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ORIGINAL PAPER

DETERMINATION OF SUITABLE AREAS OF APPLE (*MALUS DOMESTICA*) CULTIVATION WITH AHP AND GIS TECHNIQUES

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Abstract

The planning of crops to be grown in agricultural land has an important place in terms of sustainable development. In this study, it was aimed to determine the suitable areas for apple cultivation in all the land of Korkuteli district in Antalya province. For this purpose, Analytical Hierarchy Process (AHP) method, which is frequently used in suitability analysis, was used. Analytical Hierarchy Process is a multi-criteria decision-making method that makes complex problems simpler and provides solutions. This study consists of three basic stages. In the first stage, parameters related to the study area and the AHP methods were determined and data for the area was obtained. In the second stage of the study, analysis with geographical information systems (GIS) and AHP were carried out. The weights of the AHP parameters were determined according to each other by taking their importance into consideration and their suitability was checked with the consistency rate (CR = 0,057). In addition, a weighted overlay analysis was performed according to weight values and importance rates determined at this stage. At the last stage, suitable areas for apple cultivation were determined and a suitability map was established. At this stage, the study area was separated into five categories according to the United Nations Food and Agriculture Organization (FAO) land suitability classification. According to the obtained suitability map, it was determined that 14,86% (34791 ha) of the study area was highly suitable, 13,79% (32270 ha) was moderately suitable and 8,47% (19817 ha) was marginally suitable for apple cultivation. It was determined that the unsuitable area ratio for apple cultivation was 45.29% (106015 ha) and completely unsuitable area ratio was 17.59% (41166 ha). In the study, the results of the analysis were compared with the agricultural areas in the land use of CORINE 2012. According to this, it was seen that the total area determined suitable for apple cultivation overlaps with the total agricultural areas in the land use of CORINE 2012.

Key words: AHP, Antalya, GIS, land suitability, malus domestica.

INTRODUCTION

Remote sensing and geographic information system technologies have been used frequently in agricultural ecosystems in which animal and plant production are done. The studies are mainly aimed at monitoring the change of land cover and global change (Corgne et al, 2016). In addition to this, more specifically by means of high resolution satellite images, it is also possible to conduct studies for estimating the chlorophyll content of canopy based on vegetation indices in the apple trees with a larger monitoring area, more rapidly and a low cost (Li et al., 2018).

The apple plant is from the Pomoideae subfamily and is the Malus genus. Within the Malus genus, there are more than 30 species that grow in Asia, Europe, America and other countries. It is not known when the apple plant is cultivated. However, since ancient times history has been growing in Asia and the European continent. In the first place in the world apple production in China, the US, Iran, Turkey and France is located. Apple cultivation in Turkey, compared to other mild climate fruit species, has more production areas. Turkey's apple production is determined as the amount of 2.926.00 tons in 2016. Antalya apple production was 281.000 tons in the same year (Antalya Provincial Directorate of Agriculture and Forestry, 2018).

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980) is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the

consistency of the decision maker's evaluations, thus reducing the bias in the decision making process. The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multicriteria problems such as site selection and suitability models. In a weighted overlay analysis, each of the general overlay analysis steps are followed. As with all overlay analysis, in weighted overlay analysis, you must define the problem, break the model into submodels, and identify the input layers.

Weighted overlay is one method of modelling suitability, each raster layer is assigned a weight in the suitability analysis, Values in the rasters are reclassified to a common suitability scale Raster layers are overlaid, multiplying each raster cell's suitability value by its layer weight and totalling the values to derive a suitability value, these values are written to new cells in an output layer, thesymbology in the output layer is based on these values (Esri, 2018).

In terms of the sustainability of natural resources, proper use of soil, which is an indispensable element of agricultural areas, is necessary. Remote sensing and geographic information systems can play an important role in determining areas suitable for agricultural crop cultivation. In this context, suitability analysis for agricultural areas can be performed with AHP and weighted overlay techniques. The integration of GIS and AHP using different criteria can have positive effects on the decision making process. The inclusion of economic and social parameters as well as physical parameters to the studies to be conducted will contribute to the results of suitability analysis in a positive way. In addition, the subjective expert opinions used in these studies are of particular importance (Mishra et al, 2015).

In the study conducted by Akıncı et al., (2012) to determine the areas suitable for agriculture with the AHP method9 criteria reflecting the topographical characteristics of the area and the soil structure were used. As a result of the analysis, the study area was divided into 5 categories according to the land suitability classification. In another study, the factors determining the agricultural areas suitable for ecological area usage decisions were detected by taking the literature review and expert opinions into consideration. The suitability value weights of these factors were determined with the suitability value scoring system according to the AHP method. The suitability value weights obtained as a result of the evaluation were analysed by McHarg's weighted overlay method (Erdoğan et al., 2015).

Analytic Hierarchy Process and GIS techniques are used in the studies for the determination of areas suitable for apple cultivation and for the evaluation of land suitability. Two methods are used for the design of the FAO classification framework. The comparison of the suitability map obtained from the study with the actual field values is important to increase accuracy (Kim and Shim, 2018).

The planning of crops to be grown in agricultural land has an important place in terms of sustainable development. In this study, it was aimed to determine suitable areas for apple cultivation in all the land of Korkuteli district in Antalya province. For this purpose, Analytical Hierarchy Process (AHP) method, which is frequently used in suitability analysis, was used. Analytical Hierarchy Process is a multi-criteria decision-making method that makes complex problems simpler and provides solutions.

MATERIALS AND METHODS

This study consists of three basic stages (Figure 1). In the first stage, the study area and the parameters to be used in the AHP method were determined and data for the field was obtained. In the second stage of the study, Geographical Information Systems (GIS) and analysis with AHP were carried out. In this context, the weights of the AHP parameters were determined according to the significance level of each other and the consistency ratio (CR) was checked. In addition, a weighted overlay analysis was performed according to weight values and significance level determined at this stage. In the final stage, suitable areas for apple cultivation were determined and a suitability map was established. At this stage, the study area was divided into five categories according to the United Nations Food and Agriculture Organization (FAO) land suitability classification (FAO, 2018).

In the first basic step of the study, the study area was determined. In this context, the District of Korkuteli, Antalya Province, was chosen as the study area (Figure 2). The District of Korkuteli, Antalya Province, located in the Mediterranean region, has an altitude of 1020 m. above sea level,and there prevails a 1/4 Mediterranean climate and a 3/4 lakes region continental climate. Cold weather comes from the lakes region and hot weather from the Mediterranean region. Four seasons of the year are apparent in Korkuteli. The average weather temperature is -5 degrees in winter and +25 degrees in summer. The Bey Mountains, which form the beginning of the Taurus Mountains, are at the rear part of the Mediterranean Sea.TheDistrict of Korkuteli, located in the Bey Mountains, has a land structure in which there are plains and hills. As a natural structure, the slopes and hills of the Bey Mountains are covered with pine grove, shrubbery and forests; plains are used as agricultural (Korkuteli District Governorship, 2018).

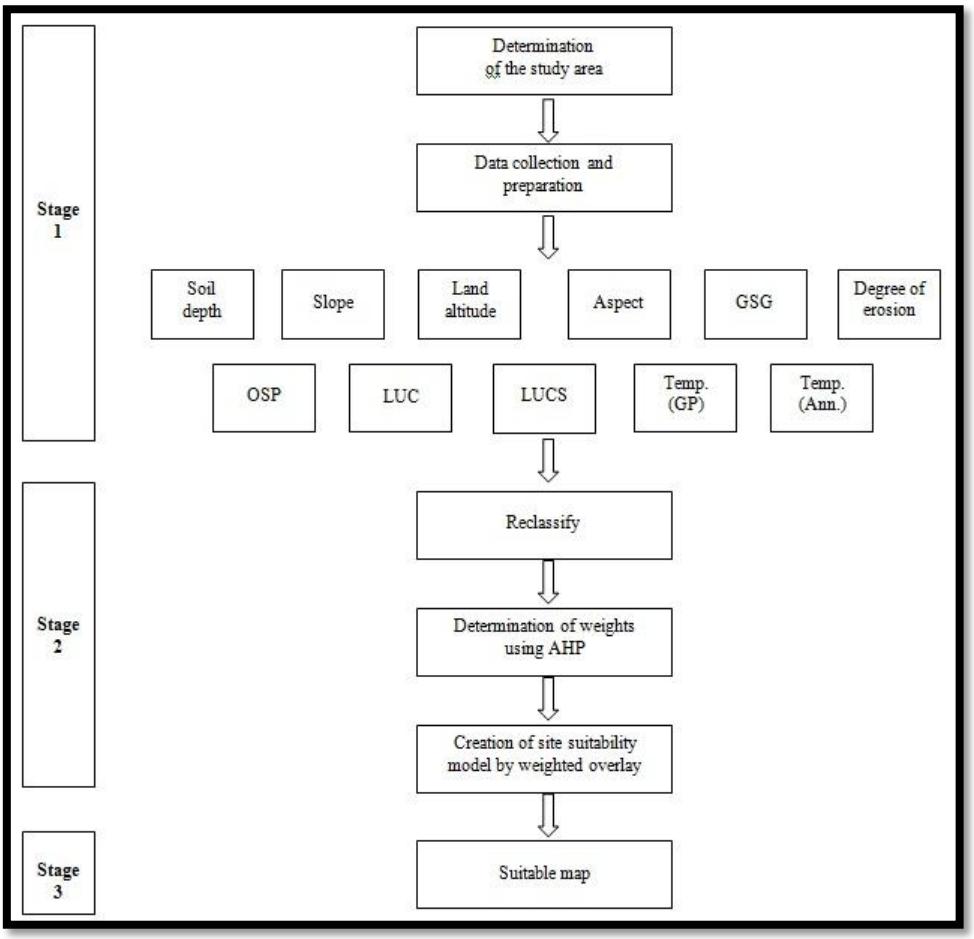

Figure 1. Flowchart

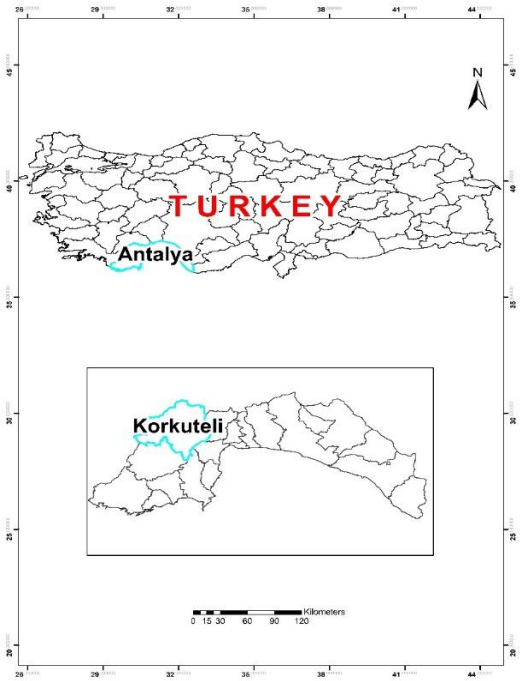

Figure 2. Study area

At this stage, the parameters to be used in the study were also determined. Then data on these parameters were provided. 11 parameters were used in this study determined suitable areas for apple cultivation. These are soil depth (cm), slope (%), land altitude (m), aspect, land use capability classes (LUC), great soil groups (GSG), degree of erosion,

other soil properties (OSP), land use capability subclasses (LUCS), temperature in the growth period (March-September) and average annual temperature.

Table 1. Sub-parameter for apple

Parameter	Sub-Parameter	Score			
Depth (cm)	Depth (+90)	10	**Erosion**	1 (no or little)	10
	Mid-depth (50-90)	8		2 (moderate)	8
	shallow (20-50)	6		3 (severe)	6
	Litozolik	2		4 (too severe)	4
	Water surface and settlement areas	1		Water surface and settlement areas	1
Slope (%)	0-2 (flat)	10	**OSP**	r (rocky)	2
	2-6 (slight)	8		t (stony)	4
	6-12 (mid)	6		y (poorly drained)	6
	12-20 (steep)	4		No data	5
	20-30 (too steep)	3		Water surface and settlement areas	8
	>30 (steep)	1	**LUCS**	es, se (slope and damage of erosion , soil insufficiency)	2
Altitude (m)	0-500	1		e, sw (slope, damage of erosion, soil insufficiency, wetness, drainage disorder or damage of flood)	4
	500-700	8		w (wetness, drainage disorder and damage of flood)	8
	700-1000	10		Water surface and settlement areas	10
	1000-1300	7	**Temperature (Growth Period-GP)**	13,5-16	15<x<18
	1300-1700	6		16-17	10
	1700-2100	3		17-18	9
	>2100	2		18-19	8
Aspect	G, GB, GD	8		19-20	6
	K	2		20-22	4
	KB, KD	5	**Temperature (Annual-Ann)**	9-10	10
	B, D	7		10-12	8
LUC	I, II, III	10		12-14	6
	IV, V	8		14-16	4
	VI	2		16-18	2
	VII	1			
	VIII	0			
GSG	A (Alluvial)	10			
	C (Colluvial)	8			
	M (Brown Forest Soil)	6			
	T (Mediterranean Terra Rosa)	5			
	H (Hydromorphic Alluvial)	3			

In the second stage of the study, first of all the sub-parameters of the parameters to be used in the study were determined.The AHP parameters were scored between 1 and 10 according to their significance level for apple trees to weightedoverlay analysis (Table 1).

Table 2. AHP matrix

AHP	GSG	LUC	LUCS	Depth	Slope	Aspect	Altitude	Erosion	OSP	Temp (GP)	Temp (Ann)
GSG	**1**	2	2	1	7	9	1	9	7	6	6
LUC	0,5	**1**	2	2	7	9	4	9	7	4	4
LUCS	0,5	0,5	**1**	2	5	7	4	7	7	4	4
Depth	1	0,5	0,5	**1**	7	7	1	7	7	4	4
Slope	0,14	0,14	0,2	0,14	**1**	1	1	1	3	1	1
Aspect	0,11	0,11	0,14	0,14	1	**1**	1	2	1	1	1
Altitude	1	0,25	0,25	1	1	1	**1**	4	2	4	4
Erosion	0,11	0,11	0,14	0,14	1	0,5	0,25	**1**	2	1	1
OSP	0,14	0,14	0,14	0,14	0,33	1	0,5	0,5	**1**	1	1
Temp (GP)	0,17	0,25	0,25	0,25	1	1	0,25	1	1	**1**	1
Temp (Ann)	0,17	0,25	0,25	0,25	1	1	0,25	1	1	1	**1**

The matrix analyse was established by determining the significance level among the AHP parameters. The AHP parameters were scored between 1 and 9 in the matrix analyses (Saaty, 1994).Then, in the study, AHP results were obtained by taking the relevant expert opinions about the soil and climatic characteristics suitable for apple cultivation. In this context, for all parameters weight values were calculated according to matrix values.

Table 3. AHP results

Parameters	W	%
GSG	0,212895	21,29
LUC	0,203631	20,36
LUCS	0,167146	16,71
Depth	0,145148	14,51
Slope	0,036583	3,66
Aspect	0,03216	3,22
Altitude	0,088412	8,84
Erosion	0,026386	2,64
OSP	0,025032	2,5
Temperature (Growth Period)	0,031303	3,13
Temperature (Annual)	0,031303	3,13
Total	1	100

AHP efficiency criteria are measured by Consistency Ratio (CR) which is estimated according to Eq.1. The CR depends on the Consistency Index (CI) and Random Index (RI). Consistency Index is estimated according toEq.2 and RI values are used from the values of Table 4. According to this,if the Consistency Ratio (CR) <0.1, then the pairwise comparison matrix is acceptable and the weight values are valid. (Saaty,1994).

$$\text{Consistency Ratio (CR)} = \text{CI/RI} \quad (1)$$

$$\text{Consistency Index (CI)} = \lambda_{max}\text{-n/n-1} \quad (2)$$

Equation 2 indicates the Consistency Index (CI) when λ_{max} is the principle or highest eigenvector of the computed matrix and n denotes the order of the matrix.

Table 4.Random Index (Saaty, 1994)

N	RI	N	RI
1	0	8	1,41
2	0	9	1,45
3	0,58	10	1,49
4	0,9	**11**	**1,51**
5	1,12	12	1,48
6	1,24	13	1,56

The consistency ratio was calculated according to the matrix that was formed for the significance level of the AHP parameters and the result was found to be 0.057 <0.1.According to this consistency ratio, the weight values obtained in Table 3 were used in weighted overlay analysis. The ratings of the sub-parameters of each parameter were also used in the analysis.

CONCLUSIONS

In the study area, suitable areas for apple cultivation were determined and a suitability map was established. The study was conducted in the District of Korkuteli, Antalya Province. At this stage, the study area was divided into five categories according to the United Nations Food and Agriculture Organization (FAO) land suitability classification (Figure 3).

According to the obtained suitability map, it was determined that 14,86% (34791 ha) of the study area was highly suitable, 13,79% (32270 ha) was moderately suitable and 8,47% (19817 ha) was marginally suitable for apple cultivation. It was determined that the unsuitable area ratio for apple cultivation was 45.29% (106015 ha) and completely unsuitable area ratio was 17.59% (41166 ha).

In addition, the results of the analysis obtained in this study were compared with the agricultural areas in the land use of CORINE 2012 (Figure 4 and Table 5). According to this, the total of highly suitable, moderately suitable and marginally suitable area for apple cultivation was found 86879.07 ha. The total agricultural area in the land use of CORINE 2012 was 85374 hectares. Accordingly, it is evaluated that the results of both analysis overlap and the difference are caused by the increase in agricultural areas over time.

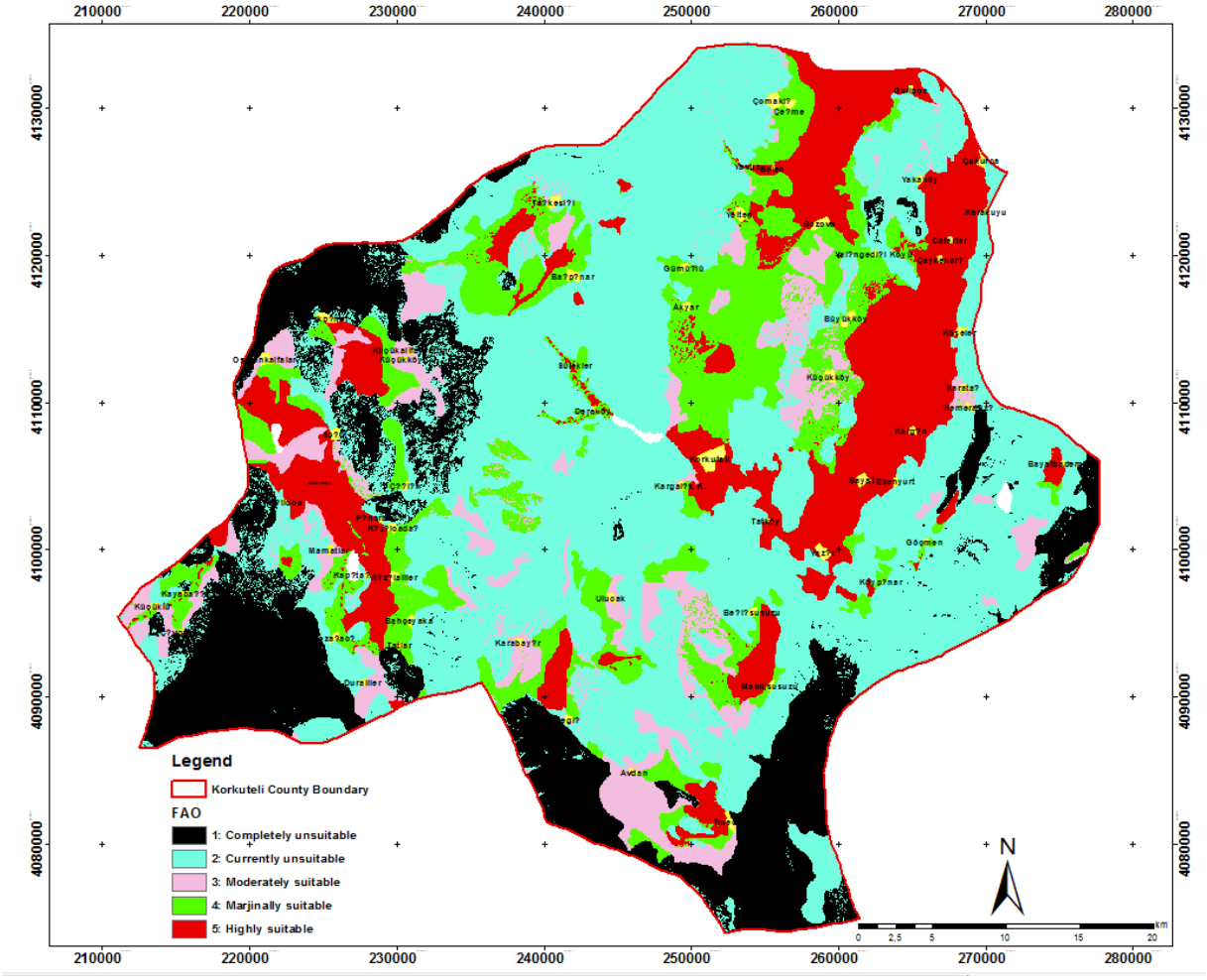

Figure 3. Suitable map

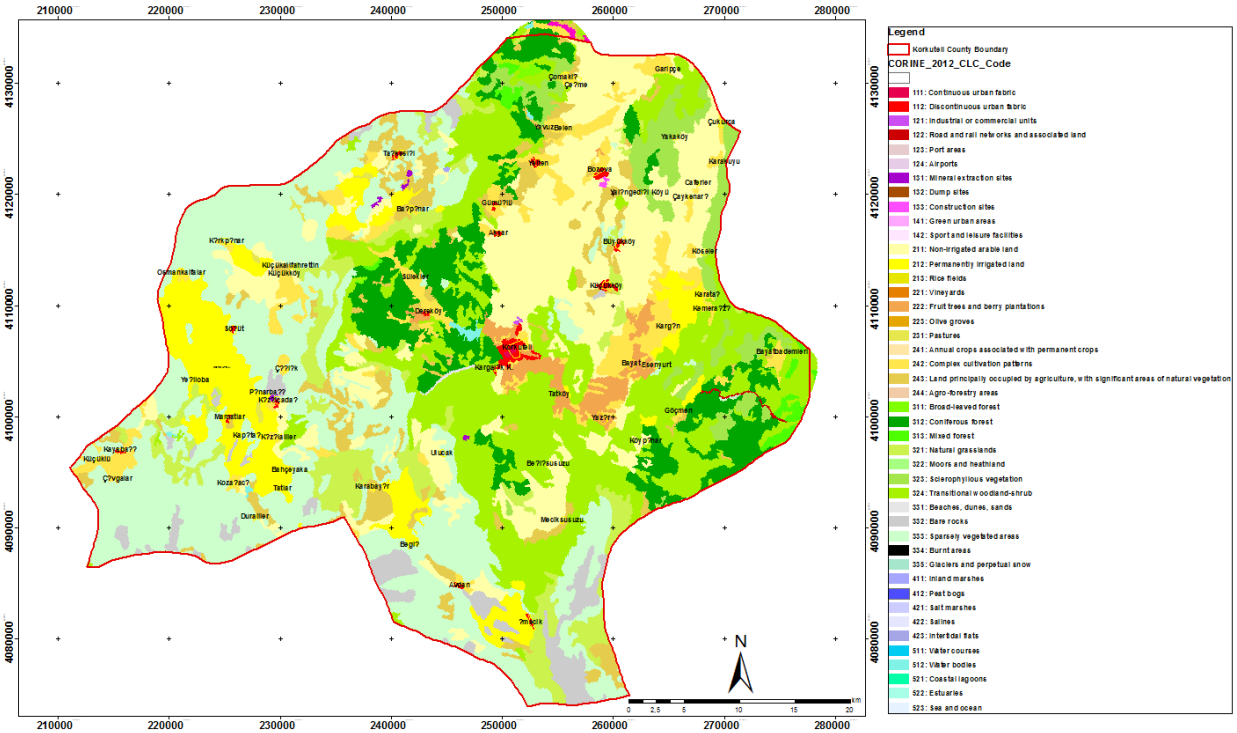

Figure 4. CORINE_2012 map and CLC code

Table 5. Comparison of analysis results with CORINE 2012 classification results

CORINE 2012	Field (ha)	ANALYSIS RESULTS	Field (ha)	%	Field (ha)
Non-Agricultural Land	148483.48				
Agricultural Land		1:Completely unsuitable	41166.18	18	147181.41
211/212: Non-irrigated arable land/Permanently irrigated land	55295	2: Currently unsuitable	106015.23	45	
222: Fruit trees and berry plantations	3893	3: Marginally suitable	19817.01	8	
242/243: Complex cultivation patterns/Land principally occupied by agriculture, with significant areas of natural vegetation	26116	4:Moderately suitable	32270.31	14	**86879.07**
Sum Of Agricultural Land For Prennial Products	**85374**	5: Highly suitable	34791.75	15	
General Total	**233787**	**Total**	**234060.48**	**100**	**234060.48**

The results of this study conducted in the District of Korkuteli, Antalya Province, reveal the usability of AHP and GIS techniques in the determination of the suitable areas for apple cultivation.

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