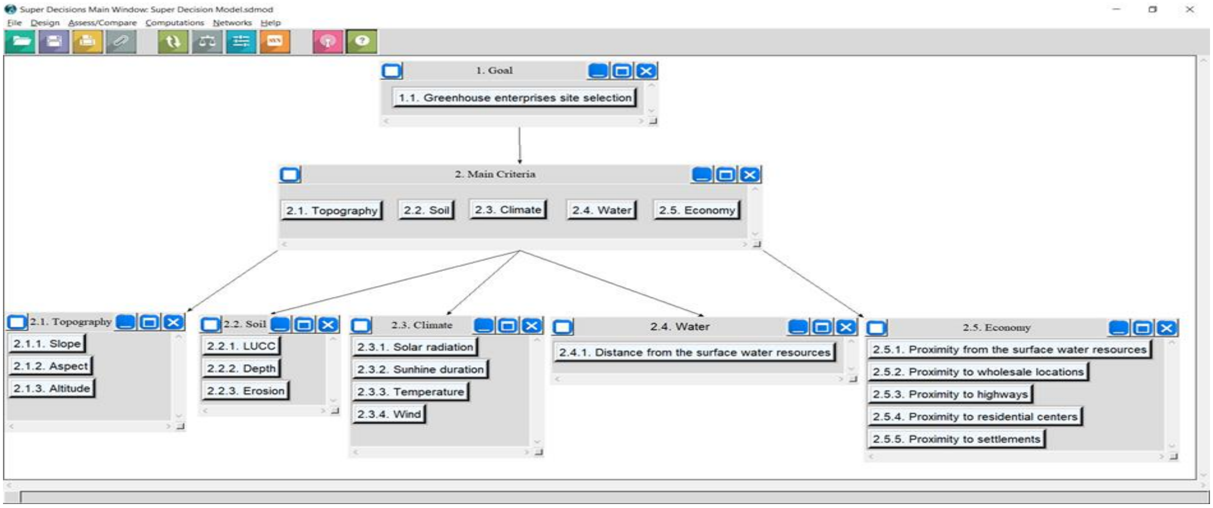

Figure 2 Screenshot showing the hierarchy structure of greenhouse site selection

Determination of Location Alternatives

In the study area, each criterion was prepared as a GIS layer and converted into a raster format. These layers converted to raster format were transformed to integers before being overlaid. These layers converted to integers were normalized and subjected to weighted sum analysis by considering the weight values determined previously. The most suitable areas were determined according to the sub, main and all criteria taken into evaluation (Figure 2). In addition, it was accepted to be evaluated as a constraint in terms of Land Use Capability Class (LUCC) and Distance to Surface Water Resources (DSWR) criteria in greenhouse site selection in the study area. As a result, all criteria subjected to the evaluation were overlapped with the constraints taken as basis and a suitability result map was obtained.

RESULTS AND DISCUSSION

Weighting of the Criteria in Greenhouse Site Selection

In the study, five main criteria were prepared in determining the suitable greenhouse site selection. These were topography, soil, climate, water and economy. Table 3 shows matrix and weight value of pairwise comparisons. In addition, the inconsistency for the pairwise comparison matrix was calculated as 0.013.

Table 3 Comparison matrix and weight values of the main criteria

Criteria	Topography	Soil	Climate	Water	Economy	Weights
Topography	1	2	1/2	1	1/2	0.17
Soil	1/2	1	1/2	1	1/2	0.13
Climate	2	2	1	2	1	0.28
Water	1	1	1/2	1	1/2	0.14
Economy	2	2	1	2	1	0.28

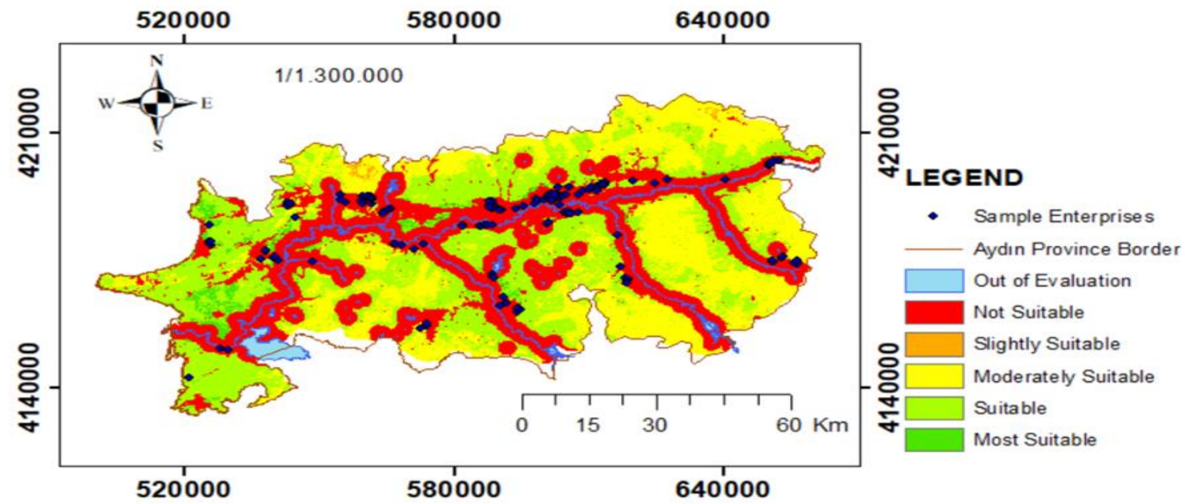

Figure 3 Suitability map of greenhouse site location based on all site selection criteria and constraints in the study area

Table 4 Distribution of the study area and current locations of the sample enterprises based on their suitability

Suitability class	The suitability of the study area * (%)							Suitability of sample enterprises locations ** (%)						
	Most suitable	Suitable	Moderately suitable	Slightly Suitable	Least Suitable	Not suitable	Out of evaluation	Most suitable	Suitable	Moderately suitable	Slightly Suitable	Least Suitable	Not suitable	Out of evaluation
All criteria and constraints	2.4	33.4	31.4	0.7	-	29.6	2.5	1.9	10.1	0.6	-	-	87.3	-

*Total study area is 801 090.2 ha. ** The total number of greenhouse sites selected is 160.

When it was examined by considering all criteria and constraints, 35.8% of the study area and areas of 12.0% of the sample enterprises were determined to be suitable (suitable and the most suitable).

CONCLUSIONS

The number of scientific studies on the selection of suitable locations for greenhouse enterprises performing plant production in Turkey is quite limited. There is no specific decision mechanism in the location selection for greenhouse enterprises and the site location is made according to the physical opportunities and wishes of the business owner. Therefore, problems caused by incorrect location selection are encountered in these enterprises. These problems are seen in the places that are not suitable for greenhouse enterprises in terms of geographical location such as climatic conditions, topography, land condition, and proximity to water, transportation and energy resources.

In this study, it was aimed to determine the most suitable areas for establishing greenhouse enterprises in accordance with legal and technical principles and to evaluate the suitability of the selected sample enterprises by using AHP method within the scope of G-MCDA technique for Aydin province. For this purpose, five criteria including topography, soil, climate, water and economy and two evaluation constraints including the land use capability class and distance to surface water resources were taken into consideration.

In the suitable greenhouse site selection, the most effective main criteria were listed starting with climate (28%) and economy (28%) which were followed by topography (17%), water (14%) and soil (13%).

When it was examined by considering all criteria and constraints, 67.9% of the study area and the areas of 12.7% of the sample enterprises were determined to be suitable.

The recommendations developed for the successful selection of the areas suitable for new greenhouse enterprises to be stablished in the study area and other regions are listed below.

•The results of the analysis and evaluation conducted in this study showed that the site location is extremely important especially for new greenhouse facilities to be established in Aydin region. Resolution and currency of the data to be used in the analysis should be increased in order to prepare the future projections for this region in a more appropriate manner.

•This study has shown that the success of determining the suitable greenhouse site locations according to the regional conditions depends on revealing the criteria and criterion weights with an accurate, reliable and scientific approach. The location determination can be made by a single person or by a group. the views of universities, related public and private institutions/organization and implementers can also be considered in the group formation. In addition, if the expertise degree is different, the responses of the group members can be weighted for making the group decision. After all these are applied, location alternatives can be determined for greenhouse site locations by conducting analysis.

•Since there is no specific decision mechanism in Turkey for the selection of greenhouse locations, it is done by the operators' own knowledge and physical opportunities. In addition, many professional fields play a role in planning and design in practice. This causes the enterprises, each of which contains their own design principles, not to fulfill the expected function in their establishment process. Incorrect location selection lies at the root of such problems. For a correct site selection, decision support systems in which especially agricultural engineers play a role should be developed and implemented.

•The criteria determined in this study and the process of weighting based on these criteria was made for the choice of greenhouse enterprises. Site location process is specific for the application and the criteria may differ for each application depending on the problem investigated. The study can also be extended to the location selection of enterprises such as seedling, vegetable, fruit and ornamental plant growing in greenhouse. In this context, the most appropriate location selection for the enterprises requires the determination of location selection criteria specific to cultivation activities and criteria weights.

•In the determination of the site location for the other agricultural production areas along with greenhouse cultivation, cooperation should be provided between universities, public and private institutions/organization, and farmers' organization. In addition, the most appropriate planning should be made considering primarily the functional requirements expected from the enterprises and the factors like social, legal, aesthetic, economic factors, etc.

•In future studies, other techniques like ANP, TOPSIS, ELECTRE etc. from MCDA methods considering dependent and independent conditions of the evaluation criteria and including qualitative and quantitative approaches in the problem can be used in the location selection of agricultural enterprises.

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