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Land Suitability Analysis using Multi Attribute Decision Making Approach

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Abstract— **Nowadays there are formidable challenges facing decision makers in order to rangeland management. Allocation of limited rangelands among the various stakeholders, lack of sufficient environmental policies for sustainable use of rangelands as well as degradation of these areas have caused increasing concern among managers and revealed the importance of Land suitability analysis. As regards a broad range of criteria is required for performing effective land suitability selecting of appropriate method to handle such wide heterogeneous criteria. Spatial Analytical Hierarchy Process method as a commonly use method of compensatory model is a suitable tool for this purpose. The main aim of this paper is to examine a relatively new method of multi criteria evaluation by using spatial analytical hierarchy method for determining the most suitable areas for rangelands in Taleghan basin. Results indicate that the spatial analytical hierarchy process is a powerful support system resolving different uses of land suitability issues in the region.**

Index Terms—**Spatial analytical hierarchy process; land suitability evaluation; rangeland use; Taleghan Basin; Multiple criteria evaluation.**

I. Introduction

Land Suitability Analysis (LSA) is a GIS-based process applied to determine the suitability of a specific area for considered use, i. e. it reveals the suitability of an area regarding its intrinsic characteristics (suitable or unsuitable). Also this analysis involved with considering wide rages of criteria including environmental, social and economic factors. Appropriate handling of such broad and heterogeneous maps requires applying a flexible tool. The Spatial Analytical Hierarchy method was introduced by Saaty in the mid 1970s and developed in 1980s [1-5] is among the best method which is suitable for carrying out these kinds of analysis. The combination of Spatial AHP method as one of the commonly used methods of spatial multi criteria analysis (SMCA) with GIS is a new trend in land suitability analysis. As regards the spatial multi criteria analysis inclusion of an explicit geographic component it is considered different from conventional multi criteria techniques [6]. In general one of the most important uses of GIS is the land use suitability mapping and analysis [7-8]. As environmental and resource planning and management point of view the Analytic Hierarchy Process is among the fastest growing decision-analytic techniques [9].

There have been a lot of researches carried out by scientist around the world. In 2000, Nisar Ahamed et al. [10] conducted Crop-land suitability analysis using GIS-based fuzzy membership model. Results presented that maximum area is potentially suitable for ground nut growing. Sicat et al. [11], modeled farmers' knowledge for land suitability classification. Malczewski [12] conducted a research to incorporate the concept of fuzzy (linguistic) quantifiers into the GIS-based land suitability analysis. Shearer and Xiang [12] conducted a land suitability assessment for a park land-banking program in North Carolina. They incorporated the synchronized voices into an assessment model to estimate which level of suitability best characterizes each parcel of land for a particular use. Marull et al. [14] indicated a Land Suitability Index for Strategic Environmental Assessment in metropolitan areas. They examined the presented model in Barcelona Metropolitan Region (BMR) and finally proposed to the other metropolitans.

This study aims to present how powerful the S-AHP method is in handling the land suitability analysis. For this propose the Taleghan Watershed was selected as study area. Taleghan is a mountainous region with sharp slopes located in 120 kilometers northwest of Tehran (capital of Iran) between latitudes 36°05′17.45″–36°20′45.93″ N and longitudes 50°39′33.39″–51° 11′26.5″ E. a wide area of the region is covered by rangelands and animal husbandry is the main job of villagers.

II. Material and Methods

A. Selecting of criteria

In this study criteria were selected using the literature reviews of internal and external references, interviewing with experts (questionnaires) and availability of data (Fig. 1).

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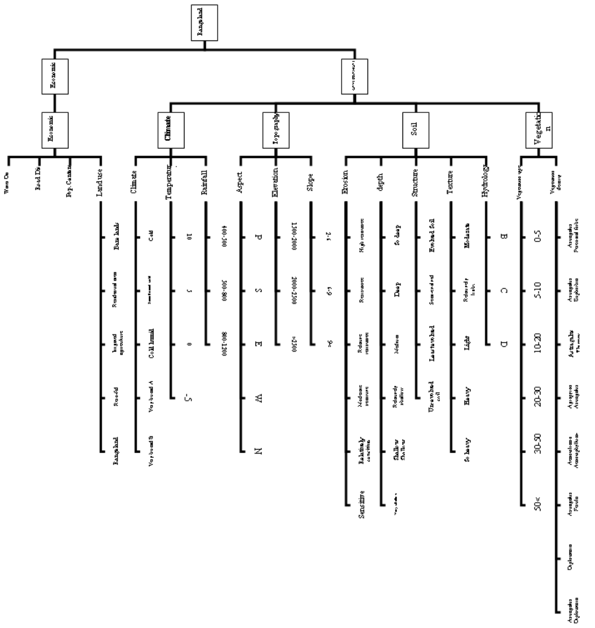

Fig. 1: the analytical structure of criteria

B. Weighing of criteria

For determining the relative importance of criteria the pair-wise comparison matrix using Saaty's nine-point weighing scale were applied.

TABLE 1: NINE-POINT WEIGHING SCALE FOR PAIR-WISE COMPARISON (SAATY, 1980)

Descriptions	Scale
Equally preferred	1
Equally to moderately	2
Moderately preferred	3
Moderately to strongly	4
Strongly preferred	5
Strongly to very Strongly	6
Very Strongly preferred	7
Very Strongly to extremely	8
Extremely preferred	9

It should be noted that for preventing bias thought criteria weighting the Consistency Ratio was used [15-18].

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \qquad \text{Eq. 1}$$

$$C.R. = \frac{C.I.}{R.I.} \qquad \text{Eq. 2}$$

Where;

n= the number of items being compared in the matrix

$\lambda_{\max}$ = the largest Eigen value

RI = random consistency index

C. Overlying

After weighing of criteria regarding their importance for land suitability analysis, all criteria maps were overlaid using suitability index.

$$SI = RI.A1 * \sum_{i=1}^{m} RI.Bi * RI.KBi$$

$$+ RI.A2 * \sum_{y=1}^{L} RICy * RIKCy + ...$$

$$RIAN * \sum_{z=1}^{j} RIDz * RIKDz$$

Where, SI is the suitability index of each cells; N is the number of main criteria; RIA1, RIA2 …RIAN are the relative importance of the main criteria A1, A2 …AN, respectively; m, i and j are the number of sub criteria directly connected to the main criteria A1, A2 …AN, respectively; RIB, RIC and RID are the relative importance of sub criteria B, C and D directly connected to the main criteria A1, A2 …AN, respectively; RIKB, RIKC and RIKD are the relative importance of indicators category k of sub criteria B, C and D and main criteria A1, A2 …AN, respectively [15-20].

III. RESULT AND DISCUSSION

A. Land suitability analysis for rangeland use

Effective parameters in land suitability for given land use are as follows which their importance is mentioned briefly:

Land cover: One of the most important factors affecting the land suitability classification for rangeland is vegetation type and density. Whatever land is rich and diverse regarding palatable species for livestock will definitely have more suitability for rangeland use.

Climate: Rainfall is among factors affecting the growth of rangeland plants.

Minimal rainfall for rangeland plant growth is not so inadequate. Usually annual rainfall of 400 mm is considered suitable.

Soil: Usually are allocated deep and heavy soils to agriculture and soils with medium to coarse gravel or rubble stone and semi-evolved with moderate deep to shallow for rangeland.

Topography: Slope is very important factor for land suitability analysis of rangeland. Places with high slope (more than 30 percent), is not suitable for livestock grazing due to being impassable. On the other hand the very sharp slopes as result of low soil depth and lack of evolved soils have not appropriate condition for growth and diversity of palatable rangeland plants. Meanwhile the elevation criteria because of effect on climate and vegetation are considered as important factor in land suitability analysis for rangeland.

Land uses: The rangeland is in conflict with industrial development but in compatible with forestry (in condition of compliance of management and control principles).

Distance from the villages, streams and springs: Considering of villagers' main job (animal husbandry), places are suitable for rangeland where in addition of having biophysical factors are not far away from villages due to easier transportation of livestock from villages to the rangelands. On the other hand the availability of surface water sources such as springs, rivers and streams in order to supplying the water needs of plants and livestock is essential.

B. Standardization of criteria

In order to compare criteria with each other, all values need to be transformed to the same unit of measurement scale (from 0 to 1), whereas the various input maps have different measurement units (e.g. distance maps, temperature etc.) [21]. In this research two standardization methods were applied as follows:

Cost- benefit analysis: for standardization of all distance criteria this method was used. For example in population centre criterion the Cost- benefit analysis assigns the highest score (suitability degree=1) to the nearest area to the population centers and the lowest one (suitability degree=0) allocates to the furthest. In this way all criteria map were converted to the same scale (0-1).

Spatial AHP: all applied criteria were standardized using AHP method but distance criteria. Pair-wise comparison matrix for standardization of vegetation is present in Table 2. Table 2: weights obtained from standardization of vegetation criteria.

TABLE 2: WEIGHTS OBTAINED FROM STANDARDIZATION OF VEGETATION CRITERI

Sub-criteria			Sub-criteria		
	layer	Weight		layer	Weight
Vegetation density	0-5	0.0024	Vegetation types	Astragalus, Perennial forbe	0.174
	5-10	0.0862		Astragalus, Euphorbia	0.114
	10-20	0.1009		Astragalus, Thymus	0.165
	20-30	0.2021		Agropyron, Astragalus	0.128
	30-40	0.3022		Acantolimon, Acantophyllum- Aat	0.145
	40-50	0.3062		Astragalus, Ferula	0.123
Vegetation density Consistency ratio (CR):0.0766				Diplotaenia	0.112
Vegetation type Consistency ratio:0.0766				Astragalus, Diplotaenia	0.239

C. Weighing of criteria

After standardization all criteria and sub criteria were weighted using pair wise comparison method. An example of main criteria weighing is given in Table 3.

TABLE 3: WEIGHING MATRIX FOR MAIN CRITERIA

Criteria	**Weight**	**Criteria**	**Weight**
Environmental factor= 0.892	**Soil=0.1905** CR=0.0722	Erosion	0.312
		Soil hydrology	0.202
		Soil depth	0.165
		Soil structure	0.165
		Soil texture	0.155
	Land cover= 0.5096	Vegetation type	0.7098
		Vegetation density	0.2902
	Climate= 0.1231	Rainfall	0.597
		Temperature	0.403
	Topography= 0.1237	Slope	0.589
		Elevation	0.403
Economic factors= 0.125	**Land use and availability factors=0.0531** CR=0.727	Land use	0.4032
		Distance from population centers	0.2984
		Distance from surface water	0.2984

D. Preparing of land suitability maps

After weighting the criteria, as regards the relative importance of each criterion as well as suitability index, all the criterion maps were overlaid and final rangeland suitability map was prepared. Suitability maps of Taleghan according to different aspect of climate, economical - social, topographical and Soil are demonstrated in Fig. 2.

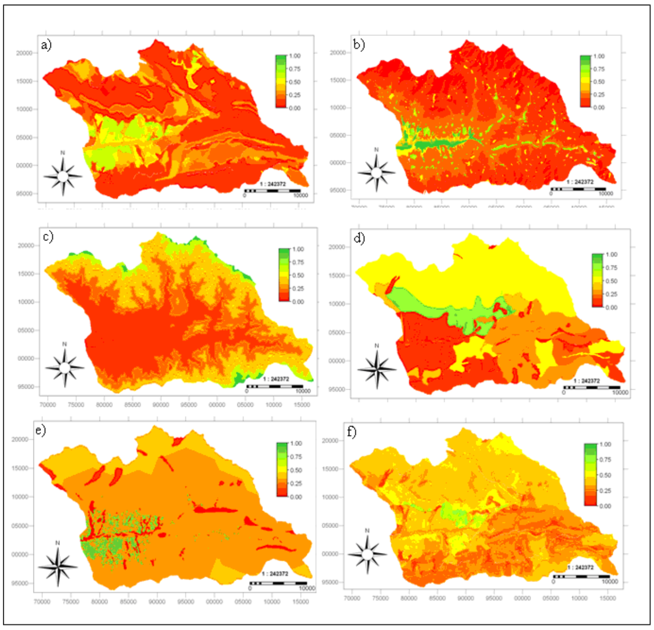

Fig.2: suitability maps of a) soil, b) topography, c) climate, d) vegetation, e) socio economic and f) final suitability map of Taleghan Basin for rangeland

V. CONCLUSION

As Figs. 4 and Table 3 present, only a small fraction of the total area has a high suitability for rangeland. The reason for this can be investigated in wide area of shallow, undifferentiated and non-fertile soils as well as poor management of livestock in study area . So the rangelands of the region have poor richness despite being so large in area . The significant point is that there is neither 0 nor 1 suitability degree among the range of regions suitability degrees. This is caused due to application of multi attribute decision making approach from compensatory models.

TABLE 4: THE AREA OF SUITABILITY DEGREES

No.	Suitability degree	Area (ha)	No.	Suitability degree	Area (ha)	No.	Suitability degree	Area (ha)
1	0.06	15000	27	0.32	42332500	53	0.58	260000
2	0.07	120000	28	0.33	60985000	54	0.59	1195000
3	0.08	177500	29	0.34	50930000	55	0.60	1092500
4	0.09	765000	30	0.35	46602500	56	0.61	830000
5	0.10	1310000	31	0.36	26345000	57	0.62	865000
6	0.11	1250000	32	0.37	25680000	58	0.63	925000
7	0.12	1605000	33	0.38	20322500	59	0.64	1850000
8	0.13	1262500	34	0.39	16347500	60	0.65	1327500
9	0.14	6050000	35	0.40	15362500	61	0.66	500000
10	0.15	5820000	36	0.41	27990000	62	0.67	780000
11	0.16	7565000	37	0.42	20927500	63	0.68	457500
12	0.17	8075000	38	0.43	10145000	64	0.69	807500
13	0.18	6240000	39	0.44	12772500	65	0.70	1142500
14	0.19	7750000	40	0.45	6477500	66	0.71	1532500
15	0.20	8075000	41	0.46	8280000	67	0.72	2352500
16	0.21	15865000	42	0.47	6740000	68	0.73	1075000
17	0.22	14255000	43	0.48	4575000	69	0.74	250000
18	0.23	18767500 0	44	0.49	21845000	70	0.75	297500
19	0.24	30492500	45	0.50	3470000	71	0.76	210000
20	0.25	37115000	46	0.51	2607500	72	0.77	260000
21	0.26	37252500	47	0.52	3392500	73	0.78	97500
22	0.27	32800000	48	0.53	2875000	74	0.79	102500
23	0.28	23620000	49	0.54	34875000	75	0.80	27500
24	0.29	16802500	50	0.55	1712500	76	0.81	5000
25	0.30	15840000	51	0.56	895000	77	0.82	2500
26	0.31	14872500	52	0.57	722500	78	0.83	15000

In this model, never the best or worst cases exist, and only satisfying result can be achieved. Due to the complexity of ecosystems, existence of all factors desirable for a particular purpose seems unlikely. So there is no perfectly suitable area in the nature. In order to better display of results, the final suitability rangeland map was classified according to suitability degrees . Thus the suitability degrees of 0-0.5 as poor, 0.5-0.75 as medium and 0.75-1 as high suitable rangeland areas were defined (Fig.4) .

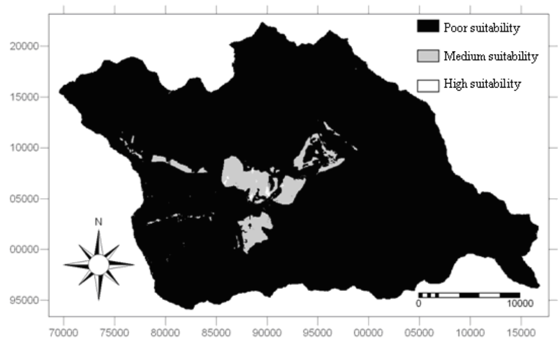

Fig.3: the classified final map of Taleghan Basin for rangeland use

In general, the results obtained from this study indicate that:

- The analytical hierarchy process is a powerful tool for decision making in land suitability issues regarding environmental and economic factors. By using this method whole area can be classified in detail about the suitability degrees for considered land use. Specified land suitability helps decision makers for defining effective management plan for each part considering its suitability index .

- High suitability areas contain only a small proportion (101.7500 ha) of whole (80000 ha) so the implementation of appropriate management plans in this watershed is essential .

-A wide ranges of area (56228 ha) applied as rangeland has poor suitability. This will lead to a widespread degradation through the region in near future .

-The region of 3670.2500 ha has medium suitability. It reveals that these areas are endangered to be poor suitable unless supervised properly.

In general to regenerate damaged pastures and to prevent further deteriorations, measures should be thought regarding rangeland and livestock management as the followings:

Conversion of mobile Animal Husbandries to the static ones, rangeland land covers reclamation, especially palatable rangeland species ,grazing considering the ranges potential, trying to conversion livestock combination from goats and sheep to cattle because of less damage to the rangeland genetic improvement in livestock in order to husbandry livestock with high productivity efficiency. On the other hand, by cultivating forage for feed, pressure of uncontrolled grazing on rangelands will be highly prevented.

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