LAND USE SUITABILITY ANALYSIS OF THE ULUBEY CANYON (USAK –TURKEY) AND ITS SURROUNDINGS

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Key-words: Ulubey Canyon, land use, land use suitability analysis, Geographical Information System, Analytical Hierarchy Process.

Abstract. The use of natural resources is important in terms of sustainability. The larger residential areas, more agricultural products and more raw-materials are needed due to an increased population. Unfortunately, the increasing people's demands and the development of world resources are not at the same level. This situation puts pressure on natural resources to increase in parallel with the population increase. Due to the pressure of population, settlements, different economic activities and the food needs have expanded. Therefore, to determine land-use suitability according to sustainable development criteria is the most meaningful way. For that reason, it is necessary to make "Land-Use Suitability Analysis" and to form land-use plans on these conditions. This study, on Ulubey Canyon (Usak – Turkey) and its surroundings is analyzed in terms of land-use suitability. Resorting to Geographical Information Systems (GIS) and the Analytical Hierarchy Process (AHP), the study-area is approached in terms of three land-use categories: agriculture, pasture and forest. For this analysis, topographic conditions, soil properties, climate types and lithological properties are evaluated. The data obtained are compared with the current land-use situation, the suitability of agriculture, pastureland and forestland is determined and the results evaluated. Finally, as a result of the AHP analysis of Land-Use Categories, such as agriculture, forest and meadow-pasture, suitability ratios are as follows: 54% agricultural lands, 39% forest lands and 7% pasture lands. These ratios evidence that the use of land for agricultural purposes is more prevalent and that agricultural areas are more dominant than meadow-rangeland and forest areas.

1. INTRODUCTION

Depending on the population growth: people need larger settlement areas, more agricultural products and more raw materials for industry. This situation puts greater pressure on natural resources and agricultural areas. For sustainability, natural resources properly should be used. For this purpose, land-use planning helps making decisions about land-use most beneficial for human use, as well as protecting natural resources for future use (FAO, 1976). While land-use planning is being made, socio-economic characteristics must be taken into consideration as well as the natural characteristics of the site (Akbulak, 2010).

Land-use suitability is the basis of land use planning (Akinci *et al.*, 2013). Land-use suitability includes the decision to use available resources based on their assessed potential (Rockström *et al.*, 2002; Bandyopadhyay *et al.*, 2009; Akinci *et al.*, 2013). The criteria used to determine suitability, differ in terms of land properties and the aim of the study.

Even criteria could be changed depending on the land use categories. Thus, the criteria used to evaluate the suitability of categories were not uniform. For instance, the parameters of agricultural suitability are slope, erosion severity, soil type, elevation and land use. On the other hand, the parameters used for forest suitability are erosion severity, geology-lithology, slope, elevation and land-use.

The suitability of land use also brings sustainability (FAO, 1985). According to FAO data, every year more than 100,000 km^2 of forest area around the world is converted into

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agricultural area (FAO, 2006). In Turkey, more than 390 km^2 of forest area were turned into farmland between 2006–2012 (Bayar, 2018). For this reason, it is important to determine by a "Land Use Suitability Analysis", the quantities and ratio that are suitable or not. In the analysis of land use suitability, many criteria are included in the evaluation and the process is becoming complicated. Therefore, in the studies conducted in recent years, Multi-Criteria Decision Making (MCDM) methods predominate. MCDM is the appropriate planning and decision-making tool for the management of natural resources (Mendoza and Martins, 2006). In recent years, studies in Environmental Sciences have been examined, the Analytical Hierarchy Process (AHP), has been found to be the most widely used among the MCDM methods (Huang *et al.*, 2011). However, these methods alone do not seem to be sufficient in order to evaluate the spatial dimension. At this stage, the Geographical Information Systems (GIS) form an appropriate framework for spatial inquiry (Carver, 1991; Jankowski, 1995; Malczewski, 2004). Land-use suitability mapping and analysis is the most useful application of planning and management (Hopkins, 1977; Collins *et al.*, 2001; Malczewski, 2004). In this study, the Analytical Hierarchy Process (AHP) and the Geographical Information Systems are used together.

In this study, agricultural, forest and pasture/meadow-use categories were examined for a land-use suitability analysis in the Ulubey Canyon and in its vicinity. In order to determine the suitability of these types of use, an evaluation was made by taking into consideration also other criteria, such as bedrock/parent material, topographic features (elevation, slope, etc.), soil properties, erosion risk and existing land-use categories.

2. THE AIM OF THE STUDY

The "Land-use suitability analysis" is made in the Ulubey Canyon (Usak –Turkey) and into near vicinity. The study-area is discussed in terms of three categories of uses; agriculture, pasture and forest areas by resorting to GIS and the AHP method. In these analyses, such features as geological-lithology, topography (elevation, slope), soil type are assessed. The data obtained are compared with the existing land-use map.

3. STUDY-AREA

The study-area is located in the south of Usak Province in the Aegean region of Turkey (Fig. 1). It covers the Ulubey canyon and its surrounding. Usak is located on a 800–900 m plateau between the coastal Aegean and the inner-Western Anatolia. As a result of its position, there is a transition zone between the Mediterranean and the Continental climatic conditions. However, the distance of approximately 200 km from the Aegean Sea, the altitude above 800 m, have made continentality features more distinctive.

Apart from the Palaeozoic schists and marbles surrounding the Ulubey canyons in the west and east, the area is composed of claystone, sandstone and limestone units belonging to the Neogene period. In that period, there was a Neogene Lake as a result of closed basin formed of crushed carbonated units. The rise of the area after the Miocene, the collapse of the Aegean Continent and the establishment of the new drainage network on these Neogene units developed the canyon valleys and the field has gained its present appearance (Photo 1).

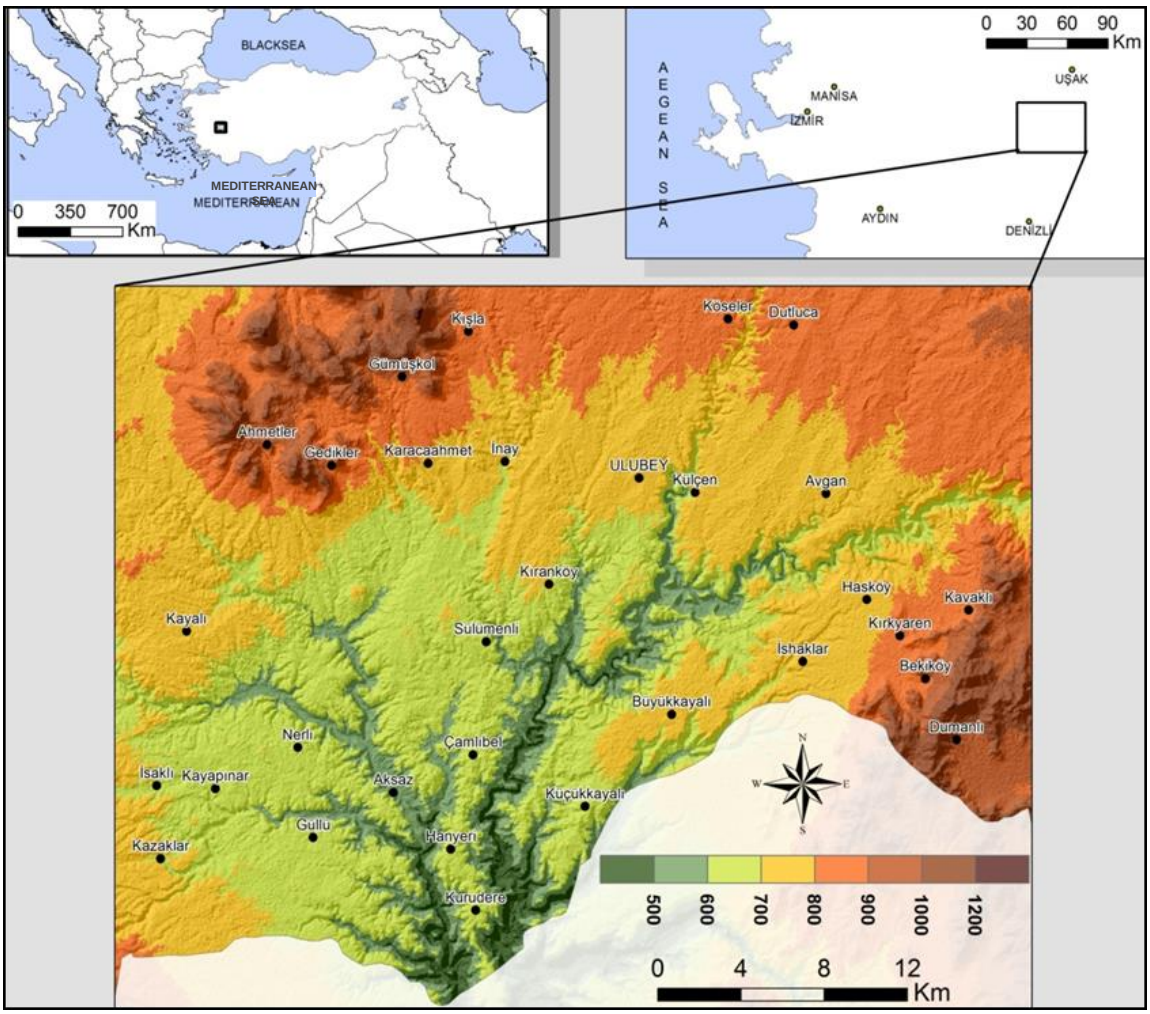

Fig. 1 – Location of the study-area.

Photo 1 – General view of the Ulubey Canyon and the Dokuzsele Stream, near the Ulubey Village.

At the end of this geomorphological process, a canyon valley system was formed by the activities of the Banaz and Dokuzsele Streams at a depth of about 200 m from the surface. These streams drain this field with a monoclinal plateau surface. The surface goes down from 900–800 m to 500 m in the south and slightly downward to the south from the Usak to the Adıguzel Dam. The Ulubey canyon is an interesting survey site with a total length of 260 km and the deepest location (190 m) from the plateau surface and widest area of 500 m.

The average annual temperature in the field is 12.5°C, with 2.4°C in January, and 23.6°C in July. The average annual rainfall is around 500 mm. In winter and spring rainfall is around 70% of the annual total rainfall, and rainfall only 7% in summer. In short, there is a long and dry summer period.

The general vegetation in the field is Mediterranean zonobiome and zono-ecoton. The Mediterranean zonobiome includes red pine and maquies. The zono-ekoton field is more outstanding because of its altitude and continentality, and there are certain types of oak not destroyed in the areas. The Ulubey settlement is generally built on a mild-slope plateau. Neogene deposits do not prevent agricultural activities. Therefore, the natural vegetation has been damaged and these areas were used for agriculture and/or pastures.

The most important centre of the study-area is the Ulubey district center and its population of over 12,000. General economic activities in the district centre and in other village settlements consist of agriculture, animal husbandry and trade depending on these activities. Plant productions in the dry-farming area are crop and forage plants. Sugar beet is an important economic activity in small areas with irrigation facilities. Animal husbandry, mostly sheep-breeding is part of traditional methods.

4. METHODOLOGY AND MATERIAL

The 1/25,000 scale topography maps (for slope and elevation studies), 1/100,000 scale Usak province land-use study (for soil characteristics), Ulubey Forest Management Chief stand maps (for Land-Use Categories such as agriculture, forest, meadow-pasture; vegetation-cover status maps), (geology-lithology reports of 1/100,000 scale, temperature and rainfall data of the Usak and Ulubey meteorological stations for climate characteristics were used.

The AHP is a technique developed by Saaty (1994) that allows a proportional relationship between multiple criteria to be established in the decision-making process. Many study areas are used in the decision-making process. This method; land use suitability analysis (Joerin *et al.*, 2001; Malczewski, 2004; Yilmaz, 2005; Akbulak, 2010; Xu, 2011; Feizizadeh ve Blaschke, 2013), agricultural product analyses (Maleki *et al.*, 2017), determination of agricultural area (Deviren Saygin and Yuksel, 2008; Akıncı *et al.*, 2013) coastal Management (Bagheri *et al.*, 2012) the effect of global warming on agricultural areas (Gaal *et al.*, 2013), location area selection (Meng *et al.*, 2011; Akyol and Alkan, 2015) is widely used in assessment studies.

In the present study, land-use suitability analysis were made by the AHP procedure (Fig. 2). This method evaluated each category of land-use; agriculture, pasture/meadow and forest.

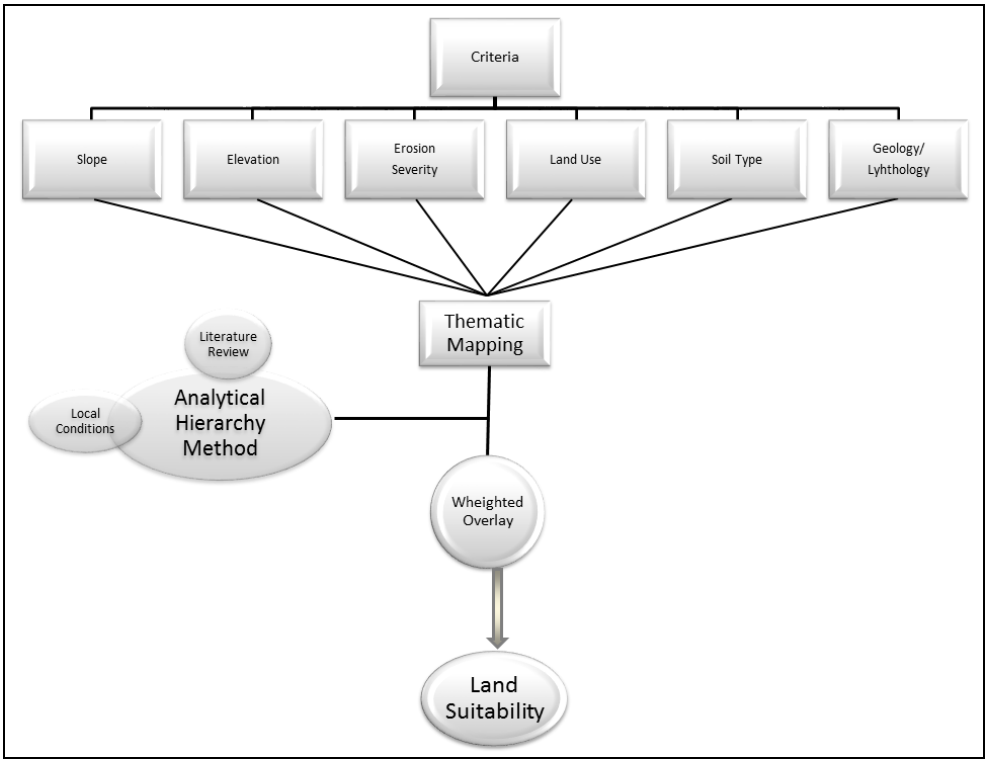

Fig. 2 – Procedure followed in land-use suitability maps.

4.1. Determination of the suitability scores of criteria

In this study, a suitability analysis was conducted for three different land-use categories (LUC), namely agriculture, pastureland and forest. For each LUC, the characteristic-criterion that affects that use is determined. For example, for agriculture evaluation criteria are slope, erosion, soil depth and current use-type. For forest LUT, in addition to agricultural LUT criteria, geological-lithological properties were assessed (Table 1).

Table 1

Criteria used and data sources

Produced Source Map	**Resolution / Data Type**	**Source**	**Factor / Layer**	**Criteria used in the analysis**		
				Agriculture	**Pasture/Meadow**	**Forest**
Topograpic Maps	Vectorized from 1/25,000 scaled raster	General Directorate of Mapping	Slope	+	+	+
			Elevation	+	+	+
Stand map	Vectorized data	Forest Management Chief	Erosion severity	+	+	+
			Soil type	+	no	no
			Land use	+	+	+
Geology	Vectorized from 1/500,000 scaled raster	General Directorate of Mineral Research and Explorations	Geology/Lithology	no	+	+

4.2. Data collection and preparation of thematic maps

After determining the criteria, spatial datasets were prepared. Land-use suitability analysis is made in the raster environment (Malczewski, 2004). Therefore, vector layers were converted to the raster format. These maps are produced with GIS software. The hierarchy between criteria was defined and the weights were calculated. Raster data produced by the analysis based on the criteria determined according to LUC and the values given to these criteria were mapped with the help of GIS Software (Arc GIS).

Table 2

AHP evaluation scale (Saaty, 1994)

Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement strongly favour one activity over another
5	Essential or great importance	Experience and judgement strongly favour one activity over another
7	Very great importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,7,6,8	Intermediate values between the two adjacent judgements	When compromise is needed

Table 3

Binary comparisons of criteria for Land-Use Categories

Comparison matrix for agriculture					
Criteria	Slope	Erosion severity	Soil type	Land use	Elevation
Slope	1	3	5	5	8
Erosion severity	1/3	1	6	3	7
Soil type	1/5	1/6	1	1/4	3
Elevation	1/5	1/3	4	1	4
Land use	1/8	1/7	1/3	1/4	1
Comparison matrix for meadow and pasture					
Criteria	Erosion severity	Geology-Lithology	Slope	Elevation	Land use
Erosion severity	1	2	4	7	8
Geology-Lithology	1/2	1	3	3	5
Slope	1/4	1/3	1	5	4
Elevation	1/7	1/3	1/5	1	2
Land use	1/8	1/5	1/4	1/2	1
Comparison matrix for forest					
Criteria	Erosion severity	Geology-Lithology	Slope	Elevation	Land use
Erosion severity	1	3	4	7	9
Geology-Lithology	1/3	1	3	5	7
Slope	1/4	1/3	1	4	6
Elevation	1/7	1/5	1/4	1	3
Land use	1/9	1/7	1/6	1/3	1

4.3. Determination of the weight points of criteria

AHP is considered an adequate mathematical method for analyzing complex decision-making problems (Saaty 1994, Malczewski 2004). After determining the criteria, weight scores are assessed considering the importance of these criteria according to each other (Table 2). The pairwise comparison method employs an underlying scale with odd values from 1 to 9 to rate the relative preferences for two elements of the hierarchy. If there is a need, then intermediate values (2, 4, 6, 8) between two adjacent intensities can be used (Meng *et al.*, 2011). Consistent with Table 2, comparison matrixes were adjusted for each land-use type (Table 3). These matrixes were composed according to field observations and the literature (FAO, 1976; Atalay, 1989; Yilmaz, 2005; Akbulak 2010; Cukur, 2017).

In this study, while the weight scores for LUC-effective factors were determined by the AHP method, first of all, matrices for binary comparisons have been created, considering the impact of the criteria for each LUC (Table 2). Then, the weight values of the criteria of the largest eigenvalue of the matrix in each LUC table were calculated.

One of the benefits of AHP is that it allows detecting and taking into account the inconsistencies of decision-makers (Saaty, 1990; Garcia *et al.*, 2014; Mishra *et al.*, 2015). For the method to be valid, the consistency rate should be 0.10 (10%) or less. If it is greater than this value, the binary comparison values between the factors need to be reviewed again (Saaty, 1994).

Subsequently, the pairwise matrix is made, and eigenvalue consistency rates are performed. In this study, the results of determining the suitability of the criteria were **0.0849** for agriculture; **0.0605** for meadow-pasture and **0.0655** for forest. Since values less than 0.10 are found, it is concluded that decision matrices are consistent and appropriate (Table 4).

Table 4

Weight scores of criteria used in the suitability analysis

Land-Use Categories	Criteria	Weights of criteria
Agriculture	Slope	0.473
	Erosion severity	0.276
	Soil type	0.072
	Land use	0.141
	Elevation	0.038
	Consistency ratio:	**0,0849**
Meadow and Pasture	Slope	0.462
	Erosion severity	0.259
	Land use	0.166
	Elevation	0.068
	Geology-Lithology	0.045
	Consistency ratio:	**0,0605**
Forest	Slope	0.482
	Erosion severity	0.262
	Land use	0.158
	Elevation	0.065
	Geology-Lithology	0.034
	Consistency ratio:	**0,0655**

4.4. Analysis of physical suitability values according to land-use categories (LUC)

Weighted overlay is a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated analysis (Malczewski, 2004, Kuria *et al.*, 2011). Thematic layers, which were used in the suitability analysis, were integrated with each other in GIS by using the weighted overlay technique (Zolekar and Bhagat, 2015). The suitability scores and weight values of the criterion were combined with the help of GIS software, and the physical suitability index for each pixel was calculated (Table 4).

5. RESULTS

As a result of field evaluation studies, the prepared maps which are the selected LUC (Land-use Categories) for this study are listed below.

According to the analysis, the categories of not-suitable and very little suitable; the ratio of the priority analysis of agricultural use is 15%, Pasture use 20% and forest use 3.0% (Table 5). That is, 15% of the agricultural land within the total agricultural area is not suitable for agricultural land-use. According to the analysis, the categories suitable and very suitable; the ratio of the priority analysis of agricultural use is 85%, pasture use 80% and forest use 97%. That is, 97% of the forest land is more suitable for forest land use. According to use, most unsuitable use is in the agricultural areas with 15% (Table 5).

In the interpretation of these maps, the use-case as a table; Table 5 summarizes the extent to which it is appropriate according to the analysis results.

Table 5

According to land-use priority; in the area covered by suitable classes and their ratios

Evaluation	**Priority analysis of agricultural use**		**Priority analysis of pasture use**		**Priority analysis of forest use**	
	km²	**%**	**km²**	**%**	**km²**	**%**
Not suitable	15.0	1.3	..	..	..	..
Much less suitable	155.4	13.4	202.0	17.4	26.0	2.2
Less suitable	364.2	31.4	574.6	49.5	94.4	8.1
Suitable	499.9	43.1	368.7	31.8	640.9	55.2
Moderately suitable	124.4	10.7	15.4	1.3	393.0	33.9
Much suitable	1.8	0.2	--	--	6.4	0.6
Total	1160.7	100	1160.7	100	1160.7	100

Figure 3 shows current land-use. Due to the fact that the area is in the transition zone between the Mediterranean climate and the Continental climatic conditions, the natural vegetation cover on the surface of the plateau is severely damaged. In Ulubey and in its close vicinity, the less sloping plateau surface is mostly used as dry farmland. Bushes and maquies communities, where forests are destroyed, are generally used as a pasture area for livestock. In the southern part of the study-area, the slopes of 500 m elevation, which was drained by branches of the Major Meander River, are covered by the red pine forests. Forest land prevails in the south of the area. There are also maquies communities and agricultural activities where there is a decrease in the slope of the valley floor and some places in study area have been destroyed.

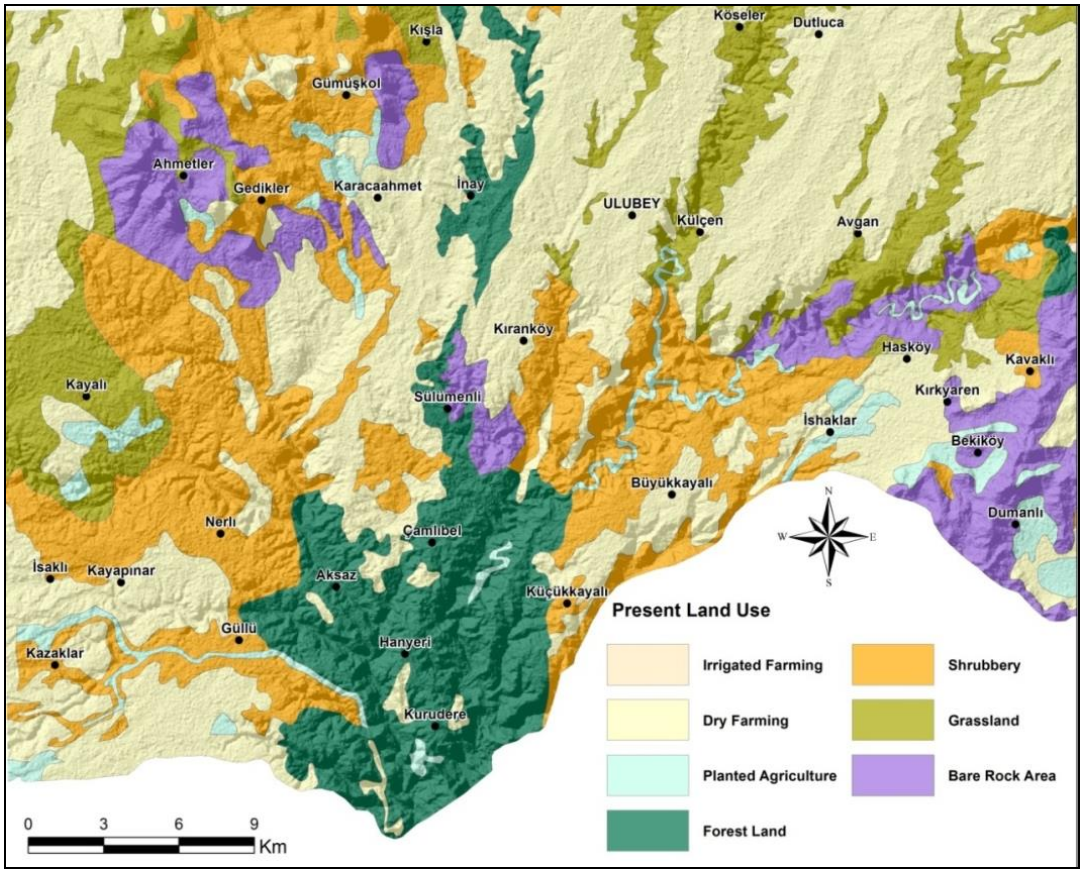

Fig. 3 – Current land-use situation in Ulubey (Usak) and its surrounding.

In Figure 4, distribution by according to the suitability was made by using AHP method about Agricultural Land-use Type (ALUT). According to ALUT, “moderate” and “appropriate areas” are 54% of total ALUT. “Less suitable”, “very few suitable” and “unsuitable areas” are up to 45% of total ALUT. According to the results of the analysis, it is seen that the areas suitable for agriculture are distributed near the flat plateau surface in the study areas (Photo 2a, 2b and 2c). “Unsuitable Areas” for agriculture are usually around high reliefs west of the site; and also in the south, the deep slopes distribution between the valley floor and the plateau surface (Fig. 4).

Photo 2a – Dry agricultural activities on the plateau surface near Ulubey Settlement.

Photo 2b – Irrigated agricultural activities in the canyon valley near Avgan Village.

Photo 2c – Agricultural activities in the canyon valley near Avgan Village.

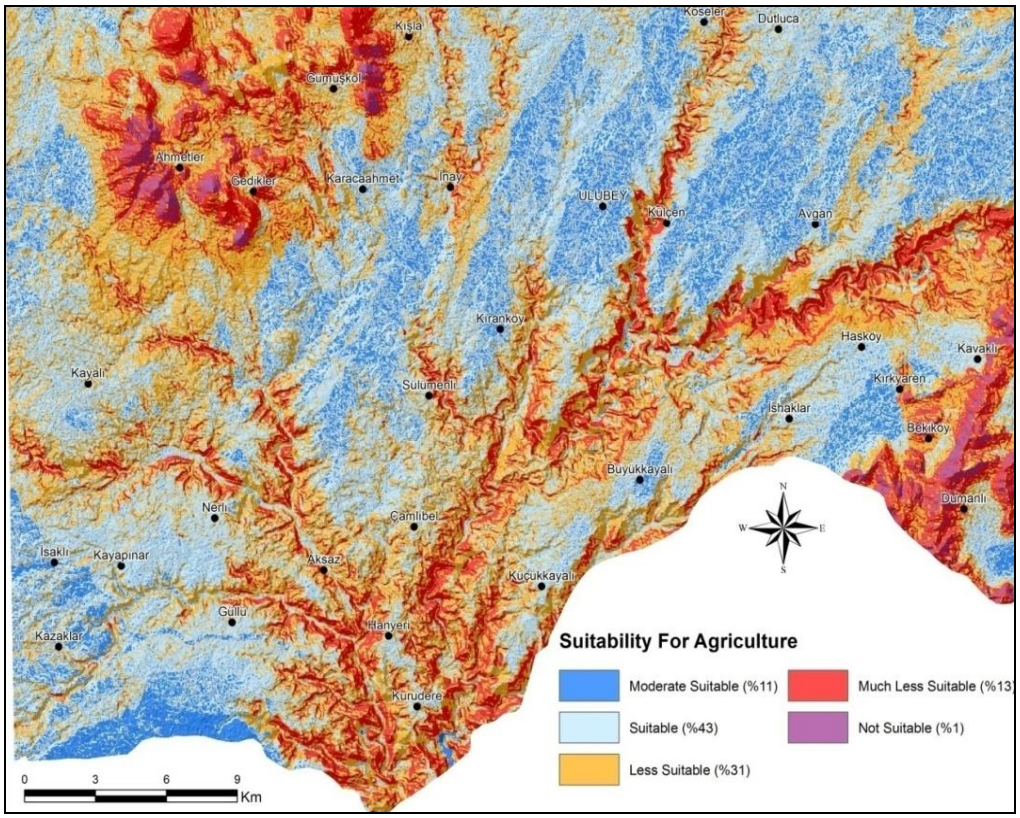

Fig. 4 – Distribution of suitability classes for agriculture of Ulubey (Usak) and its surroundings.

In Figure 5, according to the type of forest land use (FLUT), the distribution by suitability grades is made using the AHP. According to FLUT, “very affordable”, “moderately appropriate” and “suitable areas” are 90% of the total FLUT. “Less suitable”, “much less suitable” is under 10% of the total FLUT. According to the analysis results, suitable areas for forest land are located generally around the high relief west of the site; in the south, inclined fields between the valley floor and the plateau surface (Fig. 5). According to AHP, “Less suitable” for the FLUT areas are located on bushy and maquies land, on partially badlands on the plateau (Fig. 5).

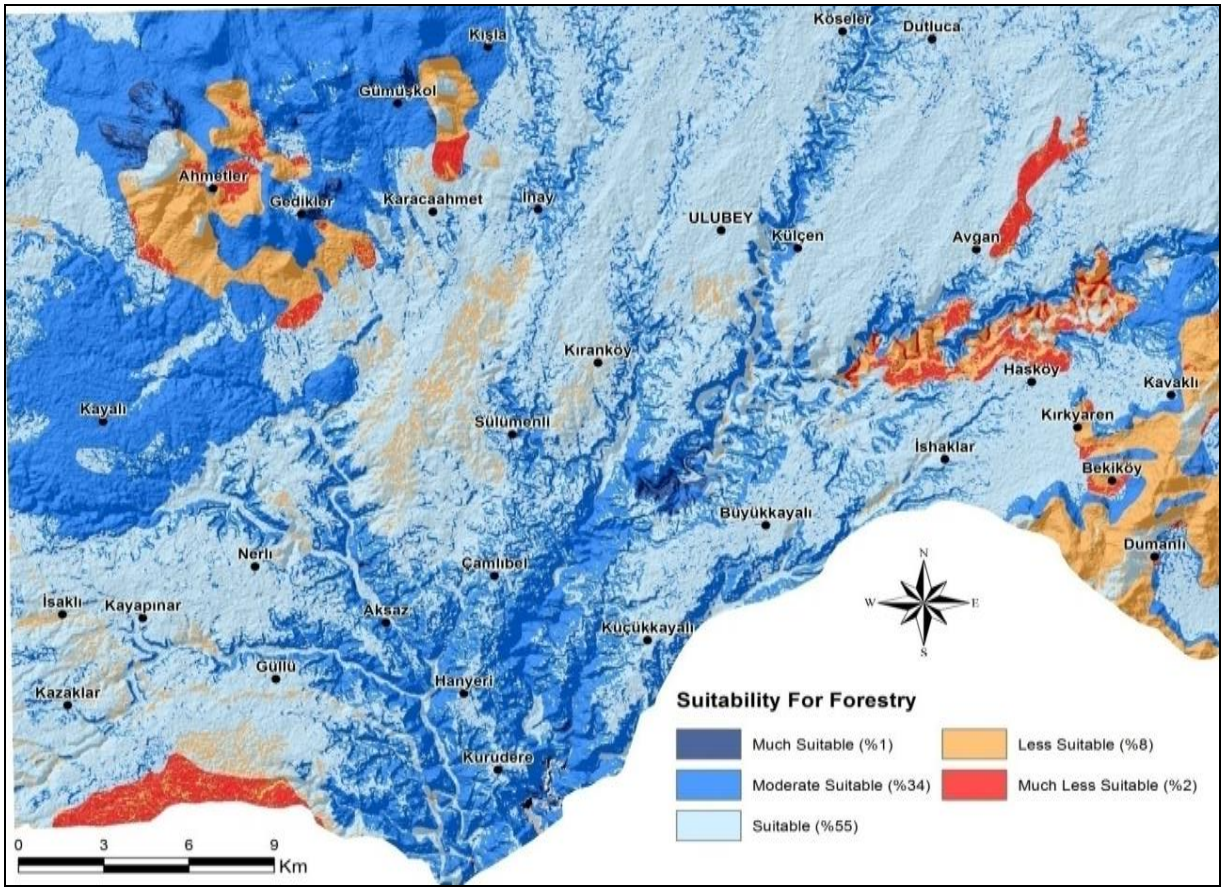

Fig. 5 – Distribution of suitability classes
for forest land in the study-area.

In Figure 6, the distribution according to suitability grades is made by using AHP according to the type of meadow-pasture land-use (MLUT). According to MLUT, “moderately appropriate” and “suitable areas” represent 33% of the total MLUT. “Less suitable”, “much less suitable” areas make up 67% of the total MLUT. According to the analysis results, the areas suitable for meadow-meadow in the field are distributed on the less inclined slopes of the plateau area (Fig. 6). The locations of the MLUT that are “less suitable” for the AHP are found in the southern part of the valley slope where there is steep slope, which should be used as forest land (Fig. 6).

As a result of the AHP analysis for Land-Use Categories, such as agriculture, forest and meadow-pasture, the conformity ratios of existing uses according to this analysis are shown in Figure 7. When the thematic map is examined, one is sees that only 54% of the total agricultural land is suitable, according to the results of the agricultural LUT analysis. This is almost half the total sum. Suitable agricultural areas are located on less inclined slopes of plateau surface. Unfavourable lands are in general located on more inclined forests, pastures and valley slopes.

The suitability rate according to forest land-use type (FLUT) AHP analysis is 39%. According to the FLUT, suitable places are the sloping fields to the south of the study-area,

the valley slopes where the slope is high, and the western part of the study-area surrounding the high mountainous masses. A ratio of more than 60% is not suitable for FLUT. Places that are not suitable for FLUT are mostly used as pasture-land and also for agricultural purposes in narrower areas.

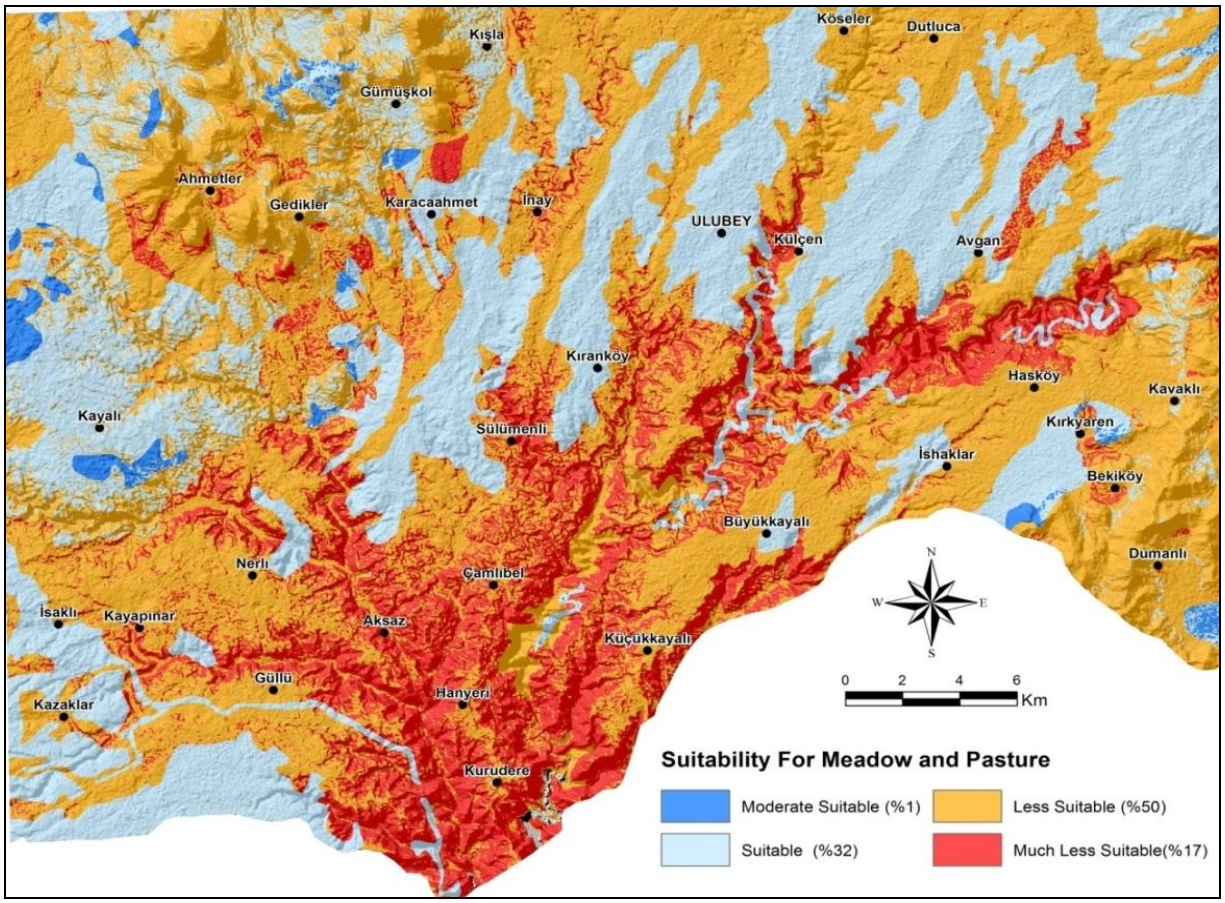

Fig. 6 – Distribution of suitability classes for the meadow-rangeland of Ulubey (Usak) and its surroundings.

According to the results yielded by the meadow-pasture land-use type (MLUT), the suitability rate is only 7% of the total area. These meadow-pasture lands on the very shallow and uneven slopes of the canyon are suitable for MLUT. A large proportion, e.g. 90%, is calculated to be inappropriate for the MLUT in accordance with the AHP. This large area is due to the fact that the areas that should be covered by the forest, forests cover-destruction is used as MLUT in areas where the heavily damaged shrub-maquies areas are used. In other words, these areas are inclined, they are not suitable for pasture, being included as forest. These degraded areas led to primitive animal husbandry activities in the study-area (Photo 3).

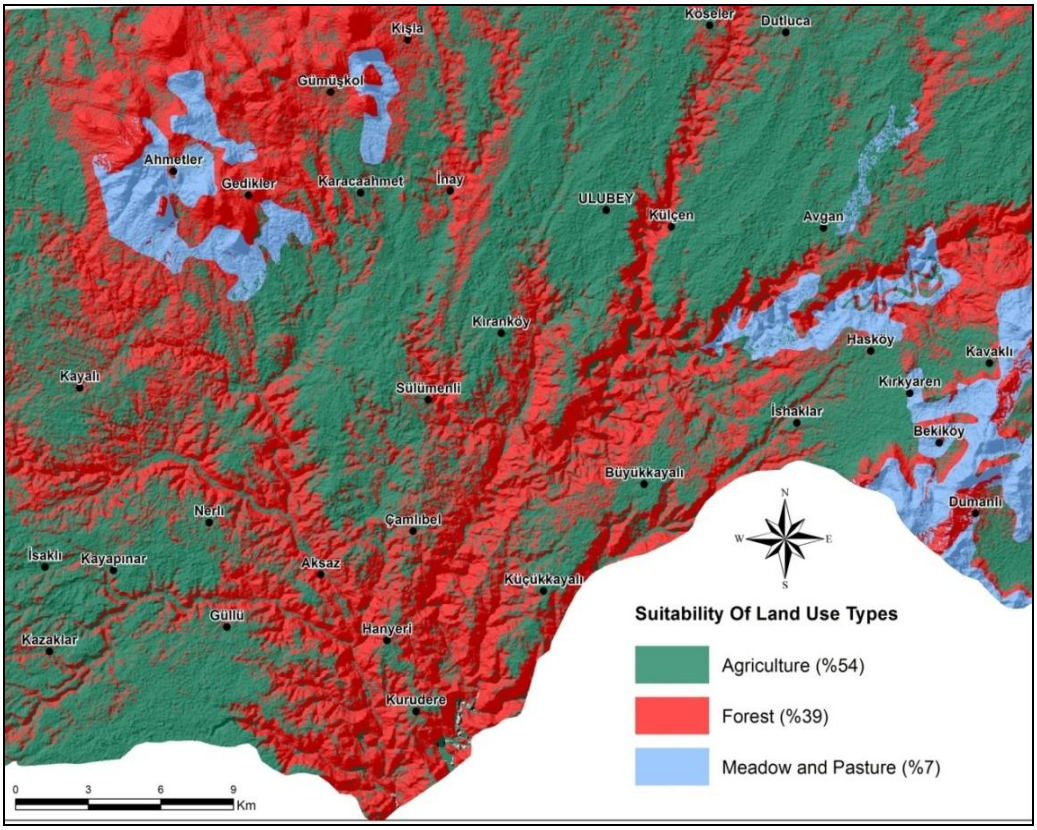

Fig. 7 – Agriculture Preferential generated "optimal land use situation" and rates.

Photo 3 – Primitive animal husbandry activities in the maquies community and on the badlands.

6. DISCUSSIONS AND CONCLUSIONS

Table 6 shows calculated values according to the AHP analysis, the "proposal" LUC ratios and field and the "current" land-use in the Ulubey Canyon and in its vicinity. According to the AHP analysis, it is possible to state that the current use of agriculture, forestry and pastureland LUT is not at a very good level in terms of sustainable land-use (Table 6).

Table 6

According to the AHP analysis results Proposed and current Land-use categories; spatial values and total area ratios

Land Use Categories	Proposal		Current	
	km²	%	km²	%
Agriculture	626	54.0	525	45
Forestry	448	38.6	395	34
Meadow and Pasture	86	7.4	135	12
Bare rocky area	.	.	105	9
Total	1,160	100	1,160	100

In current use, the ratio of bare land is 9%, and the ratio of grassland-meadow is 12%. As a result of the AHP analysis, the ratios of the indicated areas should be reduced. Suggested ratios in the analysis results are the removal of all bare lands altogether and the reduction of grassland areas to 7.5% of the general area. To achieve this, the proposal is that the rates of forest and agricultural land should be reduced from 34% to 38.6% and from 45% to 54%, respectively (Table 6). Use of areas with low inclination and suitable soil for agricultural purposes in order to reach the stated rates and improvements; the use of forest lands, as well as slopes and shallow lands, would be appropriate for sustainable use.

As shown in Table 5, 45% of the agricultural activities are carried out in areas that do not have suitable conditions in terms of soil depth and slope. Due to the use of meadow and pasture in high slope deforested scrublands, 67% of this use occurs in unsuitable areas.

As a result of it, the percentage of bare lands becomes 9% because of: agricultural activities made in shallow, rocky and slopy lands, meadow and pasture used in high-slope maquies-scrublands.

In order to avoid these disadvantages, maximum attention should be paid to land capability classes, land-use criteria and sustainability targets.

In addition to the evaluation criteria set out at the beginning of the study, soil-depth values and more detailed slope analysis should be made to achieve more accurate results, so that these rates can be further refined and values and maps can be made.

REFERENCES

Akbulak, C. (2010), *Analitik hiyerarsi süreci ve coğrafi bilgi sistemleri ile Yukari Kara Menderes Havzasi'nin arazi kullanimi uygunluk analizi*, Uluslararasi Insan Bilimleri Dergisi/ Journal of Human Science, **7**, *2*, pp. 557–576.

Akinci, H., Yavuz, Özalp, Ayşe, Turgut, B. (2013), *Agricultural land use suitability analysis using GIS and AHP technique*, Computers and Electronics in Agriculture, vol. **97**, pp.71–82.

Akyol, E., Alkan, M. (2015), *Cografi Bilgi Sistemleri ve Coklu Karar Verme Teknigi ile Mahallelerin Yerlesime Uygunlugunun Secimi: Denizli Kenti Örnegi,* AKU Journal of Science and Engineering **15**, pp. 50–58, 015801 DOI: 10.5578/fmbd.8483.

Atalay, I. (1989), *Toprak Cografyasi*, Ege Universitesi Yayin, No. **8**, Ege Univ Matbaasi, Izmir.

Bagheri, M., Sulaiman, W.N.A., Vaghefi, N. (2012), *Land Use Suitability Analysis Using Multi Criteria Decision Analysis Method for Coastal Management and Planning: A Case Study of Malaysia*, Journal of Environmental Science and Technology, **5**(*5*), pp. 364–372, DOI: 10.3923/jest.2012.364.372.

Bayar, R. (2018), *Arazi Kullanimi Acisindan Türkiye'de Tarim Alanlarinin Degisimi, In terms of land use change in agricultural areas in Turkey*, Coğrafi Bilimler Dergisi CBD, **16** (*2*), pp. 187–200.

Carver, S.J. (1991), *Integrating multi-criteria evaluation with geographical information systems*, International Journal of Geographical Information System, **5**, *3*, pp. 321–339, DOI: 10.1080/02693799108927858.

Collins, M.G., Steiner, F.R., Rushman, M.J. (2001), *Land-use suitability analysis in the United States: historical development and promising technological achievements*. Environmental Management, **28** (*5*), pp. 611–621.

Cukur, H. (2017), *Ulubey ve Yakin Çevresinin Toprak Ozellikleri ve Arazi Kullanimi*, Hasan Cukur, Raziye Çakıcigoglu Oban (Ed.) *UlubeyKanyonu (Usak) ve Yakin Cevresinin Turizm Potansiyelinin Degerlendirilmesi*, pp. 48–68, DEU Matbaasi, Izmir.

Deviren, Saygin Selen, Yuksel, M. (2008), *Ankara Imrahor Vadisi ve Yakin Cevresinin Tarimsal Kullanima Uygunluk Siniflarinin Belirlenerek Haritalanmasi,* Tarım Bilimleri Dergisi, **14** (*2*), pp. 108–115.

FAO. (1976), *A framework for land evaluation.* FAO Soils Bulletin, No. **32**, Rome. ISBN 92-5-100111-1.

FAO. (1985), *Guidelines: Land evaluation for extensive grazing.* FAO Soils Bulletin ,No. **58**, Rome.

FAO. (2006), *Global land use area change matrix.* The Forest Resources Assessment Programme, Rome.

Feizizadeh, B., Blaschke, T. (2013), *Land suitability analysis for Tabriz County, Iran: a multi-criteria evaluation approach using GIS*, Journal of Environmental Planning and Management, **56**, *1*, pp. 1–23, DOI: 10.1080/09640568.2011.6469642013.

Gaál, Marta, Quiroga, Sonia, Fernandez-Haddad, Zaira (2014), *Potential impacts of climate change on agricultural land use suitability of the Hungarian counties.* Review of Environmental Change, **14**, pp. 597–610, http://dx.doi.org/10.1007/ s10113-013-0518-3.

Garcia, J.L., Alvarado, A., Blanco, J., Jimenez, E., Maldonado, A.A., Corte´s, G. (2014), *Multi-attribute evaluation and selection of sites for agricultural product warehouses based on an analytic hierarchy process*. Comput. Electron. Agric. **100**, pp. 60–69. http://dx.doi.org/10.1016/j.compag.2013.10.009.

Hopkins, L.D. (1977), *Methods for Generating Land Suitability Maps: A Comparative Evaluation*, Journal of the American Institute of Planners, **43**:*4*, pp. 386–400, DOI: 10.1080/01944367708977903.

Huang, I.B., Keisler, J., Linkov, I. (2011), *Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends*. *Science of the Total Environment,* **409**(*19*), pp. 3578–3594. doi: https://doi.org/10.1016/j. scitotenv.2011.06.022.

Jankowski, P. (1995), *Integrating geographical information systems and multiple criteria decision-making methods*, International Journal of Geographical Information Systems, **9**:*3*, pp. 251–273, DOI: 10.1080/02693799508902036.

Joerin, F., Theriault, M., Musy, A. (2001), *Using GIS and outranking multicriteria analysis for land-use suitability assessment.* Int. Journal Geographical Information Science, **15** (*2*), pp. 153–174.

Kuria, D., Ngari, D., Withaka, E. (2011), *Using geographic information systems (GIS) to determine land suitability for rice crop growing in the Tana delta*. Journal of geography and regional planning, **4** (*9*), pp. 525–532.

Malczewski, J. (2004), *GIS-based land-use suitability analysis: a critical overview*. Progress in Planning, **62**, pp. 3–65.

Maleki, F., Kazemi, H., Siahmarguee, A., Kamkar, B. (2017) *Development of a land use suitability model for saffron (Crocus sativus L.) cultivation by multi-criteria evaluation and spatial analysis.* Ecol. Eng. **106**, pp. 140–153.

Mendoza, G.A., Martins, Helena (2006), *Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms.Forest Ecology and Management,* **230**(*1*), pp. 1–22. doi: https://doi.org/ 10.1016/j.foreco.2006.03.023.

Meng, Y., Malczewski, J., Boroushaki, S. (2011), *A GIS-Based Multicriteria Decision Analysis Approach for Mapping Accessibility Patterns of Housing Development Sites: A Case Study in Canmore, Alberta*, Journal of Geographic Information System, Vol. **3**, pp. 50–61. doi:10.436/jgis.2011.31004.

Mishra, A., Deep, S., Choudhry, A. (2015), *Identification of suitable sites for organic farming using AHP & GIS*. The Egyptian Journal of Remote Sensing and Space Sciences. **18**. 10.1016/j.ejrs.2015.06.005.

Rockström, J., Barron, J., Fox, P. (2002), *Rainwater management for increased productivity among small-holder farmers in drought prone environments*. Physics and Chemistry of the Earth, Parts A/B/C, **27**(*11*), pp. 949–959. doi: https://doi.org/10.1016/S1474-7065(02)00098-0.

Bandyopadhyay, S., Jaiswal, R.K., Hegde, V.S., Jayaraman, V. (2009), *Assessment of land suitability potentials for agriculture using a remote sensing and GIS based approach*, International Journal of Remote Sensing, **30**:*4*, 879–895, DOI: 10.1080/01431160802395235.

Saaty, T.L. (1990), *How to make a decision: the analytic hierarchy process*. Euro. J. Oper. Res. **48** (*1*), pp. 9–26. http://dx.doi.org/10.1016/ 0377–2217(90)90057–I.

Saaty, Thomas L. (1994), *"How to Make a Decision: The Analytic Hierarchy Process."* Interfaces, vol. **24**, no. *6*, pp. 19–43. JSTOR, www.jstor.org/stable/25061950.

Xu, Y. (2011), *Application of GIS Spatial Analysis Method in Landscape Planning and Design – A Case Study of Integrated Land-Use Suitability Analysis of Nanjing Zhongshan Scenic Area,* Berlin, Heidelberg. M. Zhou and H. Tan (Eds.): CSE 2011, Part II, CCIS 202, pp. 67–73.

Yilmaz, E. (2005), *Bir arazi kullanım planlaması modeli: Cehennemdere vadisi örneği.* T.C. Çevre ve Orman Bakanlığı, Doğu Akdeniz Ormancılık Araştırma Müdürlüğü, Çevre ve Orman Bakanlığı Yayın No. **253**, DOA Yayın No. **37**, Tarsus.

Zolekar, R,B., Bhagat, V.S. (2015), *Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach*. Computers and Electronics in Agriculture, **118**, pp. 300–321.

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