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Transferring the Eigenvector Obtained by the Method of Analytic Hierarchy Process to Maps

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Abstract: In this research, it has been aimed to determine the areas to be given priority in usage for the rural development of the village Alpağut, Bolu, with Analytic Hierarchy Process (AHP), a decision-making method through using multicriteria. In this research, contrary to other researches done on this issue, it has been recommended that the eigenvector obtained by means of a particular approach as a result of the AHP, should be used for transferring some sociocultural data related with this area to maps. In this way, it has been achieved to transfer qualitative factors to maps. Decisions of alternative land use have been determined as recreation-tourism, meadow-pasture and field-garden in consideration of the ecological properties of the village Alpağut, chosen as the research area. Factors affecting the study have later been grouped as; cultural factors, natural factors and objective and policies of land use according to the method of AHP and the subcriteria have been determined. Experts have been made to evaluate the determined criteria and the values of weight have been determined in consideration of these evaluations. In the AHP method, it has been explained with an example that the decision made by the experts can be the Suitability Coefficient (SC) of the area and that the data can be transferred to maps with the usage of this as SC in the formula (suitability point = suitability coefficient x suitability value) formed for suitability maps. It has been explained how the eigenvector values of the factors to be transferred to suitability maps can be used. As a result of the AHP method, recreation-tourism has been determined as the most suitable alternative of land use for the rural development of the village Alpağut. The second suitable land use has been discovered as field and garden agriculture and the third suitable area meadow-pasture.

Key words: Multiple criteria analysis, analytic hierarchy process, recreation-tourism, meadow-pasture, field-garden agriculture

INTRODUCTION

It is well known that the fundamental problem in decision making is choosing the best or the most logical and available alternatives towards meeting the desired aims at the best level possible (Büyükyazıcı, 2000). The Analytic Hierarchy Process (AHP) method, introduced by Thomas L. Saaty, is one of the decision making techniques exercised by using multiple criteria (Saaty, 1980; Lai *et al*., 2002) that helps decision making processes especially in evaluation studies. The AHP method enables the evaluation of non-quantitative measurements and the usage of decision maker's own personal knowledge and experiences (Ejder, 2000). It is mathematically helpful both in expressing what's felt and at decision making stage (Saaty, 1988). It is a method that can measure the interaction of many factors affecting the problem. It helps to benefit from the judgments and experience of many experts. In researches, for instance, it enables different experts to take place on the same platform, leading their evaluations to be healthier in general. Minimizing the error ratio of subjective judgments, by which qualitative and quantitative factors can be evaluated together, it ensures its consistency. It has got a flexible and ideal structure which is applicable to the solution of every problem (Cengiz and Çelem, 2003).

In general, the inadequate evaluation of cultural factors (immeasurable) is considered as the greatest deficiency in rural development studies. While measurable indicators have been evaluated in these types of studies, the immeasurable indicators have not been taken into consideration. From this point of view, the AHP method is an important element to be used in such developmental studies since both measurable and immeasurable indicators are used in this method. In addition, there is another problem regarding developmental studies that

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qualitative factors cannot be transferred to maps by professional disciplines such as architects, city-district planners and landscape architects, creating difficulties especially at the planning stage. Because of these reasons, it will be beneficial to use the AHP method for the solution of the problems listed above for rural development studies. In addition, while the AHP method has been used in many studies of various aspects in Turkey, it has not been used so widely in the rural area studies.

Emigration and unemployment in the rural areas and preventing the ongoing loss of the environmental resources by means of wrong usage are becoming more and more important issues in Turkey. One of the suggestions to solve these issues may be to diversify the land use with the preceding land planning followed by detailed rectifications of the areas chosen according to certain criteria. It must be researched why and for whom the area planning has got priority. While decisions are made on a plan, alternative development strategies must be determined and the most appropriate development alternatives must be selected (Bilsel, 1987).

For this reason, many researchers have made studies on the alternative land use types, which are suitable for different objectives. For example, following the open ground coal mining in Sekköy, Milas, Akpınar (1994) has evolved some suggestions of land use (e.g., agriculture, forestation, forestation and recreation) by means of the AHP method so as to prevent the present devastations. Moreover, Aydoğan (1992)has determined alternatives of land use in order to prevent the destructions and deformations occurred at the open space area of post coal mining in Kışlaköy. Alternatives have been determined as recreational usage, agriculture and wildlife, open spaces and low density areas of settlement integrated with recreational usage.

In this study, it is aimed to determine the land use priorities for the rural development of the village chosen as the study area. Other objectives of this study are to determine alternatives, factors and subcriteria in consideration of the ecological properties of the village and to have experts evaluating the fixed criteria and using outcomes of these evaluations to estimate "the weight values". In the AHP method, it has been explained with an example that decisions made by experts may be the Suitability Coefficient (SC) and that data may be transferred to maps by getting used as SC in the formula (suitability point = suitability coefficient x suitability value). This study is unique in this aspect because this is the first application of transferring the eigenvector values of the factors over to maps using the AHP method, improving the effectiveness of the method especially in rural area planning studies in Turkey.

MATERIALS AND METHODS

Location and properties of the area: The Village is located 54 km south of Seben District, Bolu within the Eastern Blacksea Region (Fig. 1). Seben, is the border district of Bolu to the Interior Anatolia Region. The study area is about 14.7 million meter square with altitude ranging between 790 and 830 m. The village is situated on a slope of a hill with an unplanned settlement. Questionnaires were used to collect data for two years in the summer periods of 2001 and 2002.

While the height is about 700 m. in the south of the area, it gradually increases when you go northward from the slope of village settlements at a height of 800-850 m. The north, east and northeast of the area are rather steep and rocky. Very steep areas are seen when groups of slope are studied. Areas with extremely high level erosion are seen at and around the settlement areas of the plateau. Low and medium level erosion are seen in the settlement areas of the village as well as the agricultural areas of the fields and gardens. The areas where the lands of fields and gardens are in Alpağut village have deep and shallow soil. The other lands have got very shallow soil (Cengiz, 2003).

In this research, Analytic Hierarchy Process (AHP) has been used as a method. According to the method, the research has been taken up in three stages (Saaty, 1980; Zio, 1996):

- A hierarchy describing the problem has been established. First of all, the aim of the hierarchy has been determined as rural development. Natural factors, cultural factors, factors in relation to the objectives and policies of area usage and the subcriteria directly related to every factor have been determined at the sublevel of this main aim. And at the lowest level are the alternatives.
- For the aim, the rural development of the village Alpağut, pair wise comparisons and pair wise comparisons in relation to the choices have been done at every level according to the importance of the criteria.
- Weight have been produced and evaluation for the choices. So the best usage of area has been determined and the choice has been made.

Stage 1: At hierarchical structure of the problem decided on (analysis): The goal to be achieved has been determined at the first level of the hierarchy. The criteria helping to achieve this goal and their subcriteria have been taken up at the following levels. And various alternatives have taken place at the last level. A factor any level is a factor of the higher level and the factors at

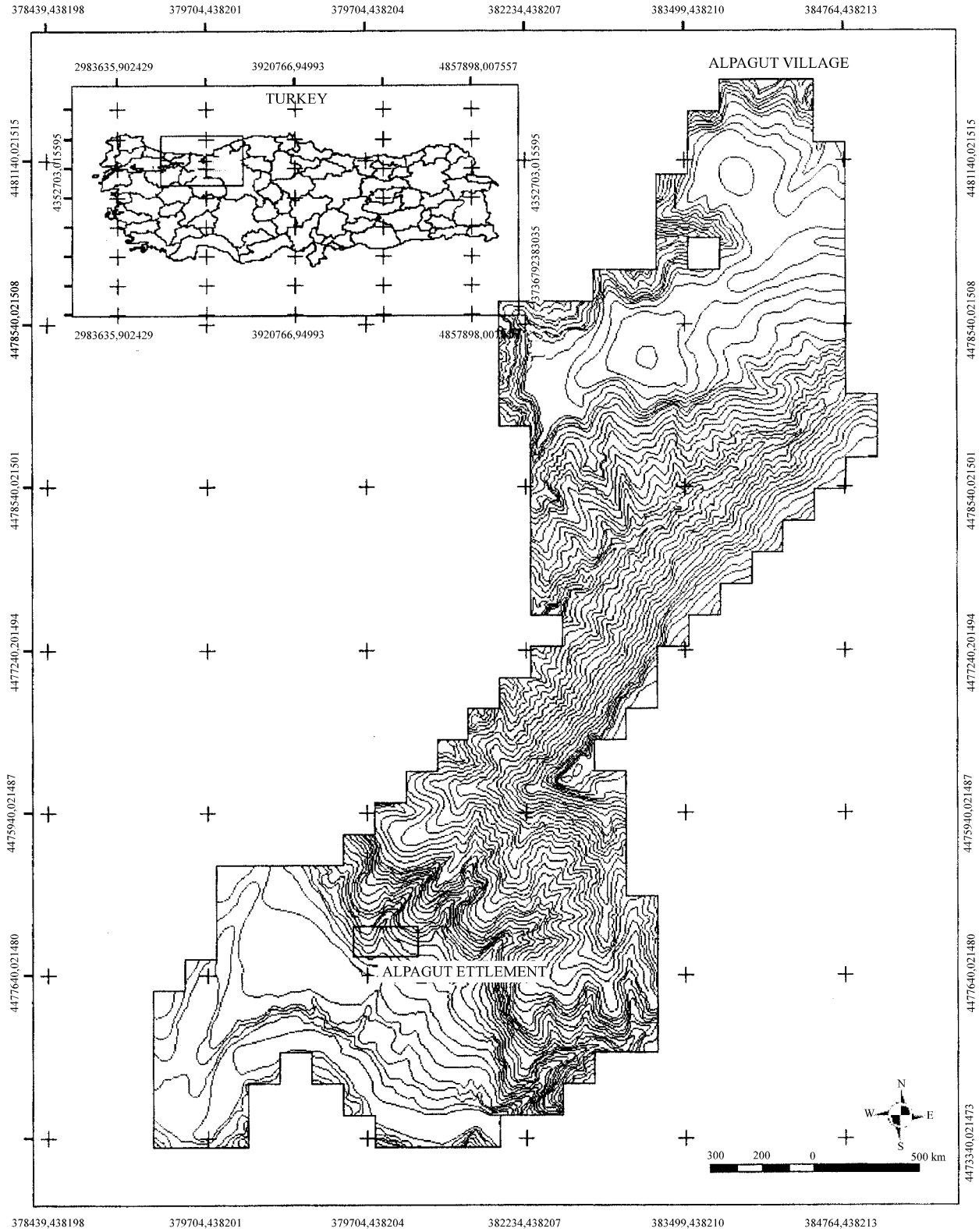

Fig. 1: Location of the study area

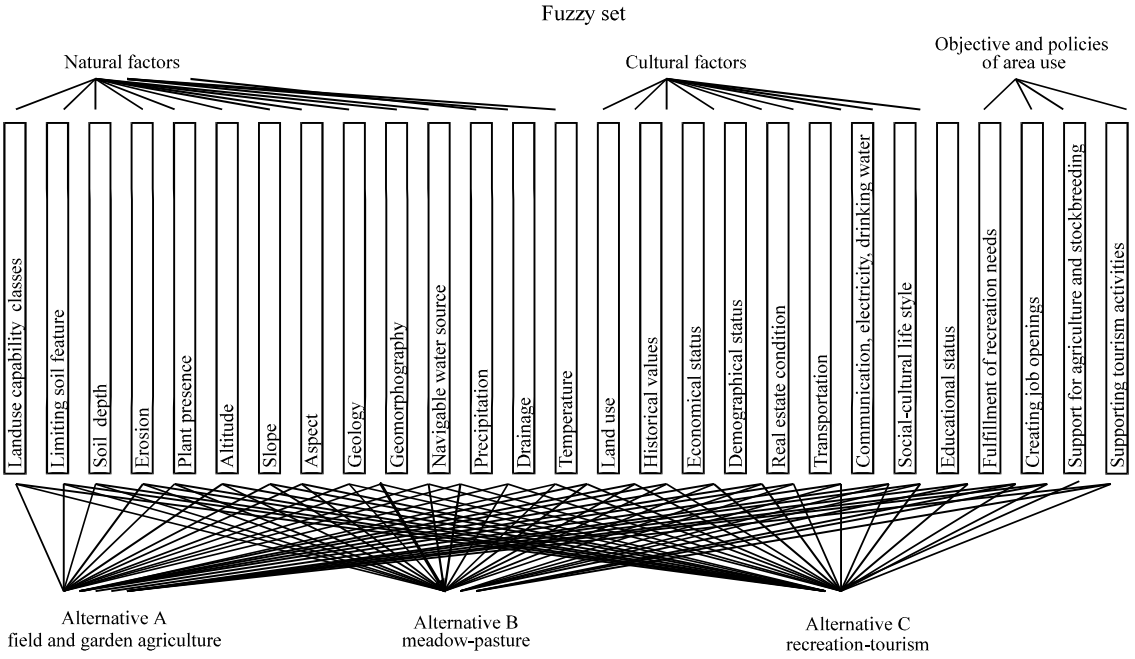

Fig. 2: Classifying the land use alternatives according to qualitative factors

the same level have been defined in an independent way from each other (Badri, 1999; Ejder, 2000).

According to the technique, rural development of the village Alpağut has been determined as the goal at the first level of the research. At the second level, the criteria helping to achieve this goal have been discussed according to three fundamental factors.

- Natural factors
- Cultural factors
- Factors with relation to the objectives and policies of area usage

And having been separated into subfactors, factors have formed a hierarchy according to the goal of this study for recreation-tourism, field-garden agriculture and meadow-pasture usage of area. Hierarchy produced for the research is shown in the Fig. 2. At the next stage, matrices have been formed within the frame of the hierarchy for the comparison of the pairs.

Stage 2: Pairwise comparison: An element at any level is a dependent element of the next higher level criterion. Degrees of effect of these dependent elements to the element above them have been compared in a pairwise way. A matrix has been formed for these pairwise comparisons and the criteria have been compared with each other to help the goal (Büyükyazıcı, 2000; Ramanathan, 2001).

While any two criteria are compared, the question which of these criteria is more important, preferable, more relevant for the goal has been answered to help the goal (Saaty, 1988; Ramanathan, 2001).

If we say A to the matrix formed in the comparison (Saaty, 1988; Ramanathan, 2001):

A = (a_{ij}) i,j = 1,2,…,n (shows the number of the criteria),
i = number of the lines,
j = number of the columns.
A = (a_{ij}) $a_{ij} > 0$ i,j = 1, 2,...,n

As a result of being reciprocally equal, the values of ij here makes the following equation (1) (matrix A is a/an positive/opposite reciprocal pairwise comparison matrix).

$$a_{ij} = \frac{1}{a_{ji}} a_{ij} \neq 0 \quad i, j = 1, 2, ..., n \tag{1}$$

If the elements c_i and c_j are equally important according to the property they are compared to (2):

$$a_{ij} = a_{ji} = 1 \; i,j = 1, 2,...,n \tag{2}$$

If an element is compared to itself (3):

$$a_{ii} = 1 \; i = 1, 2,....,n. \tag{3}$$

In this research, matrices of pairwise comparison have been improved with relation to the goal of rural development for a village.

Matrices of comparison have been done separately for

- Main qualitative factors (Natural factors, cultural factors, objective and policies of area usage),

Matrices of comparison have been done separately for

- Main qualitative factors (Natural factors, cultural factors, objective and policies of area usage),
- Natural factors,
- Cultural factors,
- Objective and policies of area use.

In grouping the natural factors, the subfactors taken in consideration of the aims of the study have been numerically more than the ones taken in other studies. In the studies of AHP, it has been taken into consideration that maximum nine factors should be grouped while accounting the relative weight of the interrelated factors as experts suggest, so as not to cause the attention to diversify. For this reason, the natural factors exceeding nine have been broken into pieces and grouped as set A, set B and set C with a specific approach in this study. In consideration of the fact that the relative weights of the groups in comparison to each other are the parts of a whole, 1 (one) was given the value, "equally important", while the main eigenvector was being calculated in the unification process of these subgroups.

Experts have made questionnaires in determining the relative importance of the pairs in comparison to each other. The questionnaire has been given to 15 scientists chosen from different branches in Turkey (Ankara University Faculty of Agriculture Department of landscape architecture, Department of the Economy of Agriculture, Department of Field Plants and Department of Soil, Language and History Faculty Department of Geography). Points given by the scientists have been evaluated with the determination of their arithmetic mean.

The 1-9 scale developed by Saaty has been used in the comparisons to change the results of the verbal comparisons in the matrix into numerical values (Saaty, 1980; 2000).

Comparative judgment	Grading scale
a_i and a_j are equally important	1
a_i is moderately more important than a_j	3
a_i is strongly more important than a_j	5
a_i is very strongly more important than a_j	7
a_i is extremely more important than a_j	9
Intermediate values between the two adjacent judgments	2,4,6,8

Stage 3: Calculations of weight and consistency: Values of priority (weight) of the factors have been found according to the next factor above them by means of the data obtained after the formation of the matrices of pairwise comparison. Values of weight are effective in finding priorities. When the matrix of pairwise comparison, by which relative weight are shown, is supposed to be existing, the vector of weight (W) is expected to be obtained by means of this matrix (4). Solution of this equation W is known as the eigenvector method in mathematics (Büyükyazıcı, 2000; Ramanathan 2001).

$$A_w = \lambda_{max} W \quad (4)$$

The nearer the maximum eigenvalue is a value to (λ_{max}) n, the more consistent the result becomes. That is to say, if the consistency ratio of the matrix is high, this situation shows that the entered values are inconsistent. According to Saaty (1980, 1989), if the consistency ratio is 0.10 and smaller than this, the matrix of pairwise comparison is consistent and the priorities obtained from this matrix are acceptable. So choices are lined up and the best choice is found according to the priorities obtained as a result of the multiplication of the priorities of the interacting elements from the highest level alternatives to the lowest level ones (Saaty, 1980, 1989).

In this research, values of weight and alternatives of the priority usage of the area have been found by means of the transfer of the judgments united with the usage of the arithmetic mean method to the computer programmers prepared for AHP (Bolloju, 2001).

Transferring to maps the values obtained as a result of the usage of the analytic hierarchy process method: The eigenvector obtained as a result of analyses have been suggested for some sociocultural data related with the area to be transferred to maps. So in this study, contrary to other studies made, it has been achieved to transfer qualitative factors to maps with a specific approach. This suggestion has been used in making suitability maps. Results of the eigenvector values have been used on suitability maps as the values of Suitability Coefficient (SC). Since the formation of suitability maps is not the subject of this article, a brief information has been given on the subject. For further knowledge, Cengiz (2003) is recommendable.

In the research, the maps related to the land loaded onto the computer have been subdivided into square parcels with the scale 1/25000 and size 250×250 m and Suitability Values (SV) of each square parcel have been found one by one for the area usages of field and garden agriculture, meadow-pasture and recreation-tourism. In order to determine the potential in the maps (5), Suitability Value (SV) of each squared plan for every land use type was multiplied with SC to reach Suitability Scores (SS). Then, by summing up suitability scores, Total Suitability Scores (TSS) was found (6) (Ortaçeşme 1996; Mansuroğlu, 1997) as follows:

$$Svn * SCn = Ssn \quad (5)$$

$$TSS = SS_1+SS_2+\ldots SSn \quad (6)$$

Where: SV is the suitability value given to of sub-factors

Table 1: Selected factors, suitability coefficients, sub-units and suitability values given to sub-units in determining suitable lands for arable and garden farming

Land use type	Selected factors	Suitability Coefficient (SC)	Selected sub-units	Suitability Values given to sub-units (SV)
Arable and garden agriculture	Land use capability classes	0.65	I. Class	4
			II. Class	3
			III. Class	2
			IV. Class	1
	Soil depth	0.65	Very deep	4
			Deep	3
			Shallow	2
			Very shallow	1
	Limiting soil feature	0.14	Non-present	4
			Present	1
	Drainage	0.53	Good	4
			Intermediate	3
			Impeded	1
	Erosion	0.14	None/Slow	4
			Intermediate	2
	Slope	0.12	% 0-2	4
			% 2-6	3
			% 6-12	2
			% 12-20	1
	Aspect	0.25	S, SE, SW	4
			E,W	3
			NE,NW	2
			N	1
	Water resources	0.25	Lake, pond, stream	4
			Natural spring	3
			Intermittent stream	2
	Precipitation	0.1	550-700 mm	4
			500-550 mm	3
			700-800 mm	2
			>800	1
			<500	
	Temperature	0.16	15-30°C	4
			10-15°C	3
			30-40°C	
			05-10°C	2
			40-54°C	
			5° <	1
			54°C >	
	Transportation	0.54	Asphalt road	4
			Stabilized road	2
			Dirt road	1

for each land use type, SC is the suitability coefficient of a factor for each land use type, SS is the suitability score estimated for each factor and TSS is the total suitability scores for each squared-plan of each land use type.

TSS values were graded as "First Degree Suitable", "Second Degree Suitable" and "Third Degree Suitable" to create suitability maps.

Factors have been chosen for each potential usage with the help obtained from the studies made in relation to the subject and from experts. Suitability values have been taken into consideration in the evaluation process of these chosen factors and the subunits of factors and numerical values varying between 1-4 have been determined. While the subunits were getting specifically evaluated, they were given the suitability values 4,3,2,1, from the most important to the least important. Following the order of these values has been considered compulsory. These values have been explained below according to this concept (Table 1-3). In addition, usage of the eigenvector values for SC will be seen more clearly in this explanation.

A sample study regarding the transfer of obtained values to maps: Only the factor of heat has been examined below for the better understanding of the subject. Values have been given to the following Table 3 by experts according to the Saaty (1980) measurement scale. Later the arithmetic mean of these given values has been taken.

Experts have been asked the question, "Which alternative is how much suitable for the rural development of the village Alpağut when heat is taken into consideration?". Values given in response to this question are as the following.

Table 2: Selected factors, suitability coefficients, sub-units and suitability values given to sub-units in determining suitable lands for meadow-pasture

Land use type	Selected factors	Suitability Coefficient (SC)	Selected sub-units	Suitability values given to sub-units (SV)
Meadow pasture	Land use capability classes	0.28	IV. Class	4
			V. Class	3
			VI. Class	2
			VII. Class	1
	Limiting soil feature	0.24	Non-present	4
			Present	1
	Drainage	0.14	Good	4
			Intermediate	3
			Impeded	1
	Erosion	0.33	None/Slow	4
			Intermediate	2
			Severe	1
	Slope	0.23	% 6-12	4
			% 12-20	2
			% 20-30	1
	Aspect	0.25	S, SE, SW	4
			E, W	3
			NE, NW	2
			N	1
	Water resource	0.16	Lakes, ponds, streams	4
			Natural spring	3
			Intermittent stream	2
	Precipitation	0.26	800-1200 mm.	4
			600-800 mm.	3
			400-600 mm.	2
			400 mm. <	1
	Temperature	0.25	20-25 °C	4
			15-20 °C	3
			25-30 °C	
			10-15 °C	1
	Plant presence	0.30	Unforested	4
			Open fields and forest openings	2

*** The matrix: (Heat)

	Field-garden agriculture	Meadow -pasture	Recreation -tourism
Field and garden agriculture	1.000000	0.500000	0.330000
Meadow-pasture	2.000000	1.000000	0.330000
Recreation-tourism	3.030303	3.030303	1.000000
Tolerance:	1.0000000000E-03		
Maximum number of iterations:	50		
Number of iterations:	5		
The approximate eigenvector:	0.156121 SC value for field and garden agriculture 0.247835 SC value for meadow-pasture 0.596044 SC value for recreation-tourism		
The associated eigenvalue:	3.053909		
Consistency index:	0.026955		
Consistency ratio:	0.046473		
Random consistency:	0.580000		
Percent of inconsistency:	15.000000		

According to the example, the following answer has been given in consideration of the heat properties of the village as stated by experts: In comparison of field and garden agriculture with meadow-picture, 1/2 (= 0.5): In respect to heat, area usage of meadow-pasture is some more important, suitable in comparison to the one of field-garden agriculture. In the comparison of field and garden agriculture with recreation-tourism, 1/3 (= 0.33): Area usage of recreation-tourism is more important, more suitable in comparison to field and garden agriculture. In the comparison of meadow-pasture with recreation-tourism, 1/3 (= 0.33): Area usage of recreation-tourism is more important, more suitable in comparison to the area of meadow-pasture.

According to the result of the computer of the matrix, the eigenvector value, namely SC value has found 0.16 for field and garden agriculture, 0.25 for meadow-pasture and 0.60 for recreation-tourism. The value which has been found has been used as SC. These performed operations have also been used for all other factors. In the example, the matrix of pairwise comparison has been accepted as true because the value 0.04, the consistency ratio of matrix is less than 0.10.

Later the following method has been used in transferring heat values to maps. Values of suitability score have been determined in this way:

15-30°C, SV = 4 ; 10-15°C and 30-40°C, SV = 3; 5-10°C and 40-54°C, SV = 2; <5°C and > 54°C, SV = 1.

On the map divided into square parcels, Suitability Score (SS) of every square parcel has been found by means of the multiplication of their locational values, between certain spaces, SV by SC.

Table 3: Selected factors, suitability coefficients, sub-units and suitability values given to sub-units in determining suitable lands for recreation and tourism

Land use type	Selected factors	Suitability Coefficient (SC)	Selected sub-units	Suitability Values given to sub-units (SV)
Recreation and tourism	Altitude	0.65	800-2000 m	4
			0-800 m	3
			2000-3000 m	2
			3000 m<	1
	Geomorphology	0.54	Mountainous	4
			High steeps	3
			Low plains	2
			Valley plateau	1
	Drainage	0.33	Good	4
			Intermediate	3
			Impeded	1
	Erosion	0.53	None/Slow	4
			Intermediate	2
			Severe	1
	Precipitation	0.64	500-1250 mm	4
			250-500 mm	2
			1250-1500 mm	
			0-250 mm	1
			1500 mm <	
	Temperature	0.6	15-25°C (mild)	4
			25-36 °C (hot)	2
			4-15 °C (cold)	
			< 4 °C (very cold)	1
			>36 °C (very hot)	
	Navigable water source	0.6	0-500 m	4
			500-1000 m	3
			1000-3000 m	2
			3000 m <	1
	Plant presence (Stand density)	0.54	% 41-70	4
			% 11-40	3
			% 0-10	2
			% 71-100	1
	Land Use	0.64	Residential	4
			Forested/Shrubby	3
			Meadow/pasture	2
			Agricultural	1
	Transportation	0.3	0-1 km	4
			1-2 km	3
			2-3 km	2
			3 km <	1
	Historical values	0.6	Present	4
			Non-present	1

Values of Suitability Score (SS) have been taken as the following in consideration of the heat factor for meadow-pasture: 20-25°C, SV = 4 ; 15-20°C and 25-30°C, SV = 3; 10-15°C, SV = 1. And SC has been determined as 0.25. SS has been found with the multiplication of their values SV by SC.

Values of Suitability Score (SS) have been taken as the following in consideration of the heat factor for recreation-tourism:15-25°C, SV = 4; 25-36°C and 4-15°C, SV = 2; >36°C ve <4°C, SV = 1. And SC has been given the value 0.60. On the map divided into square parcels, every square parcel has been given a SS for recreation-tourism by the multiplication of their locational values SV by SC.

In these performed operations, suitability values and suitability coefficient have been found for their chosen factors and their subfactors for each usage of area (field and garden agriculture, recreation-tourism, meadow-pasture).

RESULTS AND DISCUSSION

In development studies in Turkey, elements such as the following have been aimed, evaluating the natural properties in the best way, improvement of agriculture and stockbreeding, protection of the ecological balance and the environment, activation of rural population and creation of new working areas. Many problems are faced in the realization of these aims. In the solution of these problems, the most important concern faced in rural development is the fact that aims and problems cannot be defined clearly and specifically. The AHP method can

provide possibility for the development and analysis of this complex structure with its flexible property (Yıldırak, 1991; Doğanay, 1993; Cengiz, 2002; Cengiz and Çelem, 2003).

For this reason, a research has been done for the development of the village Alpağut in this study by means of AHP method. In this performed study, alternatives chosen as economic input have been discussed as agricultural sector- "field and garden agriculture" and "stockbreeding" (determination of meadow-pasture areas) and service sector- "tourism and recreation". Industrial sector hasn't been taken into consideration because there isn't such a dimension of development in the research area. In the research decisions of area usage have been made and suitable alternatives for the village have been presented in a hierarchic arrangement. Benefits related to the village have been obtained from the judgments and experiences of many experts. Interactions of many factors affecting the development have been measured. In accordance with this are the following alternative area usages suggested for the development of the village Alpağut:

- Suggested alternative area usage, recreation-tourism (eigenvector 0.392)
- Suggested alternative area usage, field and garden agriculture (eigenvector 0.386)
- Suggested alternative area usage, meadow-pasture (eigenvector 0.221)

As it can be seen from the results, there is a little difference, which isn't important enough to be taken into consideration between the values found for recreation-tourism and field and garden agriculture. This situation shows that field and garden agriculture is as important as recreation-tourism for the development of the village.

Unlike the other studies, in this research;

- Eigenvector found by the AHP method have been accepted as SC. So it has been possible to transfer these data to the maps in making the suitability maps in the planning studies. In many literatures, suitability coefficients have been found either by asking experts' openings by means of questionnaires or by using the planners' evaluation in the preparation studies of suitability maps (Ortaçeşme, 1996; Mansuroğlu, 1997). But in this research, the coefficiencies weight of the area has been found in consideration of the sociocultural and natural properties of the area. By means of this study, the factors relative importance to each other has been evaluated in the problem directly analyzed for the purpose. Weight coefficiency of each factor has been determined by its comparison with the other factors. But in the other performed studies, only the factors have been given weight. Factors' relative importance to each other hasn't been taken into consideration. In addition to this consistency of the evaluations made by experts has been achieved thanks to the AHP method. So verification of the evaluations has been obtained. But it is not possible to verify the evaluations which have been made with the conventional method.
- In grouping natural factors, cultural factors as well as objectives and policies according to the AHP method, subfactors taken for the purpose of the study are more than the ones taken in other studies. So as not to cause any diversion, it has been taken into consideration that maximum nine factors should be grouped as experts suggest while the relative weights of interrelated factors are being determined in the AHP studies. For this reason, the natural factors exceeding nine have been solid up and grouped as set A, set B and set C with a specific approach in this study. In consideration of the fact that the relative weights of the groups in comparison to each other are the parts of the whole, It was given the value, "equally important", while the main eigenvector was being calculated in the unification process of these subgroups.

It has been aimed that this study should be a sample for rural areas, especially in the places having similar problems and that useful method such as AHP be transferred to maps. So it has been aimed to be a useful research for a sustainable usage of area and the studies of rural development.

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