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ORIGINAL ARTICLE

AHP and GIS based land suitability analysis for Cihanbeyli (Turkey) County

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Abstract This paper offers an integrated approach to contribute to the process of agricultural land suitability analysis using the Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) methods. The paper addresses Cihanbeyli, the largest county in Turkey in terms of area, and focuses on determining sustainable strategies to activate/improve agriculture as a main source of income, thereby improving the economy of the region. The combined AHP and GIS methodology which consists of stages such as structuring AHP hierarchy, describing evaluation criteria, doing pairwise comparisons, and preparing criterion maps and land suitability maps has been applied to identify the areas suitable for irrigated and dry farm agriculture. A comparison of the final land suitability map with current land use has revealed that an area of 294.73 km^2 (7.18 %) is suitable for irrigation and an area of 2323.45 km^2 (56.77 %) is suitable for dry farm agriculture. Additionally, the analysis clearly shows the necessity of a decrease in irrigated agricultural land and an increase in dry farm agricultural land. The applied AHP and GIS based agricultural land suitability analysis is useful in (1) referring agricultural activities to the areas that have good physical and environmental conditions for agriculture, thus achieving maximum agricultural efficiency in countryside, (2) improving non-agricultural uses in the areas that are unsuitable for agriculture and have low efficiency, (3) avoiding the construction and environmental pressures on suitable farmland, so conducing to better land-use planning decisions.

Introduction

Urbanization and land degradation alienate and deplete agricultural land resources. The ultimate result of urbanization and urban expansion is conversion of agricultural lands into built environment. Reduced availability of lands highly suitable for agricultural production decreases the sustainability of existing agricultural systems and encourages the use of more marginal lands for agriculture (Hulme et al. 2002). Nowadays, the need for optimum use of land is extremely greater than ever due to rapid population growth and urban expansion which turn land into a relatively scarce commodity for agricultural and rangeland uses. Therefore, an increasing urgent need to match land capabilities and land uses in the most rational possible way is essential (Zarkesh et al. 2010).

Sustainable agricultural development is one of the prime objectives in all countries in the world. The broad objective of sustainable agriculture is to balance the inherent land resource with crop requirements, paying special attention

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to optimization of resource used towards the achievement of sustained productivity over a long period (Joshua et al. 2013). The increasing world population, coupled with the growing pressure on the land resources, necessitates the application of technologies such as GIS to help in identifying the most suitable areas for sustainable agricultural production for food supply according to the environmental potential. Selecting the best location for agricultural production in the context of land suitability analysis (LSA) is a complex process involving not only technical requirement, but also physical, economic, social, and environmental requirements which may result in conflicting objectives. Such complexities necessitate the simultaneous use of several decision support tools (Joshua et al. 2013).

LSA is a GIS based multi criteria evaluation process applied to determine the suitability of a specific area for a particular land use and to estimate the potential of land for alternative land uses considering wide ranges of criteria based on environmental, social, and economic factors (Jafari and Zaredar 2010). Appropriate handling of such broad and heterogeneous maps requires applying a flexible tool (Jafari and Zaredar 2010). Thus, GIS has been increasingly used as an important spatial decision support system for land suitability analysis (Cambell et al. 1992; Kalogirou 2002; Malczewski 2004, 2006; Perveen et al. 2007; Jafari and Zaredar 2010; Mendas and Delali 2012; Nyeko 2012).

In LSA, evaluation criteria objectives and attributes need to be identified with respect to the particular situation under consideration. The selected evaluation criteria should adequately represent the decision-making process and contribute towards the final goal. This analysis gives an opportunity to map suitability index for a certain study area. Hence, each evaluation criterion is represented by a separate map in which a "suitability degree" with respect to that particular criterion is ascribed to each unit of area (Prakash 2003; Bagheri et al. 2012). These "suitability degrees" then need to be rated according to the relative importance of the contribution made by that particular criterion towards achieving the ultimate objective (Prakash 2003).

LSA through environmental factors is an intrinsically complex multi-dimensional process involving multiple criteria and multiple factors (Patil et al. 2012). Multi criteria analysis is a well-known method to overcome the difficulties in defining relative weights to different criteria involved in decision making on suitability of land mapping unit (Bagheri et al. 2012). AHP is a commonly used multi criteria analysis technique to resolve complex decision-making processes which include multiple criteria, scenarios, and factors. AHP involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives. AHP completely aggregates various facets of the decision problem into a single objective function (Saaty 2000, 2001). By organizing and assessing alternatives against a hierarchy of multifaceted objectives, AHP drastically reduces the complex decision cycle (Anonymous 2015).

The integration of multi-criteria decision analysis approaches in GIS provides a powerful spatial decision support system which offers the opportunity to efficiently produce land suitability maps. The combination of AHP with GIS is a new trend in land suitability analysis. AHP and GIS based LSA has widely been applied to numerous land suitability assessment problems in the last few decades (Thapa and Murayama 2007, 2008; Cengiz and Akbulak 2009; Patil et al. 2012; Bagheri et al. 2012; Feizizadeh and Blaschke 2013; Weerakoon 2014; Ullah and Mansourian 2015).

This paper presents a combined technique of AHP and GIS to evaluate agricultural land suitability in the case of Cihanbeyli. The largest county in Turkey in terms of area, Cihanbeyli is an important agriculture region. However, lack of forested areas, existence of barren lands, insufficient water resources for agriculture, low precipitation, and discharge of domestic and industrial waste of Konya city directly to the Salt Lake are the factors negatively affecting the agriculture in the region. Significant productivity and quality issues are experienced in the agricultural areas of the region due to drought. Additionally, agricultural production is decreasing due to drought and intense population influx from the county's rural areas. Hence, the need to improve agricultural productively is real and urgent. Under these circumstances, soil (soil suitability, land use), climate (precipitation), topography (elevation, slope, aspect) and groundwater (salinity hazard-ECw, sodium hazard-SAR, chloride-Cl, depth of water table-DTW) were chosen as major factors affecting the agriculture and also the evaluation criteria of AHP based agricultural LSA for Cihanbeyli.

Materials and methods

Case study area

Located on Konya-Ankara highway in the central part of Central Anatolia, Cihanbeyli County is about 100 km away from Konya city. Cihanbeyli which seems to be the continuation of Konya Plain extending northward is the largest district in Turkey with an area of about 4100 km^2 (Fig. 1). It is surrounded by Salt Lake and Aksaray County on the east; Yunak and Sarayönü counties on the west; Altınekin counties on the south; and finally Kulu and Haymana (Ankara) counties on the north. The county has 46

Fig. 1 Location map of study area
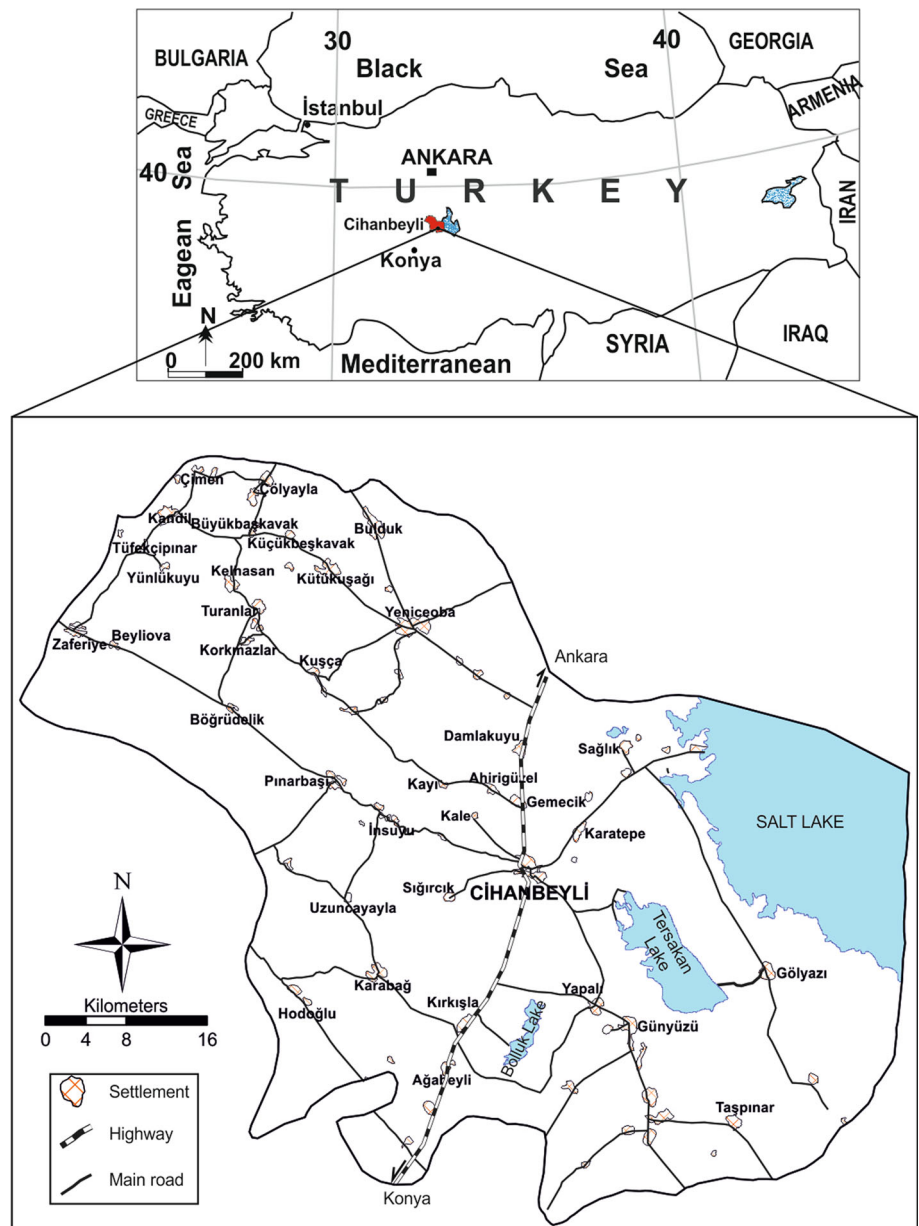
connected districts. According to data from 2012, total population is 56105. 49100 live in the county center while 7005 live in the bound provincial neighborhood. Cihanbeyli's economy is based on livestock, industrial salt production, and mainly agriculture. Cihanbeyli is one of the counties in Konya with intensive agricultural activities. All cultivated land is reserved for field farming. However, vegetable and fruit production is negligible. The main crops cultivated in the region are sugar beets, sunflower, corn, peas, wheat, barley, lentils, cumin, and legumes. Most of these products necessitate long-term irrigation; therefore, surface water is insufficient to supply irrigation water. Consequently, groundwater constitutes the major source of irrigation water in the region. The study area has

a semi-arid climate with cold winters and moderate to hot summers. The long-term average annual precipitation in the region is 293.1 mm and the average temperature is 11.1 °C. Generally, higher topographic elevation receives more rainfall. Rainfall occurs mainly in the wet period, with the maximum in December and January. Generally, the lowest rainfall is recorded in July and August.

Scarcity of surface water, reduction of groundwater reserves depending on mindless consumption, and low quality groundwater reserves in terms of irrigation in the majority of the region are the factors affecting agricultural activities negatively. Agricultural cultivation in the region decreases due to drought and intensive migration from rural to urban areas.

Methodology: AHP and GIS based agricultural land suitability analysis

AHP

The AHP is a mathematical method that may be applied to resolve highly complex decision-making problems involving multiple scenarios, criteria, and factors (Saaty 2000). The AHP is a powerful and flexible decision-making process to help people set priorities and make the best decision when both quantitative and qualitative aspects of decisions need to be considered (Weerakoon 2014). The AHP applies to the decision problem after it is structured hierarchically at different levels, each level consisting of a finite number of elements (Srdjevic 2005). Proposed in the 1970s by Thomas L. Saaty, it constructs a ratio scale associated with the priorities for the various items compared. In his initial formulation in the conventional AHP, Saaty proposed a four-step methodology comprising of modeling, valuation, prioritization, and synthesis. At the first stage, a hierarchy representing relevant aspects of the problem (criteria, sub-criteria, attributes, and decision alternatives) is constructed. The goal or mission of the decision-making problem is placed at the top of this hierarchy. Other relevant aspects (criteria, sub-criteria, attributes, etc.) are placed in the remaining levels (Patil et al. 2012).

The second stage involves the comparison of pairs of criteria, pairs of sub-criteria (pairs of sub–sub-criteria, etc.), and pairs of alternatives. The AHP uses a fundamental 9-point scale measurement to express individual preferences or judgments (Saaty 1980), creating a matrix of pairwise comparisons (Table 1). These pairwise comparisons allow independent evaluations of each factor's contribution, thereby simplifying the decision making process (Rezaei-Moghaddam and Karami 2008). The matrix format in pairwise comparisons describes $A = [a_{ij}]_{n \times n}$ as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & \cdots & a_{nn} \end{bmatrix}$$

where for all i and j, it is necessary that and $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$. After all pairwise comparison matrices are formed, the vector of weights, $w = [w_1, w_2, w_3 \ldots w_n]$ is calculated based on Saaty's eigenvector method. Then, this eigenvector is normalized by Eq. 1 and then the weights are computed by Eq. 2. The elements of the normalized eigenvector are weighted with respect to the criteria or sub-criteria and rated with respect to the alternatives (Bhushan and Rai 2004; Carrion et al. 2008).

$$a_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \tag{1}$$

$$w_{ij} = \frac{\sum_{j=1}^{n} a_{ij}}{n} \tag{2}$$

where $i, j = 1, 2, 3 \ldots n$.

The AHP also provides mathematical measures to determine the consistency of judgment matrix. Based on the properties of the matrix, a consistency ratio (CR) can be calculated. In a matrix, the largest eigenvalue (λ_{max}) is always greater than or equal to the number of rows or columns (n). A consistency index (CI) that measures the consistency of pairwise comparisons can be written as (Saaty 1980):

$$CI = \frac{\lambda_{max} - n}{n - 1}, \tag{3}$$

where CI is the consistency index (1), n is the number of elements being compared in the matrix, λ_{max} is the largest or principal eigenvalue of the matrix. If this consistency index fails to reach a threshold level, then the answers to

Table 1 The comparison scale in AHP (Saaty 1980)

Intensity of importance	Definition	Explanation
1	Equal importance of i and j	Two activities contribute equally to the objective
3	Weak importance of i over j	Experience and judgment slightly favor one activity over another
5	Strong importance of i over j	Experience and judgment strongly favor one activity over another
7	Demonstrated importance of i over j	An activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance of i over j	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

Table 2 Random index (RI) table (Saaty 1980)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

comparisons are re-examined. To ensure the consistency of the pairwise comparison matrix, the consistency judgment must be checked for the appropriate value of n by CR. The CR coefficients are calculated according to the methodology proposed by Saaty (1980). The CR coefficients should be less than 0.1, indicating the overall consistency of the pairwise comparison matrix (Ying et al. 2007; Chen et al. 2010; Park et al. 2011). CR is defined as:

$$CI = \frac{CI}{RI}, \tag{4}$$

where RI is the average of the resulting consistency index depending on the matrix (Ying et al. 2007). The RI values for different numbers of n are shown in Table 2. If the CR ≤ 0.10, it means that the pairwise comparison matrix has an acceptable consistency. Otherwise, If CR ≥ 0.10 it means that pairwise consistency has inadequate consistency. In this case, the AHP may not yield meaningful results unless one re-examines the judgments and changes them as necessary to reduce the inconsistency below 0.10. (Saaty 1980; Chakraborty and Banik 2006; Chen et al. 2010). In this study, the resulting CR for the pairwise comparison matrix was 0.025 for irrigation land suitability and 0.036 for dry farm land suitability. These values indicate that the comparisons of land characteristics were perfectly consistent.

Finally, the rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. Then the local ratings are multiplied by the weights of the criteria and aggregated to get global ratings (Bhushan and Rai 2004).

Selection of evaluation criteria and AHP application

For evaluating agricultural land suitability, ten criteria including elevation, slope, aspect, soil suitability, land use, precipitation, depth of water table (DWT), sodium absorption ration (SAR), chloride (Cl-mg/l), and electrical conductivity (ECw-μS/cm) of groundwater were selected based on relevant literature review (Thapa and Murayama 2008; Reshmidevi et al. 2009; Akmal Rahim et al. 2010; Chen et al. 2010; Jafari and Zaredar 2010; Jie et al. 2010; Shahadat Hossain and Das 2010; Mendas and Delali 2012; Feizizadeh and Blaschke 2013; Akıncı et al. 2013) and local expert interviews. These evaluation criteria were classified into four main groups (topography, climate, soil, and groundwater) in context of how they affect agricultural land suitability in Cihanbeyli. Additionally, three

suitability criteria for dry farm agriculture (topography, climate, and soil) and four suitability criteria for irrigated agriculture (topography, climate, soil, and groundwater) were determined (Table 3).

Land use and soil suitability maps were prepared from satellite images and the remote sensing methods. The 1:25,000 scale topographical maps were digitized and all the criteria maps were prepared from the related maps by scanning, digitizing, and geocoding the relevant information. Digitized topographical maps were also used to create TINs, DEM, and derivate layers such as elevation, slope, and aspect. Meteorological data for a 30-year period (National Meteorological Agency of Turkey) were used to create precipitation map. Water samples were collected from 75 locations to determine EC, SAR, and chloride values and all data was transferred to ArcGIS Software. All vector layers were then converted into raster format with 10 m resolution and the spatial datasets were processed in ArcGIS.

The evaluation criteria used within the scope of the study are explained in detail in the following sections.

Soil

Soil suitability The type of soil is one of the most important factors for agricultural land suitability. Soil behavior helps to estimate the soil performance for agricultural production. Thus, when deciding on the suitability of land for agricultural production, it is necessary to know the soil types (Akıncı et al. 2013). Eight soil types are situated in the study: alluvial, brown soil, reddish-brown, hydromorphic, colluvial, siorezem, and regosol soil. Alluvial soils contain rich nutrients for crops (Brady 1974) and are rich in

Table 3 Evaluation criteria of agricultural land suitability for the study area

Goal	General criteria	Criteria
Agricultural land suitability	Soil	Soil suitability
		Land use
	Climate	Precipitation
	Topography	Aspect
		Slope
		Elevation
	Groundwater	Salinity hazard (EC$_w$),
		Sodium hazard (SAR)
		Chloride (Cl)
		Depth of water table (DTW)

organic matter content. Therefore, alluvial soils are assigned as "highly suitable" for agriculture. Calcification plays an important role in the formation of brown soil; therefore, this type has very high calcium content (TRGM 2008). Chemical and biological activities slow down in this soil type when they remain dry for long periods in summer. In addition, brown soils are moderate in organic matter content. Reddish-brown soils that are observed in the rugged terrain at the western edge of the area usually do not have depth/thickness due to the slope of the terrain. The main substances are mostly limestone and old gravel deposits. Agriculture can be applied in areas of non-calcic brown soils and reddish brown soils which do not have high slope. Therefore, these types of soil are assumed to be "moderately suitable". Hydromorphic soils which are constantly moist have high salt and alkalinity. Colluvial soils are stony, shallow, or dry soils and highly sloped or exposed to a high level of erosion. Siorezem soils are composed of grained rocks with high content of calcite. Regosols are typically coarse textured, more permeable, and shallow soils with low water-holding capacity. These kinds of soils need very high external inputs to support plant growth; hence, they are considered "marginally suitable". The built-up areas (settlements) and water bodies are considered "unsuitable" for agriculture. The grading criterion is shown in Tables 5 and 6 (Fig. 2a).

Land use In the study area, ten land use types were identified: bare soils, industry and mining areas, built-up areas, mixed agriculture, marsh, meadow, pasture, dry farm agriculture, irrigated agriculture, and water bodies (Table 4). In this study, mixed agriculture, dry farm agriculture, irrigated agriculture, and pasture fields are classified as "highly suitable" areas for agriculture whereas meadow fields are classified as "moderately suitable". Marshes have poor drainage and wetness problem or flooding. Bare soils have low moisture-holding capacity, are stony, infertile, and sensitive to erosion. These soil types, besides built-up areas, industry and mining areas, and water bodies are considered "unsuitable" for agriculture. The grading criterion is shown in Tables 5 and 6 (Fig. 2b).

Climate

Precipitation Precipitation is one of the fundamental factors affecting the growth of plants. Usually, annual precipitation of 400 mm is considered suitable for the growth of plants (Jafari and Zaredar 2010). Precipitation with a >400 mm was evaluated as "highly suitable"; 350–400 mm was evaluated as "moderately suitable"; 330–350 mm was evaluated as "marginally suitable"; and <330 m was evaluated as "unsuitable" for agriculture in the study area. Higher AHP weight was assigned to the

areas which are more suitable for agriculture. The grading criterion is shown in Tables 5 and 6 (Fig. 2c).

Topography

The topography category comprises three criteria: aspect, slope, and elevation. These criteria affect agricultural land suitability and must be taken into account in agricultural land selection.

Aspect Plants need sun exposure at certain intervals in order to maintain their physiological activities. The duration of this need varies according to the species of plant. Plants generally exhibit optimum growth in the southern and western aspects that receive sunlight for a substantial portion of the day (Akıncı et al. 2013). Therefore, aspect is taken into consideration as an assessment criterion for selecting the land to be used for agriculture. In the present study, south, southeast, southwest, and flat areas were addressed as "highly suitable" areas for agriculture in terms of receiving sunlight (Tables 5, 6; Fig. 2d).

Slope The soil formation is closely related to geomorphologic properties. Slope degree is the main factor determining erosion control (Koulouri and Giourga 2007). The amount of materials carried away with erosion increases with the growing degree of slope. An increase in slope degree slows down the development of soils and decreases soil depth and fertility (Atalay 2006). Furthermore, slope affects agricultural production negatively by restricting machinery and management applications such as soil tillage, irrigation, and drainage (Akıncı et al. 2013). Carrying out the transportation and agricultural operations in an effective manner is extremely important for the efficient use of agricultural land. Otherwise, expected yield cannot be achieved due to high costs and increased labour force. Cihanbeyli's rural area generally has a flat structure and is less hilly. The slope of the land surface for agricultural land suitability with a 0–2 % was evaluated as "highly suitable"; 2–4 % was evaluated as "moderately suitable"; 4–8 % was evaluated as "marginally suitable", and >8 % was evaluated as "unsuitable" (Tables 5, 6; Fig. 2e).

Elevation Elevation is an important factor affecting agricultural land suitability due to its role in temperature changes, thus in variation of plant cover. The periods of vegetation and bloom are delayed by 4–6 days for every increase of 100 m in elevation on the mountains (Atalay 2006). This fact negatively affects the plant variety to be selected for agricultural production. Elevation of the study area ranges between 900 and 1350 m above sea level. Elevation with a <1000 m was evaluated as "highly suitable", 1000–1100 m as "moderately suitable", 1100–1200 m as "marginally suitable", and >1200 m as "unsuitable" for agriculture. High regions such as hills and mountainous areas have the lowest weight values of AHP (Tables 5, 6; Fig. 2f).
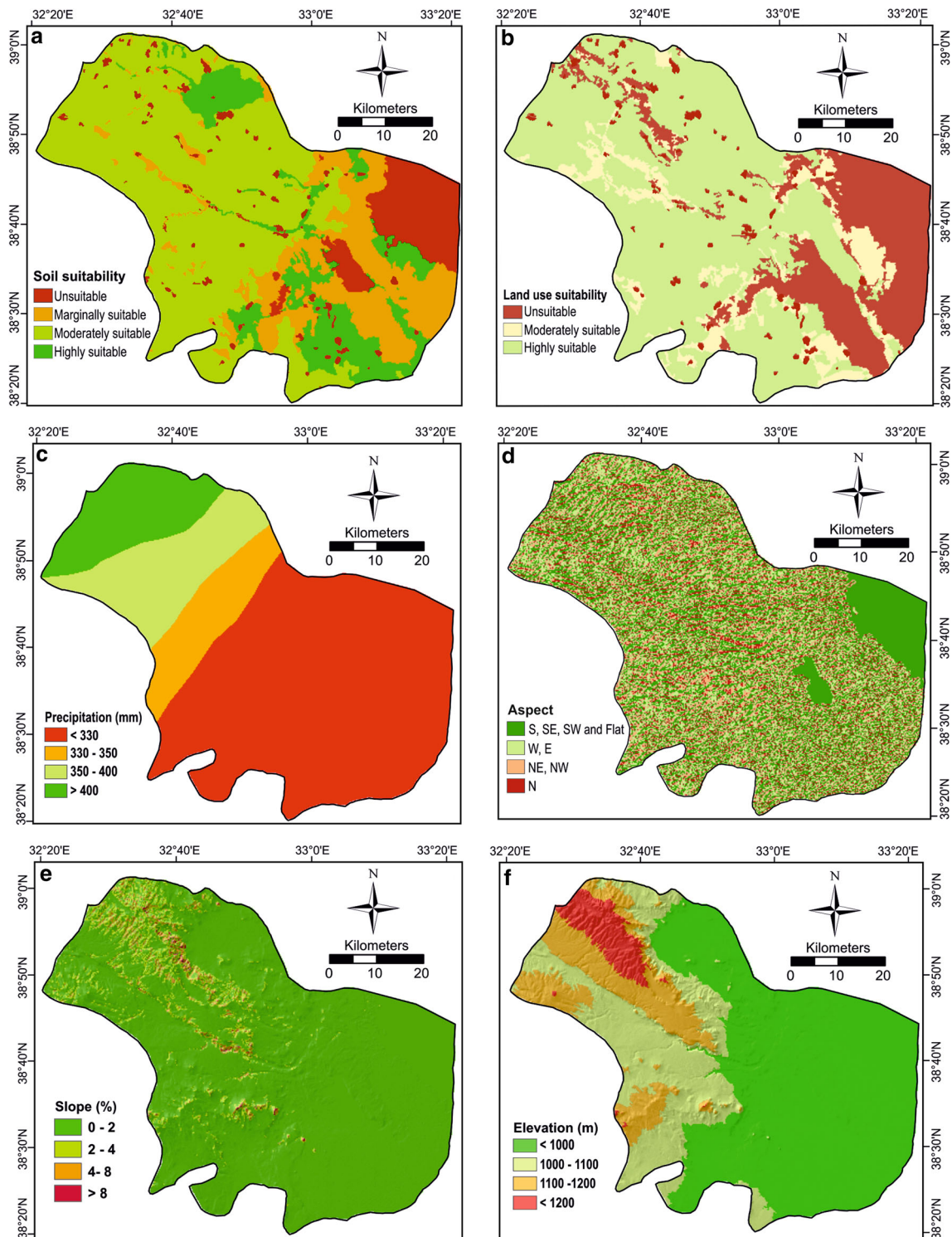
Fig. 2 Criteria distribution maps of the study area **a** soil suitability, **b** land use suitability, **c** annual precipitation (mm), **d** aspect, **e** slope (%), **f** elevation (m)

Irrigation

Salt-affected soils may occur under the influence of a wide range of factors such as soil type, field slope and drainage, irrigation system type and management, fertilizer and manuring practices, and other soil and water management practices (Bauder et al. 2011). In study area, the most critical factor in predicting, managing, and reducing salt-affected soils is the quality of irrigation water. Besides affecting crop yield and physical conditions of soil, quality

Table 4 Land use pattern in Cihanbeyli County

Land use	Area (km²)	Percent
Settlement	78.78	1.92
Industry and mining area	3.06	0.08
Water bodies	248.81	6.07
Bare soils	453.19	11.05
Marsh	308.62	7.53
Meadow	468.28	11.42
Pasture	0.40	0.01
Mixed agriculture	359.32	8.76
Irrigated agriculture	804.27	19.61
Dry-farm agriculture	1375.68	33.55
Total	4100.412	100

of the irrigation water can affect fertility needs, irrigation system performance and longevity, and how the water can be applied. Therefore, knowledge of irrigation water quality is critical to understand the required management changes for long-term productivity.

In this study, classes of groundwater suitability for irrigation which consist of ECw, SAR, and Cl values of

groundwater were adapted from irrigation water quality guideline presented by Ayers and Westcot (1985).

Salinity hazard The most influential water quality guideline on crop productivity is the water salinity hazard as measured by ECw. Higher ECw means that less water is available to plants even though the soil may appear wet. Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as ECw increases (Bauder et al. 2011). The ECw of groundwater with a <700 μS/cm was evaluated as "highly suitable"; 700–2000 μS/cm as "moderately suitable"; 2000–3000 μS/cm as "marginally suitable"; and >3000 μS/cm as "unsuitable". The ECw criterion map was obtained by ArcGIS (10.0) software with weighted values for each criterion which is presented in Table 6 (Fig. 3a).

Sodium hazard While ECw is an assessment of all soluble salts in water, sodium hazard is generally defined separately due to sodium's specific detrimental effects on soil's physical properties and plant survival. Thus, sodium hazard is expressed as SAR, which defines the relative proportions of sodium to calcium and magnesium ions in a water sample (Bauder et al. 2011; Simsek and Gunduz 2007). The SAR is calculated as follows:

Table 5 Weights of all criteria used for dry-farm agriculture in the study area

Goal	Main Criteria	Weight	CR[a]	Criteria	Weight	CR[a]	Sub-criteria (1)	Weight	CR[a]	Σweight
Dry-farm agricultural land suitability	Soil	0.581	0.025	Soil suitability	0.6	0	Highly suitable	0.531	0.037	0.18511
							Moderately suitable	0.335		0.11678
							Marginally suitable	0.09		0.03137
							Unsuitable	0.043		0.01499
				Land use	0.4		Highly suitable	0.595	0.070	0.13828
							Suitable	0.347		0.08064
							Not suitable	0.058		0.01348
	Climate	0.309		Precipitation	1	0	>400	0.558	0.044	0.17242
							350–400	0.263		0.08127
							330–350	0.122		0.0377
							<330	0.057		0.01761
	Topography	0.11		Aspect	0.556	0.03	S, SE, SW, flat area	0.341	0.006	0.03235
							W, E	0.229		0.01878
							NE, NW	0.151		0.00654
							N	0.112		0.00349
				Slope	0.333		0–2	0.588	0.057	0.02154
							2–4	0.258		0.00945
							4–8	0.111		0.00407
							>8	0.043		0.00158
				Elevation	0.111		<1000	0.616	0.056	0.00752
							1000–1100	0.241		0.00294
							1100–1200	0.099		0.00121
							>1200	0.045		0.00055

[a] *CR* consistency ratio

Table 6 Weights of all criteria used for irrigated agriculture in the study area

Goal	Main criteria	Weight	CR[a]	Criteria	Weight	CR[a]	Sub-criteria (1)	Weight	CR[a]	Σweight
Irrigated agriculture land suitability	Groundwater	0.544	0.036	DWT	0.309	0.06	<30	0.592	0.056	0.09951
							30–40	0.25		0.04202
							40–50	0.113		0.01899
							>50	0.045		0.00756
				ECw	0.470		<700	0.602	0.033	0.15392
							700–2000	0.243		0.06213
							2000–3000	0.105		0.02685
							>3000	0.050		0.01278
				SAR	0.149		<3	0.643	0.056	0.05212
							3–9	0.283		0.02294
							>9	0.074		0.006
				Cl	0.073		<140	0.685	0.047	0.0272
							140–350	0.221		0.00878
							>350	0.093		0.00369
	Soil	0.236		Soil suitability	0.6	0	Highly suitable	0.531	0.037	0.07519
							Moderately suitable	0.335		0.04744
							Marginally suitable	0.090		0.01274
							Unsuitable	0.043		0.00609
				Land use	0.4		Highly suitable	0.595	0.070	0.05617
							Suitable	0.347		0.03276
							Not suitable	0.058		0.00548
	Climate	0.165		Precipitation	1	0	>400	0.558	0.044	0.09207
							350–400	0.263		0.0434
							330–350	0122		0.02013
							<330	0.057		0.00941
	Topography	0.055		Aspect	0.556	0.03	S, SE, SW, flat area	0.529	0.006	0.01618
							W, E	0.307		0.00939
							NE, NW	0.107		0.00327
							N	0.057		0.00174
				Slope	0.333		0–2	0.588	0.057	0.01077
							2–4	0.258		0.00473
							4–8	0.111		0.00203
							>8	0.043		0.00079
				Elevation	0.111		<1000	0.616	0.056	0.00376
							1000–1100	0.241		0.00147
							1100–1200	0.099		0.00060
							>1200	0.045		0.00027

[a] *CR* consistency ratio

$$SAR = Na/\sqrt{(Ca + Mg)/2} \qquad (5)$$

In this study, the SAR value with a <3 was evaluated as "highly suitable"; 3–9 was evaluated as "moderately suitable"; and >9 was evaluated as "unsuitable" for irrigation. The SAR criterion map was obtained by ArcGIS (10.0) software with weighted values for each criterion in Table 6 (Fig. 3b).

Chloride Although chloride is essential to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations (Bauder et al. 2011; Ayers and Westcot 1985). Chloride is a common ion in irrigation waters of Cihanbeyli County. Chloride's toxic effects are immediately seen as leaf burns or leaf tissue deaths. Normally, injury to plant occurs first at the leaf tips and progresses from the tip back along the edges as severity increases. In excessive cases, early leaf drop or defoliation occurs (Ayers and Westcot 1985). Therefore, chloride value of groundwater in the study area was taken into consideration
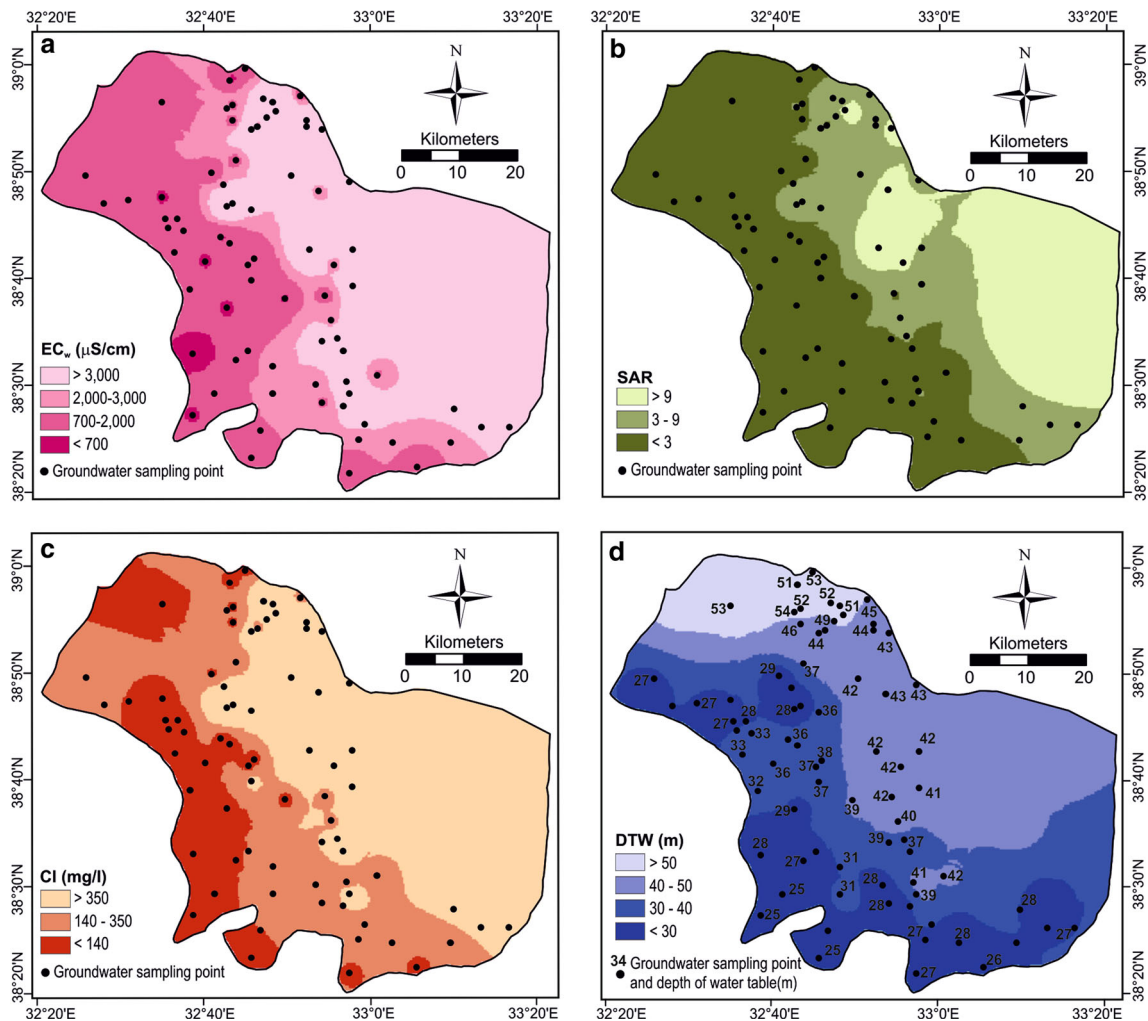
Fig. 3 Criteria distribution maps of the study area **a** ECw, **b** SAR, **c** Cl, **d** DTW

in the irrigated agricultural suitability. Chloride value of groundwater with a <140 mg/l was evaluated as highly suitable; 140–350 mg/l was evaluated as moderately suitable; and >350 mg/l was evaluated as unsuitable. The chloride criterion map was obtained by ArcGIS (10.0) software with weighted values for each criterion in Table 6 (Fig. 3c).

Depth to water table Surface water in the region is limited and restricted for the urban water supply. Therefore, agricultural production substantially relies on groundwater irrigation. Accessibility of groundwater resources is a very important criterion for irrigation in the study area. Thus, depth of water table in the study area was taken into consideration in the irrigated agricultural suitability. In the present study, the depth of water table with a <30 m was evaluated as "highly suitable"; 30–40 m was evaluated as "moderately suitable"; 40–50 m was evaluated as "marginally suitable"; and >50 m was evaluated as "unsuitable". The depth of water table criterion map was obtained

by ArcGIS (10.0) software with weighted values for each criterion in Table 6 (Fig. 3d).

Results and discussion

The main goal of applied AHP based agricultural land suitability analysis is to identify the suitable areas for agriculture that will increase productivity in the case study area. Pairwise comparison matrix shows the relative importance of the factors and criteria (Tables 5, 6). Subsequent to pairwise comparison matrix, the composite weights are derived via a sequence of multiplication. Then, in order to generate the overall score of the alternatives in the GIS environment, dry farmland suitability index (DLSI) and irrigated land suitability index (ILSI) were calculated by means of multiplication of each criteria weight with each sub-criteria weight (Tables 5, 6). DLSI and ILSI are defined as

$$
\begin{aligned}
DLSI =& [S \times ((S_1 C_{wi} \times S_1 SC_{wi}) + (S_2 C_{wi} \times S_2 SC_{wi}))] \\
&+ [C \times (C_1 C_{wi} \times C_1 SC_{wi})] \\
&+ [T \times ((T_1 C_{wi} \times T_1 SC_{wi}) + (T_2 C_{wi} \times T_2 SC_{wi}) \\
&+ (T_3 C_{wi} \times T_3 SC_{wi}))]
\end{aligned}
$$

$$
\begin{aligned}
ILSI =& [G \times ((G_1 C_{wi} \times G_1 SC_{wi}) + (G_2 C_{wi} \times G_2 SC_{wi}) \\
&+ (G_3 C_{wi} \times G_3 SC_{wi}) + (G_4 C_{wi} \times G_4 SC_{wi}))] \\
&+ [S \times ((S_1 C_{wi} \times S_1 SC_{wi}) + (S_2 C_{wi} \times S_2 SC_{wi}))] \\
&+ [C \times (C_1 C_{wi} \times C_1 SC_{wi})] \\
&+ [T \times ((T_1 C_{wi} \times T_1 SC_{wi}) + (T_2 C_{wi} \times T_2 SC_{wi}) \\
&+ (T_3 C_{wi} \times T_3 SC_{wi}))]
\end{aligned}
$$

where S weight index of soil main criteria; $S_1 C_{wi}$ weight index of soil suitability criteria; $S_1 SC_{wi}$ weight index of soil suitability sub-criteria; $S_2 C_{wi}$ weight index of land use criteria; $S_2 SC_{wi}$ weight index of land use sub-criteria; C weight index of climate main criteria; $C_1 C_{wi}$ weight index of precipitation criteria; $C_1 SC_{wi}$ weight index of precipitation sub-criteria; T weight index of topography main criteria; $T_1 C_{wi}$ weight index of aspect criteria; $T_1 SC_{wi}$ weight index of aspect sub-criteria; $T_2 C_{wi}$ weight index of slope criteria; $T_2 SC_{wi}$ weight index of slope sub-criteria; $T_3 C_{wi}$ weight index of elevation criteria; $T_3 SC_{wi}$ weight index of elevation sub-criteria. G weight index of groundwater main criteria; $G_1 C_{wi}$ weight index of water table depth criteria; $G_1 SC_{wi}$ weight index of depth of water table depth sub-criteria; $G_2 C_{wi}$ weight index of electrical conductivity criteria; $G_2 SC_{wi}$ weight index of electrical conductivity sub-criteria; $G_3 C_{wi}$ weight index of sodium adsorption ratio criteria; $G_3 SC_{wi}$ weight index of sodium adsorption ratio sub-criteria; $G_4 C_{wi}$ weight index of chloride criteria; $G_4 SC_{wi}$ weight index of chloride sub-criteria.

In accordance with AHP application, each criterion was mapped via GIS. To determine the suitable areas for both dry farming agriculture and irrigated agriculture lands, AHP was used to evaluate the scores based on suitable criteria. Each criterion map was prepared using Arc-GIS Spatial Analyst and these maps were converted into Esri Grid Format using weight values obtained from AHP. The dry farm agriculture suitability and irrigated agriculture suitability of the study area were calculated by the DLSI and ILSI, respectively. Then, land suitability maps for both irrigated and dry farm agriculture were derived with the aid of the map calculator function of ArcGIS and overlay analyses of ArcGIS spatial analyst (Fig. 4a, b).

According to the DLSI and ILSI values, the study area was divided into five land suitability classes by using the equal interval ArcView classification method. These classes are "highly suitable", "suitable", "moderately suitable" "marginally suitable", and "unsuitable" for agriculture. The results are displayed in Table 7. The land

suitability maps for both irrigated and dry farm agriculture excluding the water bodies, marsh, industry and mining areas, and built-up areas for Cihanbeyli County were obtained from the reclassified suitability map. Afterwards, a final land suitability map was derived via overlay of both irrigation and dry farm suitability maps. The final land suitability map simultaneously represents the most suitable agricultural lands in terms of dry farm agriculture and irrigated agriculture to ensure the most crop yield (Fig. 5a). The final land suitability map classified the case study area into six land suitability classes: "highly suitable for irrigation", "moderately suitable for irrigation", "highly suitable for dry farming", "moderately suitable for dry farming", "marginally suitable for dry farming", and "unsuitable" for agriculture (Table 8).

The agricultural suitability map for dry farm (Fig. 4a) shows that 5.34 % (218.98 km^2) of the study area is "highly suitable"; 12.48 % (509.28 km^2) is "suitable"; 45.19 % (1852.83 km^2) is "moderately suitable"; 16.73 % is "marginally suitable"; and 20.32 % is "unsuitable". The suitability categories of "highly suitable", "suitable", and "moderately suitable" cover 62.95 % (2581.83 km^2) of the total area. A field survey was performed in order to check the suitability of the determined areas. According to field survey, the "marginally suitable" class is generally located in marsh and bare areas. Marsh areas submerge during the rainy period (December to April) of winter. In addition, salt and alkalinity of soil is high. Bare areas are located in areas with high slope and in mountainous areas. The soils which are "moderately suitable" (45.19 %) are mostly located on the middle part of the area and these areas do not have an obstacle for dry farming in terms of height, slope, and soil quality.

The map of irrigated agricultural suitability (Fig. 4b) shows that 1.36 % (55.80 km^2) of the study area is "highly suitable", 4.57 % (187.20 km^2) is "suitable", 7.44 (304.98 km^2) % is "moderately suitable", 54.86 % is "marginally suitable", and 31.78 % is "unsuitable". Only 13.37 % (547.98 km^2) of the total area is suitable (highly suitable, suitable, and moderately suitable) for irrigated agriculture (Table 7).

Comparison of current land use map and final land suitability map

According to the land use map, 61.92 % of the case study area is currently used for agriculture, which includes 33.55 % used under dry farm agriculture, 19.61 % used for irrigated agriculture, and 8.76 % used under mixed agriculture. A cross-comparison between the current land use map and the final land suitability map shows that the majority of land classified as "highly suitable and moderately suitable for irrigated agriculture" is already being used for irrigated agriculture. According to final land
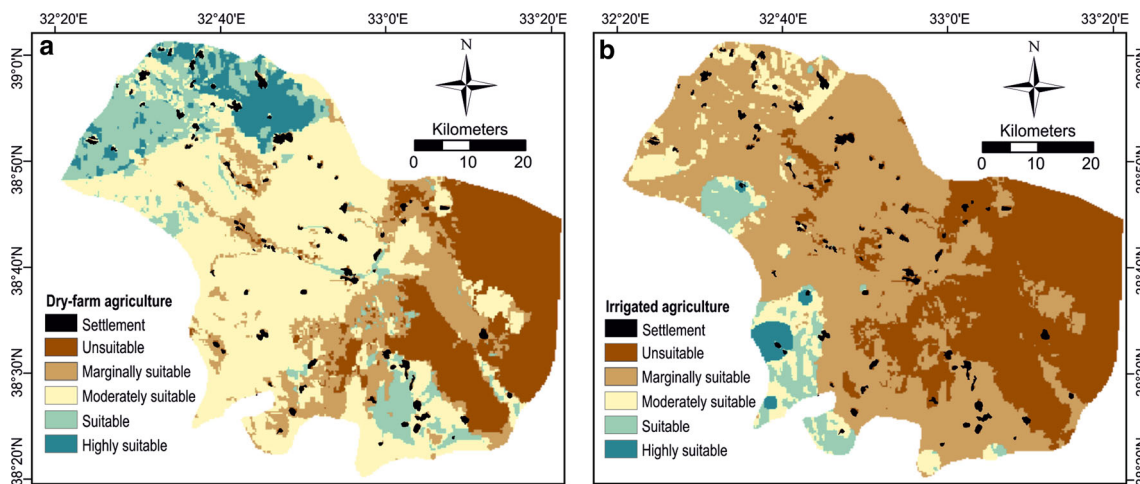
Fig. 4 Land suitability maps of the study area **a** suitability map of dry-farming agriculture land, **b** suitability map of irrigated agriculture lands

Table 7 Different suitability index classes for irrigated agriculture and dry-farm agriculture in Cihanbeyli County

Land use	Dry-farm agriculture		Irrigated agriculture	
	Area (km^2)	Percent	Area (km^2)	Percent
Unsuitable	833.06	20.32	1302.85	31.78
Marginally suitable	685.85	16.73	2249.12	54.86
Moderately suitable	1852.83	45.19	304.98	7.44
Suitable	509.28	12.42	187.20	4.57
Highly suitable	218.93	5.34	55.80	1.36
Total	4099.955	100	4099.954	100

suitability map, 0.51 % (21.09 km^2) of irrigated agricultural land covering 7.18 % (318.980 km^2) of total area is "highly suitable" while 6.67 % (273.64 km^2) is "moderately suitable". However, current irrigated agricultural land forms 19.61 % (804.27 km^2) of the study area (Table 8).

Areas classified as "highly suitable for dry farm agriculture" (655.63 km^2) are already being used for dry farm agriculture. Also, areas classified as "moderately suitable for dry farm agriculture" (1667.82 km^2) are suitable for dry farm agriculture, too. Thus, totally 56.77 % (2323.45 km^2) of the study area is suitable for dry farm agriculture. Currently an area of 1735 km^2 (42.31 %) classified as "highly and moderately suitable" for dry farm agriculture is indeed being used for dry farming. In addition to the areas currently used for dry farm agriculture, an area of 588.45 km^2 (14.46 %) can also be used for dry farm agriculture.

Sensitivity analysis

Sensitivity analysis is a common approach used in AHP methodology to change input factors One-At-a-Time to see the effects each input change produces on the output. Sensitivity analysis is a logical approach as any change observed in the output will unambiguously be due to the single factor that is changed. By changing one factor at a time, all other factors can be fixed, at least to a great extent,
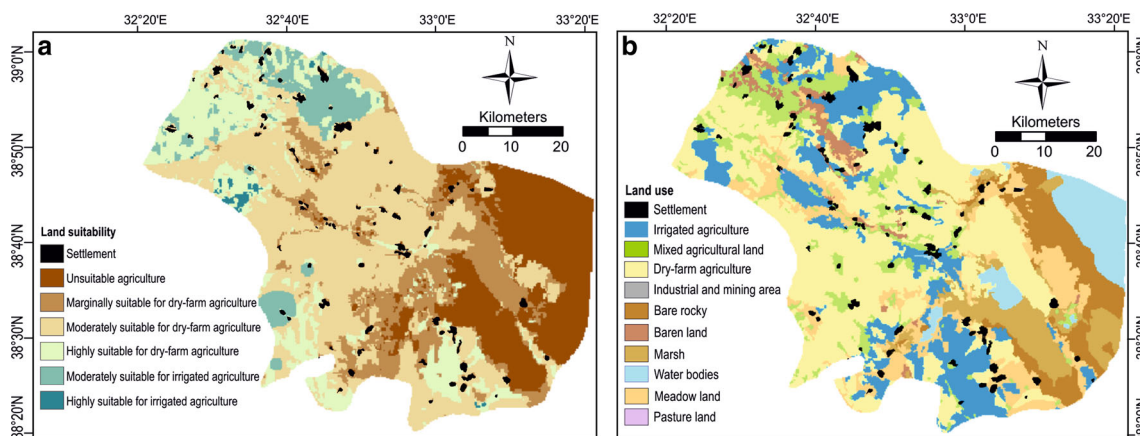

Fig. 5 Land suitability maps of the study area **a** final land suitability map, **b** current land use map

Table 8 Different suitability index classes for final agricultural land suitability in Cihanbeyli County

Land use	Area (km²)	Percent
Unsuitable	827.85	20.20
Marginally suitable for dry-farm agriculture	653.92	15.95
Moderately suitable for dry-farm agriculture	1667.82	40.68
Highly suitable for dry-farm agriculture	655.63	15.99
Moderately suitable for irrigated agriculture	273.64	6.67
Highly suitable for irrigated agriculture	21.09	0.51
Total	4099.955	100

to their central or baseline value, increasing the comparability of the results. Criteria sensitivity can commonly be analyzed via changing criteria values, changing relative importance of criteria, and changing criteria weights (Chen et al. 2010).

This study, mainly focused on highly suitable areas for dry farm agriculture and irrigated agriculture, explored the dependency of model output on the weights of input parameters and visualized the spatial change of evaluation results. Thus, different weights of criteria were used to determine the areas that are suitable for dry farm agriculture and irrigated agriculture. Soil, climate, and topography criteria are less sensitive than groundwater criteria. Groundwater is considered to be the most sensitive parameter according to irrigated agricultural land suitability (Fig. 6).

The applied land suitability evaluation for agriculture in our study area is robust yet relatively and locally sensitive to weight changes (Fig. 4). Analysis of sensitivity criteria is beneficial for validation and robustness of the results. The outcomes of this research would help the development of a sustainable land suitability model for agriculture development by providing more sustainable land use decisions and creating effective agricultural policies.

Conclusion

This research intends to provide a basic guideline to identify the suitable lands for sustainable urban agriculture practices. In this context, a methodology of GIS and AHP based LSA has been used to determine the suitability of Cihanbeyli County for agricultural production using soil, climate, topography, and groundwater characteristics of the area.

Research results evince the comparison of current land use and land suitability index classes for different agriculture uses. "Highly suitable" and "suitable" lands for dry farm agriculture are already being used in the area for irrigated and dry farm agriculture. At the same time, areas classified as "moderately suitable" (1667.82 km²) for dry farm agriculture have a potential for dry farm agriculture. Excluding the areas currently used for irrigated and dry farm agriculture, an area of 588.75 km² is potentially
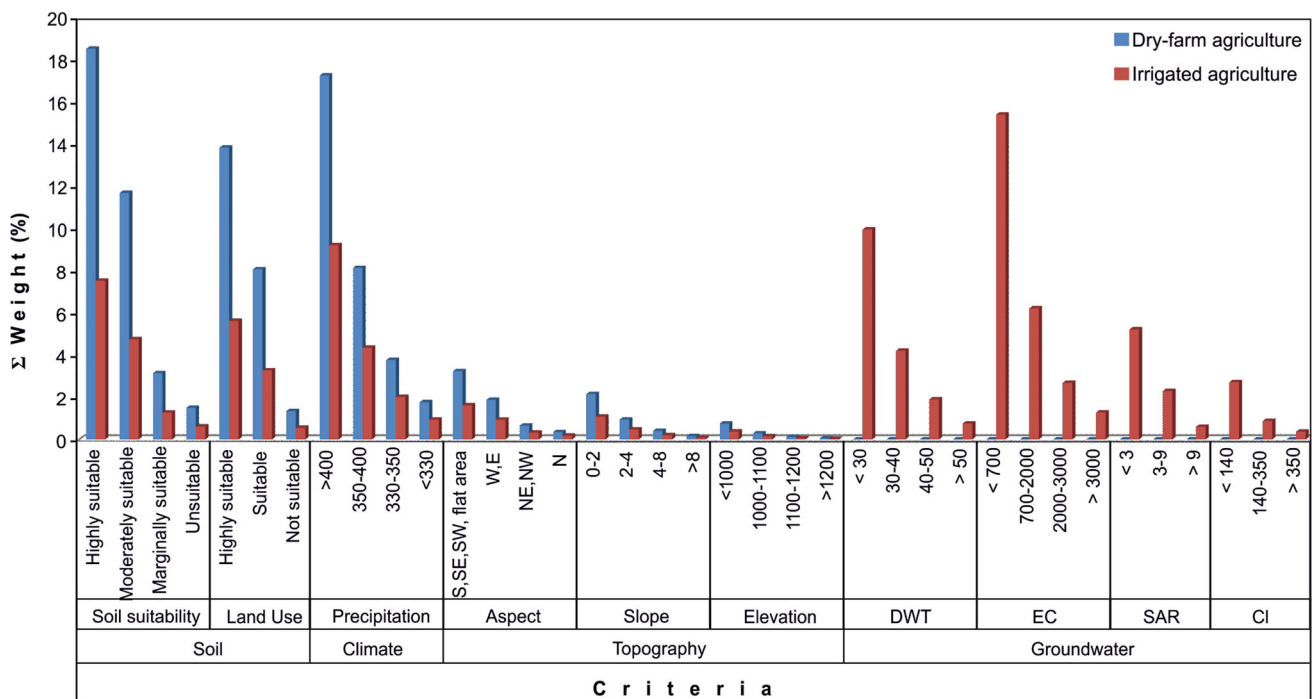

Fig. 6 Total weights of the selected criteria for dry-farm agriculture and irrigated agriculture land suitability

suitable for development in terms of dry farm agriculture. The irrigation activities in the areas classified as unsuitable and marginally suitable in terms of irrigation decreases the product quality. 12.43 % (509.54 km^2) of the area currently used for irrigated agriculture (19.61 %, 804.27 km^2), therefore, should be turned into dry farm agricultural land with regards to production efficiency. Also high irrigation rates lead to a decrease in groundwater level in the region which has an arid and semi-arid climate. Consequently, regulations should be urgently introduced for agricultural activities in the study area which is morphologically quite suitable for agriculture. Moreover, plant pattern should be amended according to water quality using technology, especially in areas designated for irrigated agriculture.

AHP and GIS based LSA supports decision making for sustainable agricultural production in Cihanbeyli and offers an opportunity to enhance agricultural planning by providing the much required information for farmers and agricultural planners. Consequently, the resultant agricultural land suitability map (1) facilitates a better understanding of alternative agricultural land use suitability patterns for future development, thus can be used for decision-making in agricultural development of the area, (2) refers agricultural activities to the areas that have good physical and environmental conditions for agriculture, thus achieving maximum agricultural efficiency in countryside, and (3) improves non-agricultural uses in the areas that are unsuitable for agriculture and have low efficiency.

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