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Ecological Capability Assessment for Multiple-Use in Forest Areas Using GIS- Based Multiple Criteria Decision Making Approach

Sasan Babaie-Kafaky, Asadollah Mataji and Naser Ahmadi Sani
Department of Forestry, Science and Research Branch, Islamic Azad University, Tehran, Iran

Abstract: Problem statement: A valuable Source of plant and animal various species in the west of Iran is Zagros forests that, misuses by foresters and local societies has caused severe degradation. In this study, forest areas ecological assessment was carried out with a (GIS)-based MCDM approach for multiple-use planning in order to reduce degradation and improving sustainability. **Approach:** All of possible land uses were evaluated separately. The AHP was used to defining weight of criteria and sub-criteria. Sub-criteria were mapped at GIS environment using available data, fieldwork and IRSp6 data. A priority map for each land use was created using GIS-based WLC model. The final priority map was produced of overlying all priority maps. Ecological capability map were generated with editing priority map using present land use map, IRSp6 data, forest laws and fieldwork. **Results:** The Weights of criteria and sub- criteria was defined for all land uses with CR<0.10. The most important criteria and sub-criteria for each land use were resulted, too. The final priority map was indicated preference of suitable land uses for each area, ecologically. The suitability map was showed areas that are enforceable land use together. Also, the area of each suitable land use was distinct. In more than of 70% study area, current use is not based on ecological criteria, which were caused severe degradation. **Conclusion:** The results of this study showed that various land uses meaning multiple-use can be exist in area study that executing of those will be cause decreasing of foresters dependence to forest trees, decreasing of degradation and forest sustainability. Thus, this integrated approach could be benefit forest planners and decision makers. Recommendation: Through this study, we aimed at suggesting to forest management and other stakeholders an approach that is scientifically sound and practical.

Key words: Zagros forests, multiple-use, MCDM, GIS, ecological capability

INTRODUCTION

An area about of 5-milion hectares, from northwest to southwest, has covered by Zagros forests that are one of the most important floristic zones in Iran. The main and dominant tree and shrub species are Persian oak (Qeurcus brantti), Qeurcus infectoria and Qeurcus libani. In this forests, so far away from the past, many of the incorrect use has caused severe degradation[20] currently considered as degraded forests with firewood production and livestock feeding recognized as the main causes[47]. Although, this forests are national but foresters use incorrectly because, they are unemployment and very poor. Current uses of this forests area are firewood production, livestock feeding and agriculture. It is explicit that continuation of degradations and regardless to land suitability cause plenty multilateral damage for all beings. The traditional use of forests is multi-objective so that forests have been used for hunting, as a source of firewood and construction materials, for collection various non-wood products, protecting soil from erosion and regulate water resources. Some forests also have cultural and religious significance[41]. All of this uses there are in Zagros forests but regardless land capability. Recently, ecologically sustainable forestry has gained acceptance[42]. If the importance of the multiple-use of forests is not continuously recognized in forest management, there is a risk that the forests will lose many of the recreational and near-natural ecosystem characteristics[19]. Nowadays, forests are often managed for multiple uses. Forest planning is a very complex activity because there are many goals, which should be achieved simultaneously, and a lot of components and elements, which must be considered[4]. In planning forest ecosystem management, evaluations

Corresponding Author: Naser Ahmadi Sani, Department of Forestry, Islamic Azad University, Science and Research Branch, Tehran, Iran.

of alternative plans with respect to ecological values are usually based on a set of variables describing the forest and the relationships between the variables and ecological values is assessed on the grounds of expert judgments[27]. Forest management policy decisions are complex due to the multiple-use nature of goods and services from forests, difficulty in monetary valuation of ecological services and the involvement of a large number of stakeholders[2]. In addition, other characteristics make natural resources decision-making situations complex. For example, group decision making and public participation are often required. To help decision makers make good choices, information and analyses are needed on the decision situation, on alternative of action, and on consequences of alternatives as well as on the preferences among these consequences. Because, decision results are very critical, thus choice of appropriate decision technique is necessary[15]. The MCDM is an umbrella approach that has been applied to a wide range of natural resource management situations. From the overview and critical reviews of MCDM, it is clear that MCDM offers a suitable planning and decision-making framework for natural resources management and regional forest planning, because it is inherently robust and can accommodate conflicting, multidimensional, incommensurable and incomparable objectives[2,33]. Multiple Criteria Decision Support (MCDS) methods are decision analyses tools that have been developed for dealing with all that information in order to support complex decision making with multiple objectives[41]. As application of multi-criteria methods in natural resources and forestry studies with various abilities such as accommodating conflicting, multidimensional, incommensurable, incomparable objectives, formalizing public Participation in decision-making, increase the transparency and the credibility of the Process has been confirmed[1,3]. Thus, group decision-making and participation planning about multiple objective and multi-criteria evaluation and for forest planning and landscape ecological analyzes qualitative improvement is needed[23,33,41]. Potentiality integration of MCDM methods with GIS showed in various researches[8,21,24,26,33,34,37,39,43]. The GIS-based multi-criteria decision-making approach is so simple and flexible that any number of criteria and indicators can be employed. Also GIS-based multi-criteria decision-making approach allows incorporation of decision makers, experts or other stakeholders into the forest conservation planning[39]. On the other hand, although with the fieldwork could be generated very precise data but often are difficult, time and cost consuming[29]. On the other hands, remote sensing data can apply as preparing tool some of ecological data and maps. For example spatial information and data estimation and mapping[6,25], quantitative and qualitative assessment of ground resources[10,28], suitability and change detection evaluation[42,48,49], criteria and indexes assessment in combination with GIS and fieldwork[14,39]. Thus, it is necessary to assessing ecological capability and land suitability using a GIS-based MCDM approach, in order to reduce of degradation, decreasing forester's dependence and Zagros forests sustainability applying multiple uses.

MATERIAL AND METHODS

Study area: The study area is about 10000 ha of Bane city forests, which is located in Iran, north part of Zagros mountainous forests (Fig. 1). The main species of these forests are *Q. brantii*, *Q. infectoria* and *Q. libani* that dominant species is *Q. brranti*. Although, this forests are national but, long term misuses from the past by foresters such as firewood production, livestock feeding and agriculture has caused severe degradation. At present, about 20% of the forest areas are forestland, 25% agriculture and residential and 55% forest with crown cover less than of 50 % (Fig. 2).

Executing methods: The possible land uses were distinguished. Criteria and sub-criteria influencing the suitability of land uses were selected by expert's judgment within AHP and reviewing relevant information from the literature[5,9,11,17,18,30,32,35,36,38,40,50,53]. Sub-criteria were mapped using available maps and data, fieldwork, RS, GIS and various methods. The maps with the same properties in the whole study were not interference in analysis. Sub-criteria classified to indicators and then score of each class added to the attribute file according to expert's judgment and reviewing relevant information from the literature. The scores were ranged from 0-9 where a score of 0 and 1 meant constraint and equal importance, and where as 9 indicated extreme importance. All of criteria and sub-criteria for each land use were weighted using pairwise comparison by expert judgments within the analytical hierarchy process and the most important of criteria and sub-criteria for all land uses were determined. A set of questionnaires

within the AHP framework was developed. In the questionnaire, respondents were determined relative importance of each criterion with respect to other, for example, importance of soil with respect to water, land cover and land unit. A priority map for each land use was created using GIS-based Weighted Linear Combination (WLC) model by MCE analyzes. The thresholds were generated by cluster analyze and resulted maps were classified. Then final priority map were produced of overlying all priority maps. Ecological suitability map were generated with editing priority map using current land use, water, density maps, satellite data and fieldwork.

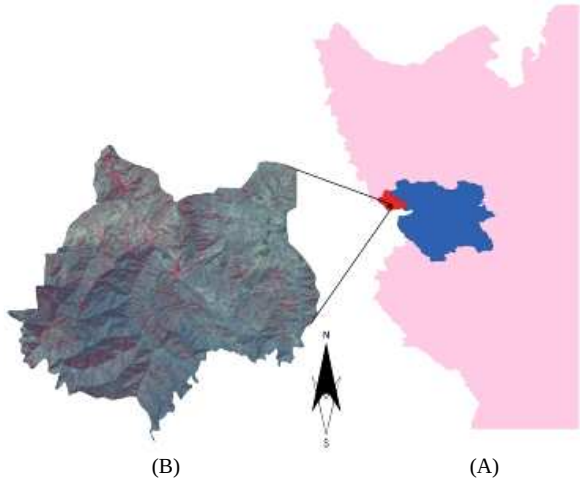

Fig. 1: (A) Study area location in Bane city, Kurdistan state, northwest of Iran. (B) IRSp6 image of study area (RGB)

Fig. 2: A sight of study area

RESULTS

The distinguished possible land uses were forestry, range management, nature tourism, apiculture, pisciculture, dry farming, irrigated farming, horticulture and intensive husbandry. Table 1 shows the criteria and sub-criteria influencing the ecological suitability of land uses, too. Sub-criteria, indicators and their score map were created for all land uses. For example, Fig. 3 shows indicators (classified sub-criteria) maps of slope, forest density and their scored maps for dry farming land use.

The weights of criteria and sub- criteria were defined for all land use. The consistency ratio coefficients for final weights were fall in the acceptable range. For example, Fig. 4 and 5 show sub-criteria weight with CR<0.10 for horticulture and forestry land uses. The most important criteria and sub-criteria for each land use were resulted, too (Table 2).

The suitability map that was created shows areas that are enforceable land use together. The priority map was created for all land use, separately.

For example Fig. 6 shows priority map of apiculture, nature tourism, forestry and dry farming. The resulted final priority map indicates preference of suitable land uses for each area, ecologically (Fig. 7). However, in three cases (Fig. 7), land uses could not be executed with together. Also, the area of each suitable land use was distinct (Table 3). So that Table 3 shows, in more than of 70% study area, current use is not based on ecological criteria, which were caused severe degradation. The finally, suitability map was generated that show areas that are enforceable land use together (Fig. 8).

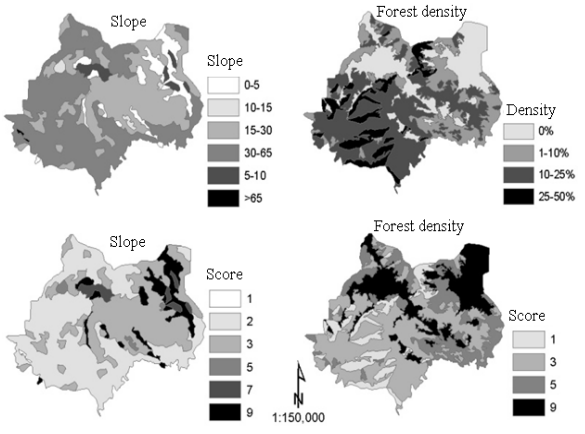

Fig. 3: Indicators map of slope and forest density and their score for dry farming

Table 1: Source, mapping methods, scale and utilization of criteria and sub-criteria

Criteria	Sub-criteria	Source and mapping methods	Scale and utilization
Land cover	Type	Sampling + visual interpretation of IRSp6 + current land use	1:25000, all land uses
	Forest density	Sampling + classification and IRSp6 interpretation + current land use	
Water Resources	Quantity	Current land use + interpretation IRSp6 + Water quantity of springs and wells (L sec^{-1})	1:50000, all land uses, except forestry and dry farming
	Quality	existing data	Same in whole study
Soil	Texture	sampling + Geology map + land type map + land cover	150000, all land uses, except pisciculture, apiculture, intensive husbandry
	Fertility	map + lab work	1:50000, all land uses, except pisciculture, apiculture, intensive husbandry and nature tourism
	Ph		
	Erosion	Fieldwork + IRSp6 + existing data + created maps using FAO method	1:50000, all land uses
Landscape	Landscape	Fieldwork + hill shade + visual interpretation of IRSp6 + roads	1:50000, nature tourism, only
Climate	Precipitation	Determining of equation using	1:50000, all land uses
	Temperature	neighbor meteorology stations + generalization using DEM	
Land unit	Slope	Using DEM	1:50000, all land uses
	Elevation		
	Aspect		
Geology	Slide	Geology map	1:100000, Non-existence in whole study
	Fault		
Necessary maps other		**Source and mapping methods**	**Scale and utilization**
Current land use		Ground truth with GPS + visual interpretation of IRSp6	1:25000, suitability mapping
Land type		Visual interpretation of IRSp6 + hill shade + slope and elevation map	1:25000, soil parameters mapping
Constrant1		Ground truth with GPS + sampling + visual interpretation of IRSp6	1:25000, all land uses, except Nature tourism
Constrant2		Ground truth with GPS + sampling + visual interpretation of IRSp6	1:25000, pisciculture, intensive husbandry, irrigated farming and horticulture

Table 2: Most important criteria, sub-criteria and their weight for each land use resulted from AHP

Land use	Nature tourism	Forestry	Range management	API culture	Dry farming	Irrigated farming	Pisciculture	Horticulture	Intensive husbandry
The most important criteria	Water source + landscape	Climate + plant cover	Water source + plant cover	Plant cover	Climate	Water source	Water source	Water source	Water source
Weight	0.279+0.217	0.427+0.310	0.302+0.285	0.342	0.513	0.393	0.517	0.362+0.315	0.448
The most sub-criteria important	Water quantity + landscape	Density	Water quantity + cover type	Cover type	Precipitation	Water quantity	Water quantity	Water quantity	Water quantity
Weight	0.206+0.160	0.198	0.188+0.178	0.24	0.298	0.234	0.394	0.2	0.31

Table 3: area comparison of current land use and ecological suitable land use

Suitable land use	d-n-a	f-n-a	r-n-a	n	i-n-a	p-n	Ho-n-a	Ho-p-hu-n-a	Ho-p-i-hu-n-a	Ho-p-n-a
Area (%)	12.5	57	14.25	2.5	3	0.5	1	1.75	7	0.5
Current land use	d-i-hu-ho-r	f-r	fl-r	res-hu	-	-	-	-	-	-
Area (%)	23	54.7	20.5	1.8	-	-	-	-	-	-

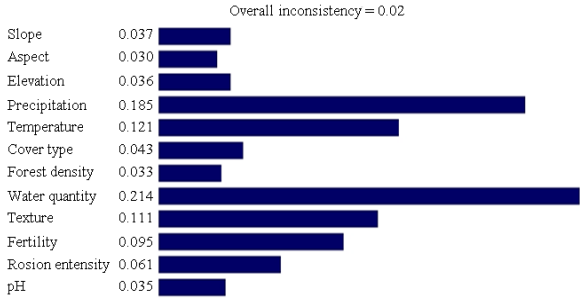

Fig. 4: Sub-criteria weight and overall inconsistency for horticulture land use

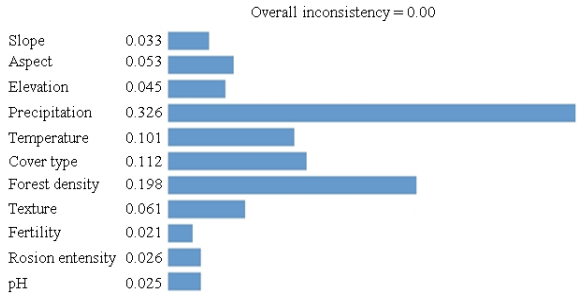

Fig. 5: Sub-criteria weight and overall inconsistency for forestry land use

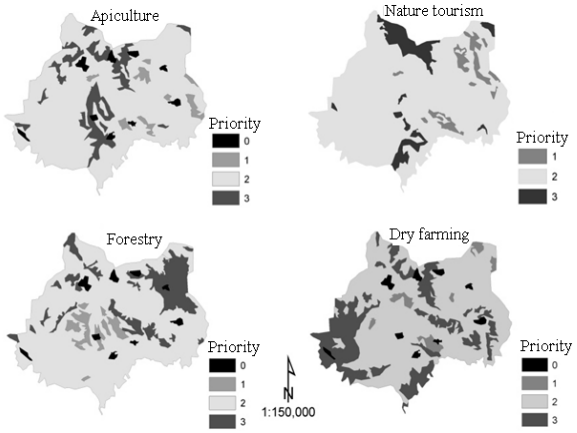

Fig. 6: Priority map of apiculture, nature tourism, forestry and dry farming

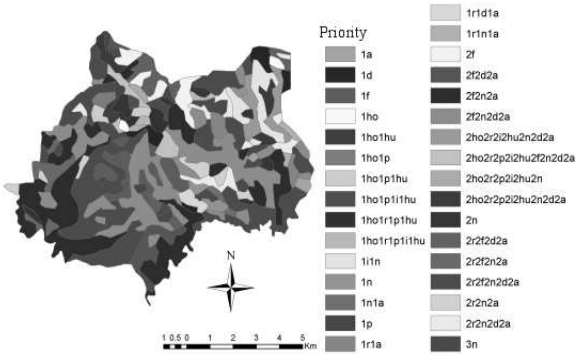

Fig. 7: Final priority map

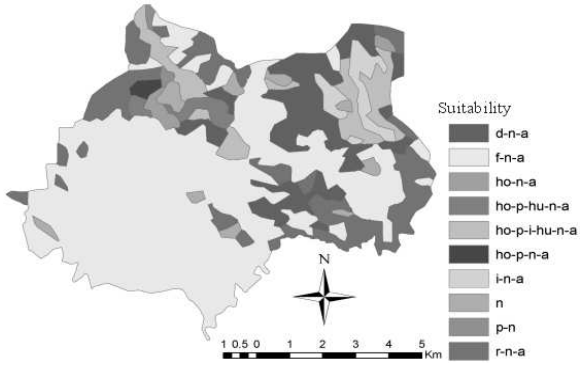

Fig. 8: Suitability map

DISCUSSION

The AHP[44,45,46] is a known and common multi-attribute weighting method for decision[12,13,16,51,52]. AHP is a comprehensive, logical and structural framework, which allows improving the understanding of complex decisions by decomposing the problem in a hierarchical structure. AHP allows the consistent comparison of both qualitative and quantitative criteria or alternatives, since different scales of input information are transformed to uni-dimensional priorities[54]. Use of AHP for assigning the weights of relative importance to the objectives is relatively new[52]. The use of AHP insures that the suitability maps are comparable for all land uses[31]. In this research, using AHP, consistent weight of all of criteria and sub- criteria for all land use, through pairwise comparison was evaluated, properly and confirmed result of previous studies in related with AHP. In addition, within AHP the criteria and sub-criteria influencing the ecological suitability of land uses were defined, properly and perfectly (Table 1). Although the AHP[45] method is widely accepted in solving multi-criterion problems, the accuracy of the results depends on accuracy of spatial data. Moreover, the selection of land suitability assessment parameters, priority weights within the AHP framework are greatly influenced by objectives, location, maps, people involved in discussions and key informants. In this research, AHP in combination with RS and GIS were three major tools in a manner that reached the correct solution to assist the decision maker in determining appropriate values for the ecological suitability criteria. A CR<0.10 indicates a reasonable level of consistency among pairwise comparisons[31]. In this study, consistency ratio coefficients for the final weightings were fall in the acceptable range (Fig. 3 and 4).

In similar with various studies[6,7,22], GIS provided valuable information for spatial forest-management planning in adjacency, proximity and juxtaposition of patches. In addition to the refinement of compartment maps, GIS was also applied in managing and visualization of ecological data in different stages. Remote sensing techniques assessed the land use information cost effectively[49]. Remote sensing now a day has become a modern tool for mapping of land use/land cover for micro, meso and macro level planning[48]. In this research, the role of RS is much more apparent by setting out some of the new opportunities for RS data sources, analysis and applications to forest resource assessment (Fig. 3). As sub-criteria, indicators and their score map created with high precious at GIS environment using IRSp6 data and fieldwork for all land uses is showing of this roles. For example, Fig. 3 shows indicators (classified sub-criteria) maps of slope, forest density and their scored maps for dry farming land use.

In addition to, so that Fig. 3 and 4 and Table 2 shows, similar to previous researches, weights of

criteria and sub-criteria for each land use were resulted, properly. That shows efficiency of AHP for parameters preference determining in the same researches. The priority map that was generated indicates preference of suitable land use for each area, ecologically. The suitability map that was created shows areas that are enforceable land use together. However, in three cases (Fig. 7), land uses could not be executed with together thus; the best land use must be identified by economical studies in combination with the results of this study. So that table 3 shows, in more area of study area, current use of these forest areas is not based on ecological criteria, which were caused severe degradation. For example, although ecologically, in 14% of study area, range management and extensive husbandry is allowed but there is in more than of 95% study area. Thus, this integrated approach could be benefit forest planners and decision makers. If, the importance of the multiple-use of Zagros forests is not recognized in forest management, the forests will lose many of the recreational, natural ecosystem characteristics and countless values.

CONCLUSION

This study demonstrates the ecological assessment potentiality of multiple-use for forest planning, comprehensive sight of integrating quality of MCDM and GIS in the suitability assessment process, characteristics and tools. If, the importance of the multiple-use of Zagros forests is not recognized in forest management, the forests will lose many of the recreational, natural ecosystem characteristics and countless values. Thus, integration of GIS and MCDM could benefit forest planners and decision makers. This method also provides a cost effective, rapid land evaluation framework, which help policy makers, regional planners, forest manager and researchers working in developing countries. The results of this study show that various land uses can be exist in area study that executing of those will be cause decreasing of foresters dependence to forest trees, decreasing of degradation and forest sustainability. Consolidation of local people knowledge and expert's views with modern geographic techniques to evaluate the land uses was caused this research results more empirical and original. The results of this study are suggesting to forest managers and other stakeholders so approach that is scientifically complete, sound and practical.

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