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A NEW PROPOSED MODEL OF EMOLUP FOR ASSESSING OF ECOLOGICAL CAPABILITY OF DIFFERENT UTILIZATIONS AND LAND USE PLANNING IN SEPIDAN TOWNSHIP, IRAN

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ABSTRACT. The optimum use and appropriate management of renewable resources, with dynamic characteristics, needs to evaluate and classify the ecological capability of environment and its socio-economic conditions. Land use planning (LUP) is an iterative process based on the dialogue amongst all stakeholders aiming at the negotiation and decision for a sustainable form of land use in rural areas as well as initiating and monitoring its implementation. The main objective of this paper is the implementation of integration quantitative model namely EMOLUP (Eco-Socioeconomic Model of Land Use Planning) in Sepidan Township of the Fars province in Iran. Therefore, two main steps were prepared for the new model: I. Ecological capability evaluation of different land uses. This step is composed of the geometric mean method instead of the Boolean and MCE methods. II. Land use planning and prioritizing for the various uses. This step has been composed intersecting ecological capability maps and land use planning, based on two scenarios (economic and social). Then, it was compared with current qualitative and quantitative methods. Also, current land use is used for calibrating and modifying the proposed models. Results show using the geometric mean method is better than Boolean models, and the method of the calibrated geometric mean (with overall accuracy > 63 and kappa index > 0.39 for all land uses) is the best among different used models. Also, results of prioritizing and land use planning showed that quantitative method with two socio-economic scenarios (with an average of EPM erosion model = 0.31) is the best method for land use planning in the study area. We confirmed that the EMOLUP model can contribute to a better understand land use planning in different regions of the world.

Una nueva propuesta del modelo EMOLUP para la evaluación de la capacidad ecológica de diferentes manejo y planificación del uso del suelo en Sepidan, Irán

RESUMEN. El uso óptimo y la gestión adecuada de los recursos renovables, con características dinámicas, necesita evaluar y clasificar la capacidad ecológica del medio ambiente y sus condiciones socioeconómicas. La planificación del uso del suelo (LUP) es un proceso basado en el diálogo entre todas las partes interesadas con el objetivo de negociar y decidir una forma sostenible del uso del suelo en áreas rurales, así como iniciar y monitorear su implementación. El objetivo principal de este documento es la implementación del modelo cuantitativo de integración denominado EMOLUP (Modelo Eco-socioeconómico de Planificación del Uso del Suelo) en el municipio de Sepidan, en la provincia de Fars (Irán). En concreto, se prepararon dos pasos principales para el nuevo modelo: I. Evaluación de la capacidad ecológica de los diferentes usos del suelo. Este paso incluye el método de la media geométrica en lugar de los métodos booleano y MCE. II. Ordenamiento territorial y priorización de los distintos usos. Este paso considera la intersección de mapas de capacidades ecológicas y la planificación del uso del suelo, en base a dos escenarios (económico y social). Posteriormente, se comparó con métodos cualitativos y cuantitativos actuales. Además, el uso actual del suelo se utilizó para calibrar y modificar los modelos propuestos. Los resultados muestran que usar el método de la media geométrica es mejor que los modelos booleanos, y el método de la media geométrica calibrada (con una precisión general >63 y un índice kappa >0,39 para todos los usos del suelo) es el mejor entre los diferentes modelos utilizados. Además, los resultados de la priorización y la planificación del uso del suelo mostraron que el método cuantitativo con dos escenarios socioeconómicos (con un modelo de erosión EPM promedio = 0,31) es el mejor método para la planificación del uso del suelo en el área de estudio. Confirmamos pues que el modelo EMOLUP puede contribuir a una mejor comprensión de la planificación del uso del suelo en diferentes regiones del mundo.

Key Words: EMOLUP model, geomean, boolean, Prioritizing, land use, capability.

Palabras clave: modelo EMOLUP, media geométrica, booleano, priorización, uso del suelo, capacidad.

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1. Introduction

Land refers to earth's terrestrial surface and includes climate, soil, landform, water, plants, animals, human settlements and infrastructure. In biophysical land evaluation analysis and land performance assessment, there are two major trends: qualitative and quantitative. In general terms, a land evaluation system is considered qualitative when in its development the values of diagnostic properties define categories (Makhdoum, 2006). The system is considered quantitative when these values are combined mathematically to give an index on a sliding scale. Land use planning (LUP) is a procedure which leads to an optimal and sustainable use of the land and all its attributes (Sarvazad *et al.,* 2015; Yohannes and Soromessa, 2018; Nazari Viand *et al.,* 2019). Use of the land may take various forms, from intensive use such as settlements and irrigated agriculture to less intensive use such as livestock production, forestry or nature reserves (Alavi Panah *et al.,* 2001; Asadifard *et al.,* 2019). The same piece of land can be used for more than one purpose at the same time (e.g. forestry and livestock production) or have different uses during different periods of year (e.g. rainfed cropping during the wet season, followed by grazing during the dry season). Land use planning is not something new: it has been practiced from the time that humans domesticated animals for livestock production and started crop cultivation (O'Neill, 1989; Abu Hammad and Tumeizi, 2010; Benthem, 2013; Ayalew, 2015; Masoudi *et al.,* 2017; Jokar *et al.,* 2021). It should be noted that land use planning must deal with the understanding of all problems, of potentials and alternatives for land use in all areas of the planning unit. It cannot be concerned selectively with partial areas, which are particularly intact or degraded. The whole area used by the stakeholders has to be planned (Mokarram and Zarei, 2021). Hence, before the beginning of development, it is better to select the suitable developing site in terms of ecological capability and land use planning in order to prevent reduction of natural resources, which may happen for the reason of illogical usage (Nouri and Sharifpour, 2004; Masoudi, 2014; Hosseini, 2018).

A significant amount of literature and research has been dedicated to intelligent systems for land use and management. The study conducted by McHarg (1969), land suitability assessment has become a standard practice in land use planning. Land uses include both natural and man-made uses. The FAO (Food and Agriculture Organization of the United Nations) (1976) defined land evaluation as the process of assessment of land performance when used for specified purposes. In this way, land evaluation can be useful for predicting the potential use of land based on its attributes (Rossiter, 1996). In such classic methods like the FAO, Storie (1987) made the classification quite strict based on maximum limitation. This is because, according to Boolean logic, only one low index is enough to reduce the suitability of land from a highly suitable class to a not suitable class (Masoudi, 2018). Also, computer-assisted overlay techniques such as the Geographic Information System (GIS) were developed as a response to the manual method's limitations in mapping and combining large datasets (Steinitz *et al.*, 1976; Najafinezhad *et al.,* 2013; Lahmian, 2016; Jahantigh *et al.,* 2019). Methods such as Multi-Criteria Decision Making (MCDM) and genetic algorithms have considerably advanced the conventional map overlay approaches to land use suitability analysis (Oyinloye and Kufoniyi, 2013; Safaripour and Naseri, 2019). However, it is well-known land use suitability analysis methods have one problem. They do not assure a spatial pattern with contiguity or compactness in land allocations for different types of land use. Also, these methods are complex to use (Masoudi, 2018).

Among leading models in the field of economic planning (prioritizing), the French and the Anglo-Saxon models can be mentioned (Kindleberger, 1967; Metze, 2002). Also, there is a model designed by Nakos (1984) in Greece related to land use planning. Fallahshamsi (2004) investigated the economic evaluation of different land uses in the kalibar-chai forest-covered watershed in Iran, using linear programming and the GIS (Geographic Information System), and based on the cost-benefit method. Najafinezhad *et al.* (2013) compared the efficiency of systematic and multi-objective land allocation (MOLA) methods for land use planning using the GIS. They found that the map obtained from MOLA was better in terms of land use allocation and also, for reducing erosion and sediment production as compared to that of the systematic method. Piran *et al.* (2013) had utilized AHP and GIS methods for assessing land suitability for forest at Bdresh county western Iran. Pan *et al* (2021) conducted practical efficient regional land-use planning using constrained multi-objective genetic algorithm optimization for Dapeng, China. Results showed that the comprehensive model gave superior fitness compared to the contrast experiments.

Considering the above mentioned-lack the main goal of this paper is the implementation of accurate integration quantitative models in order to evaluate ecological suitability and prioritize different land uses including forest, rangeland, agriculture, conservation, and development. Our research will help to achieve the Sustainable Development Goals of the United Nations and the Land Degradation Neutrality challenges due to the soil and water proper management we propose (Keesstra *et al.,* 2018; Keesstra *et al.,* 2021). To achieve this goal, an experimental area including total area of Sepidan county placed in Fars Province, Iran was selected because of available data for this land evaluation and also different variation in climate and topographic condition.

2. Materials and methods

2.1. Study Area

Sepidan county is situated in Northwest of the Fars province of Iran with an area of 286,000 hectares. Sepidan city is located in 51° 59' east longitude and 30° 15' north latitude (Fig. 1). The population of this county was equal to 91,049 people based on the 2015 census. Its average rainfall thirty-years past is 758 mm, with 35% and 65% relatively in the form of snow and rain, respectively, evenly distributed. The weather is very cold in the winter and reach to -15°C and cool and mild in the summer with average daily temperature of 25°C. From the contemporary technicalities of climatic classification and general populace, this city is considered cool and moist to semi-dry (Goudarzian and Yazdani, 2015). A major part of this county is mountainous and covered with forest, and due to its climate, it is one of the important agricultural and animal husbandry areas of Fars province. This county has been successful in preparing and distributing meat outside the province. Walnut, peach, apple and cherry trees comprise the most products of the region. It should say that Sepidan is one of the most famous ecotourism regions in Fars province and Iran. The region's cool climate in summer and snow-covered mountains in winter and the natural tourist attractions of the region and the existence of riding tracks and ski tracks and areas such as Tangheh-Tizab and Chalehgah have given a special boost to the tourism industry. Figure 1 shows the location of the study area.

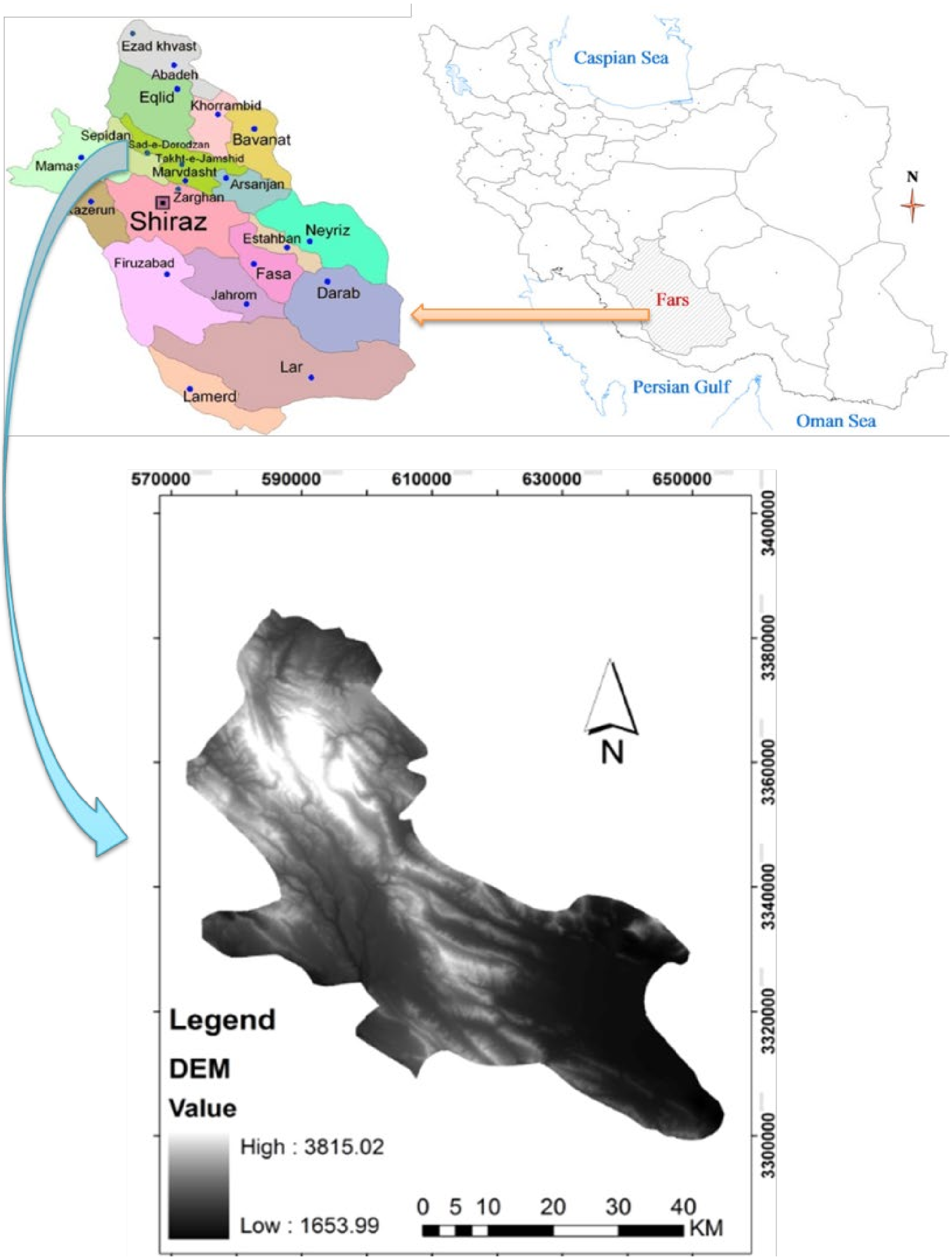

Figure 1. Location of the study area in Iran.

2.2. Ecological capability evaluation

2.2.1. Modeling Process for Ecological Capability Evaluation

The present paper aims to find a suitable model for land capability evaluation, for different land uses in the study area, using software like ArcGis9.3 (Produced by ESRI Company, USA), ENVI4.7, and Excel. Two types of data were obtained: numerical data and thematic maps, mainly in the map format. All such relevant data were obtained from the local and main offices and institutes of the Ministries of Agriculture and Energy in Iran. Figure 2 shows the platform structure of the designed model.

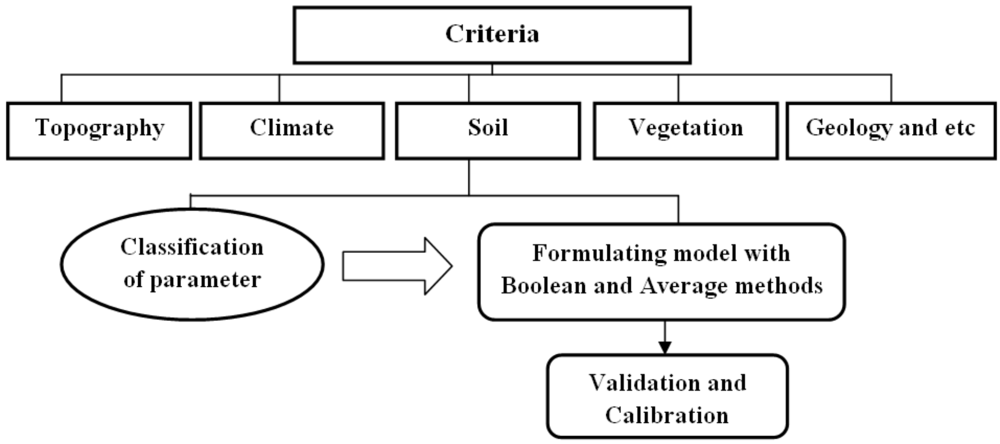

Figure 2. Flowchart showing the methodology adopted for ecological capability evaluation in this study.

2.2.2. Classification of Models

The Iranian Ecological Model (Makhdoum, 2006, Masoudi, 2018) is a land evaluation model for different land uses. For example, forestry (including 7 Classes), agriculture and rangeland management (including 7 Classes), development (including 3 Classes) and ecotourism (including 3 Classes). It should be noted that the ecological potential in every use reduces by increasing the capability number of the class. In the revised method, classes mentioned were reclassified (in order to make a standard classification). Accordingly, the uses of agriculture and natural resources (forest and rangeland) were reclassified into four Classes (Anex 1a) including: highly suitable (1), moderately suitable (2), poor (3), and not suitable (4). Human-made uses (development and ecotourism) were reclassified into 3 Classes including: highly suitable (1), moderately suitable (2), poor and not suitable (3) (Anex 1b). Also, environmental conservation uses or protected land was classified into 2 Classes including: suitable (1), not suitable (2) (Anex 1c).

2.2.3. Formulating Model

Boolean Algebra: Boolean logic has three basic operators: Intersection (logical term AND), Union (logical term OR), and Inverse (logical term NOT).

Geometric Mean: In the geometric mean method such as the MEDALUS model (Kosmas *et al.,* 1999; Zakerinejad and Masoudi, 2019) and according to criteria, in the uses with four classes, every indicator was given the weight between 0 and 3 (Anex 1). In this, 0 indicates the non-suitability of the ecological condition (Class 4) and 3 represents the most suitable ecological condition (Class 1) for a utilization like irrigation. Scores of 1 and 2 are given to the third and second classes, respectively. In uses like development with three classes, every indicator was given the weigh between 0 and 2 (Anex

1). In this, 0 stands for poor and non-suitable ecological condition (Class 3) and 2 stands for the most suitable ecological condition (Class 1).

Then every criterion (like topography) was calculated based on the geometric mean of indicators (Equation 1).

$$\text{Criterion\_X} = [(\text{Layer-1}) \times (\text{Layer-2}) \ldots \times (\text{Layer-n})]^{1/n} \qquad \text{(Equation 1)}$$

In this, Criterion_X is the defined criterion; Layer is the indicator map of criterion; and n is the number of used indicators. Then the criteria were multiplied through the geometric mean (Equation 2).

$$\text{Final Criterion} = [(\text{Layer-1}) \times (\text{Layer-2}) \ldots \times (\text{Layer-n})]^{1/n} \qquad \text{(Equation 2)}$$

In this, Final Criterion is the final layer of ecological capability; n is the number of used criteria. Then classes of qualitative and suitable ecological capability were defined, for uses of three and four classes, in the study area in a GIS (Table 1).

Table 1. Suitability classes in capability maps and models for 4 classes' uses (a) and models for 3 classes' uses (b) regarding the scores of polygons.

(a)

	Suitability classes			
Their score	Good (1)	Moderate (2)	Poor (3)	Not suitable (4)
	2.5-3	1.5 - 2.5	0.5 - 1.5	< 0.5

(b)

	Suitability classes		
Their score	Good (1)	Moderate (2)	Poor & Not suitable (3)
	1.5-2	0.5-1.5	< 0.5

Note: The capability of conservation use was calculated based on the Boolean (OR) method.

Arithmetic Mean (Sum): In the arithmetic mean method, scores given to indicators were averaged (Tables 2 for classification).

MCE (WLC) method: In this paper, MCE was used for assessment. Accordingly, questionnaires were given to experts in the field of different uses for weighting the criteria and factors. Then calculation of weightings was done in Expert Choice software. Weight of criteria and factors was obtained with Consistency Ratio or CR<0.1. Then WLC (weighted linear combination) method used for the weighted overlay of the input data layers. With the weighted linear combination, factors are combined by first applying a weight to each factor and criteria (Equations 3), followed by a summation of the results to yield a suitability map (Equations 4). Finally, constraint factors (C_i) were multiplied in map (Fallahshamsi, 2004).

$$[(W_1 \times \text{factor1}) + (W_2 \times \text{factor 2}) \ldots + (W_n \times \text{factor})] \times C_i \qquad \text{(Equation 3)}$$

$$[(W_1 \times \text{Criteria1}) + (W_2 \times \text{Criteria2}) \ldots + (W_n \times \text{Criteria})] \times C_i \qquad \text{(Equation 4)}$$

2.2.4. Validation and Calibration

Validation: In order to validate models, samples of ground reality (current land use map) were gathered by "Create Fishnet" algorithm (a systematic random sampling) in ArcGIS 9.3 environment (Congalton, 1991). Number of samples was based on importance of ground reality in every use. So, the regions with more suitable condition for every use were sampled more than other regions (Fallahshamsi, 1997).

Then these points were overlaid to land capability maps. The obtained result is observed in a table named “Error Matrix” and by quantitative indices such as “Overall Accuracy, Kappa and Inclass Coefficients” (Fallahshamsi, 1997).

Calibration: To ensure the agreement of capability maps to current conditions (regarding omission and commission in errors and maps of parameters in the geometric mean method), quantitative ranges of suitability classes (Table 1) were slightly changed. For example, the range of Class 0.5-1.5 was changed to 0.5-1.85. This kind of calibration was done in other classifications like the MEDALUS method.

2.3. Prioritizing Different Land Uses

2.3.1. Modeling Process

The present paper aims to find a land use planning model for prioritizing different land uses of the study area using ArcGis9.3. Every use with the best accuracy was intersected in a vector format in the ArcGIS software environment. Current land use was also applied. Figure 3 shows platforms structure of the designed model.

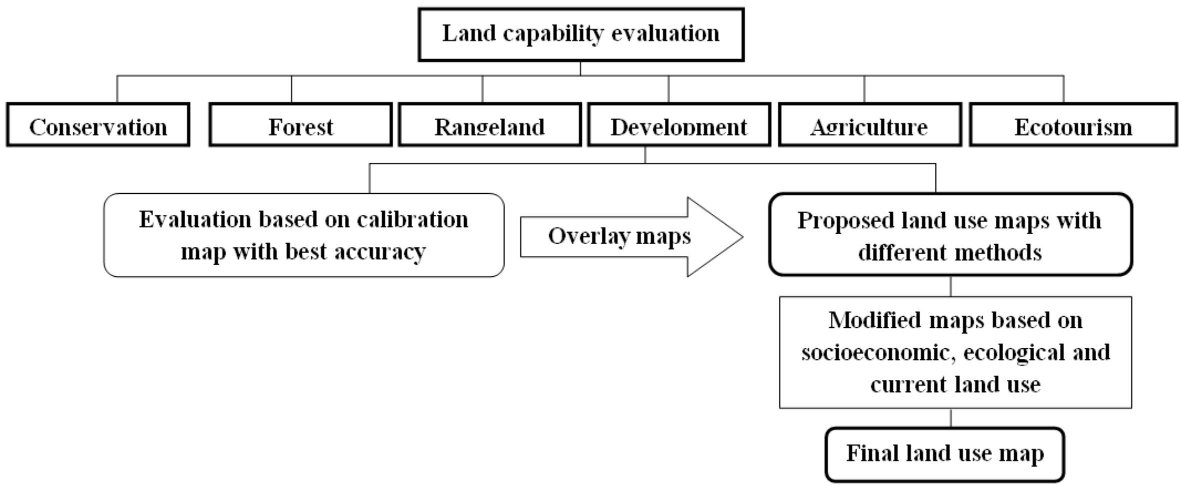

Figure 3. The conceptual framework of land use planning for the proposed model.

It should be noted that the land use planning process is based on selection of the best use in every polygon (unit). Hence, different methods were applied in order to select the best use.

Quantitative Method: Initially, the quantitative method developed by Nakos (1984) was used. Then it was revised (based on conditions in Iran) by Makhdoum (2006). To be more specific, four scenarios were developed for different land uses based on the regional information, including: current land use area, ecological scenario, economic scenario, and social scenario. Table 2 shows one example describing the four scenarios in a study area (as a planning unit).

The first scenario was ranked by evaluating the current land use. The land use with highest area in this region (forest) was given highest rank and the land use with least area in this region (protected zones) was given the least rank. But for other scenarios questionnaires was prepared. Experts of the study area were asked to rank different land uses for these other scenarios based on their knowledge and experience. Then all land uses were ranked for each scenario and given scores of 10 and below based on their ranks (Table 2a) and classes of ecological capability (Table 2b). For example, if in one scenario in a land unit, the rank of forest is in third place and its ecological capability is in Class 2, then the score in its first step is 8, and one point is lowered for its capability reduction (Class 2), making the forest score 7. If ecological capability is in Class 3, the reduction in each scenario would be of two points.

To achieve a systematic analytical model, all layers of ecological capability maps were used by a vector format in GIS software environment. Then appropriate utilization of each land unit (polygon) was determined and prioritized. Appropriate utilizations are those that have a higher sum of scores among the used scenarios (Table 2b). Many of the units were seen to be fit for two appropriate uses by the quantitative model, considering the socio-economic status of the area, consistency of land uses and current land use.

Table 2. Example of scenarios designed for the study area (a) and Relative values (0-10) assigned to different land uses according to capability classes of the land with taking into consideration of different scenarios (b).

(a)

Scenario1 Scenario2 Scenario3 Scenario4	Rangeland > Conservation > Development > Development >	Forest > Rangeland > Agriculture > Agriculture >	Agriculture > Forest > Rangeland > Conservation >	Conservation > Agriculture > Conservation > Rangeland >	Development Development Forest Forest
Weighted values	10	9	8	7	6

(b)

Capability class / Scenario	Rangeland	Forest	Agriculture	Conservation	Development
	1	3	2	1	2
1	10	7	7	7	5
2	9	6	6	10	5
3	8	4	8	7	9
4	7	4	8	8	9
Sum	34	21	29	32	30
Priority	**1**	**5**	**4**	**2**	**3**

Modified Quantitative Method (four scenarios): Modifications were made in the process of work for assessing land use planning with a quantitative model. These modifications are described as follows:

a. Each use was prioritized based on the highest score derived after summing up the scores of the scenarios. Of course, it is necessary to have appropriate capability (suitable or Classes 1 and 2) for the utilization with highest score.

b. The compatibility of uses was considered. If uses are compatible together (for example, forest and conservation), they will be considered together. If uses are not compatible together (for example, development and forest), they will be considered based on economic needs (especially current land use).

c. Current land use map was applied for assessment because of socio-economic compulsions of the population, especially in rural areas. The main modifications in this step are to hold the following land utilizations:

   1) Agricultural lands with suitable capability (classes 1 and 2).

   2) Settlement lands (urban, rural, and industrial areas).

3) Forest lands with a canopy cover of more than 25% (F_1 and F_2) and those with conservational roles based on compatibility of uses.
4) Forest lands with a canopy cover of less than 25% (F_3) that were prioritized as rangeland. They are prioritized as Forest – Rangeland based on compatibility of uses.
5) Rangelands with a canopy cover of more than 25% (R_1 and R_2), F_3, and ecotourism with suitable capability (Class 1) with taking into consideration of compatibility of uses.
6) Current protected lands with taking into consideration of compatibility of current land use (for example, natural resources) and holding man-made current land use in current protected lands (except core zones).
7) Lakes and river beds.
8) Lands not prioritized in earlier steps (with suitability Classes 3 and 4); their utilizations are retained.

In this study proposed land uses are defined with different codes including: F (Forest), E (Ecotourism), R (Rangeland), IF (Irrigated Farming), DF (Dry Farming), D (Settlement & Development), E (Ecotourism), C (Conservation), BL (Bare Land), L (Lake and water body).

Modified Quantitative Method (two scenarios): Due to problems in evaluation of the quantitative methods (4 scenarios) [a) the larger area of one utilization (for example, rangeland) as compared to the smaller area of another utilization, giving higher weight to the former; b) the existing ecological scenario in land ecological capability evaluation where experts may mistakenly prioritize the ecological scenario], the revised quantitative method was used based on two scenarios (economic and social) with mentioned modifications.

Qualitative and its Modified Method: Qualitative method (Makhdoum, 2006; Khosravi *et al.,* 2012; Masoudi, 2018) keeps current utilizations with suitable capability (Classes 1 and 2) after intersecting ecological capability maps with the land use map. Other lands are prioritized based on utilizations that have better land capability. In modified qualitative method, some positive changes (mentioned in the modified quantitative method) were added.

2.3.2. Validation of Models

In order to validate models, the EPM (Erosion Potential Method) model was used (Gavrilovic, 1998). Based on the EPM model assigned with land uses, maps of proposed models were compared with the current land use map. The model close to good land uses assigned to the EPM model is considered to be the better model. The ranked land uses (agriculture and natural resources) assigned to the EPM model (with a little modification) were sorted based on their impact on soil protection (Table 3a). This ranking helps to compare land use planning maps to current land use. Based on Table 3a, if the optimized uses have better situations than current land use (A), positive (+1) score is given; if the optimized uses have worse situations than current land use (B), negative (-1) score is given; and if the optimized uses are the same as current land use (C), zero (0) score is given.

Point 1: If the current land use is kept and its ecological capability is in Class 1 (except protected lands), a positive (+1) score is given (D) due to its socio-economic importance.

Point 2: Converting a river bed to other uses is equivalent to a negative (-1) score.

It should be noted that the use of residential and industrial development has not been mentioned in the EPM model. Hence, a separate table (Table 3b) was made to compare current and optimized land uses with regard to destructive out-site and in-site effects, and socio-economic special features for this use.

Also, for future (not current) environmental conservation, the score was considered to be positive due to land improvement and its protective role. Additionally, to convert areas of natural resources and agriculture to ecotourism, the rating -1 to +1 was used based on the capability degree of agriculture and ecotourism areas, and due to environmental and socio-economic special features for these uses.

Based on the above points, the proposed models were compared together. For this purpose, a certain number of points (1707) was scattered with the Create Fishnet algorithm in ArcGIS9.3 environment and was based on the study area (a systematic-random sampling). In the next step, proposed models were compared based on average ratings. So, the final number is between ±1. If the positive number obtained is larger, it represents the suitability of the prioritization process.

Table 3. Validation of proposed models by EPM model to compare with current land use (a) and validation of proposed models by comparing with current land use and development (b).

(a)

Order	Land use	Description
1	F_1, F_2	Current Dense and Semi dense Forest (capability classes of 1 and 2 in optimized use)
2	IF, DF with suitable capability (Classes of 1, 2)	Irrigated and Dry Farming with suitable capability (classes of 1 and 2)
3	F_3, R_1	Current Sparse Forest (capability class of 3 in optimized use), Current Dense Range (capability class of 1 in optimized use)
4	R_2	Current Semi dense Range (capability class of 2 in optimized use)
5	IF, DF with none suitable capability (3, 4) and R_3	Irrigated and Dry Farming with weak to none suitable capability (classes of 3 and 4) and Current Sparse Range (capability class of 3 in optimized use)
6	Desert (BL, SL)	Barren and Saline lands
Examples		Examples Code
R_2 (current) to F_2 (optimized)		A
F_2 (current) to R_1 (optimized)		B
F (current) to F (optimized)		C
IF (current) to IF (capability 1)		D

(b)

Current land use	Optimized Use	Score	Reason and Description
Development	Every use (e.g., range)	-1	Socio-economic conditions
Development	Development	0	No change
Every use	Development	-1 to +1	Based on capability degree of both uses

3. Results and discussion

3.1. Ecological Capability Maps

The final results of validation for different uses are observed in Table 4. The final maps of ecological capability, with the best accuracy and suitability classes for different methods, are observed in Figure 4. The maps include methods of Iranian ecological model and maximum limit by Boolean algebra, MCE, arithmetic and geometric mean, and calibration of geometric mean.

Results (Table 4) generally show that the revised method using the geometric mean (with overall accuracy > 59 and kappa index > 0.39 for all land uses except for the natural resources area with kappa index < 0.2) is better than Boolean and MCE models. Of course, in the results of rainfed agriculture, development and natural resource uses there are not any difference between geometric mean and MCE (WLC) models. Also, the method of the calibrated geometric mean (with overall accuracy > 63 and kappa index > 0.39 for all land uses) is the best among different used models. It should be noted that the arithmetic mean (with overall accuracy 17 to 57% and kappa index < 0.01 for all land uses except for the natural resource area) have the lowest accuracy. In fact, the Boolean method (with overall accuracy 34 to 48 and kappa index = 0.0) is the worst suitable way in natural resources uses. Also, inclass coefficient was found to be the best to estimate suitable classes. These results are in good agreement with study results of Sanaee *et al.* (2010), Jokar and Masoudi (2016) and Asadifard (2016). In relation to natural resource utilizations, it was found that the calibration of geometric mean (with overall accuracy > 78 and kappa index > 0.64) has the best accuracy as compared to the other models like geometric mean evaluation and the difference in the results is almost significant. But between accuracy indices for geometric mean and their calibration in man-made utilizations like irrigated farming, development and etc. are not significant difference.

Table 4. Overall Accuracy, Inclass and Kappa coefficients in the used models.

Land Uses	Index / **Model**	**Boolean**		**Average**			
		Ecological	**Max limit**	**Arithmetic (Simple MCE)**	**MCE (WLC)**	**Geometric**	**Calibrated**
Irrigated farming	Overall Accuracy	37.5	47.1	57.44	57.36	63.44	63.44
	Kappa Coefficient	0.17	0.29	0.02	0.09	0.39	0.39
	Inclass Coefficient	1.1	0.22	1.41	1.82	1.17	1.17
Rainfed farming	Overall Accuracy	74.59	66.4	38.4	78.68	78.37	79.4
	Kappa Coefficient	0.45	0.15	0	0.55	0.54	0.56
	Inclass Coefficient	0.9	0.14	0.62	1.33	1.25	1.3
Rangeland	Overall Accuracy	48.3	46.7	73.65	73.73	73.73	92.5
	Kappa Coefficient	0.05	0.03	0	0.004	0.004	0.79
	Inclass Coefficient	0.1	0.04	2.79	2.8	2.8	9.83
Forest	Overall Accuracy	33.81	41.3	53.71	59.29	59.29	77.6
	Kappa Coefficient	0.02	0.14	0	0.2	0.2	0.64
	Inclass Coefficient	0.05	0.07	1.16	1.34	1.37	3.08
Development[8]	Overall Accuracy	82	88	17	88	88	88
	Kappa Coefficient	0	0.46	0	0.46	0.46	0.46
	Inclass Coefficient	0	0.52	0.2	0.52	0.52	0.52
Ecotourism	Overall Accuracy	54	74	38	73	81	82
	Kappa Coefficient	0.2	0.56	0.09	0.59	0.7	0.72
	Inclass Coefficient	0	0	0.49	0.76	1.14	1.35

[8]Urban and industrial development

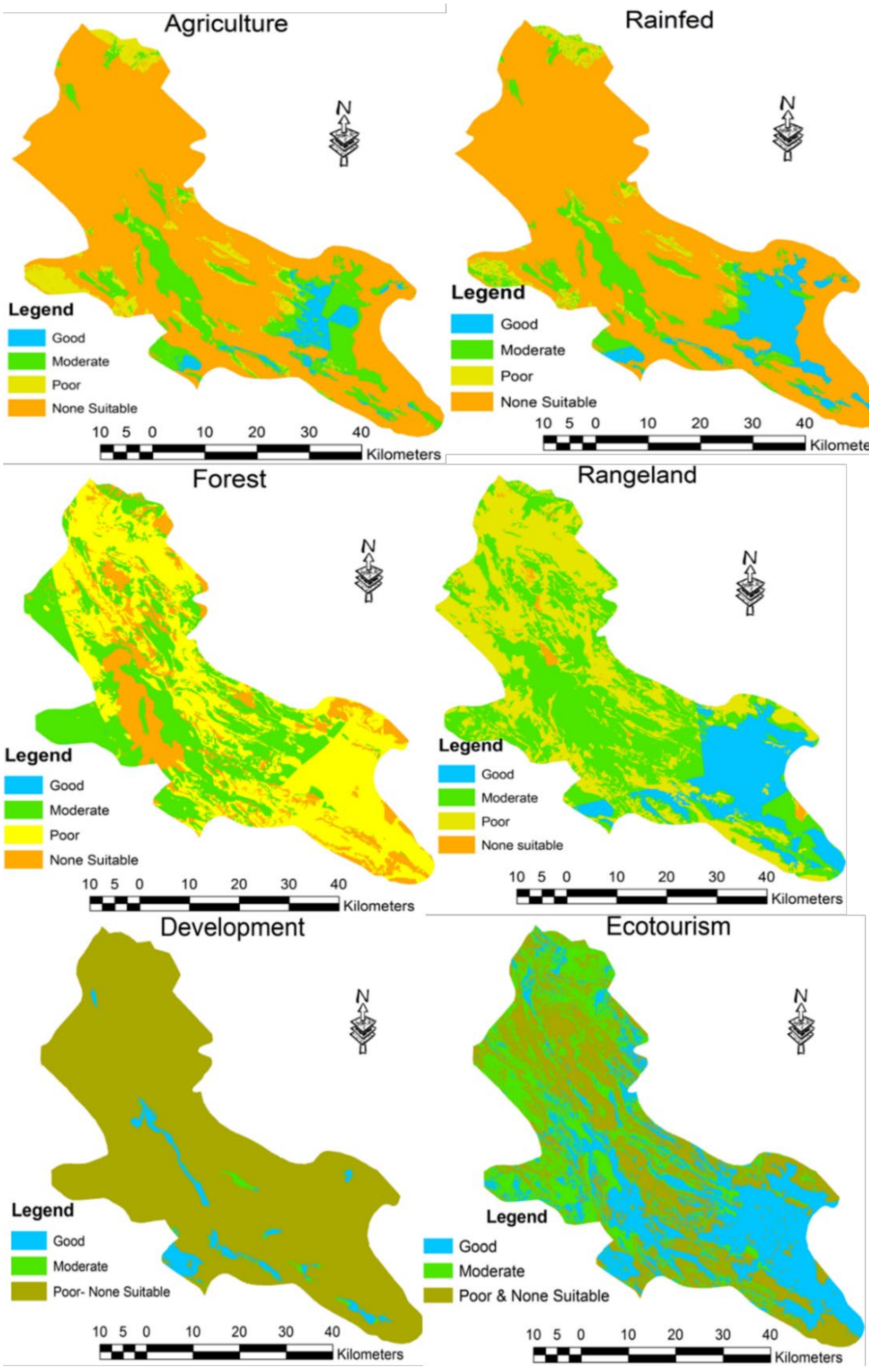

Figure 4. Ecological capability maps prepared with best accuracy.

Additionally, Figure 5 (for example ecotourism use) shows that the study area by the Simple MCE (arithmetic mean) methods tend to fall under good classes; Boolean methods tend to fall under not suitable classes; and the geometric mean and its calibration and WLC methods tend to be placed between the other methods. This indicates that the geometric mean and its calibration can be a useful and flexible model for finding the potential of use. This format of changes in the range of classes in different models for other uses in the region was also observed. These results are in good agreement with results of Elaalem *et al.* (2010), Najafinezhad *et al.* (2013), Jokar (2015) and Asadifard (2016) and are based on the same methods.

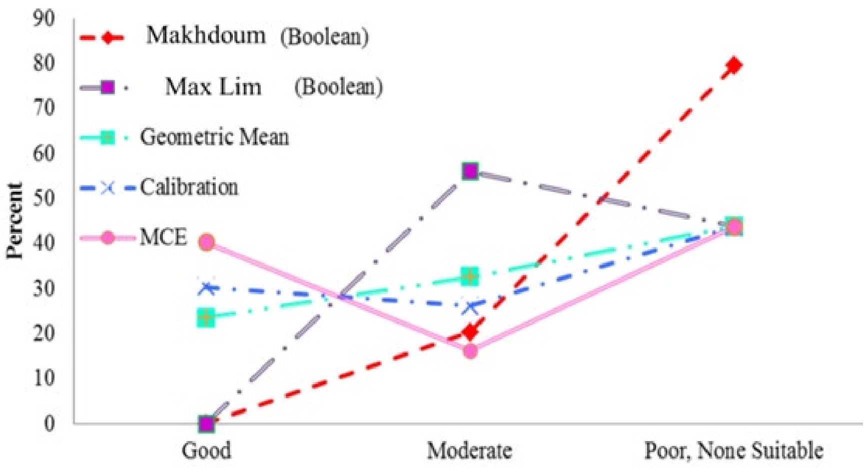

Figure 5. Percent of land under different capability classes for different methods of ecotourism use.

As a whole, AHP is a widely used method in WLC and was introduced by Saaty (Saaty, 1977; Saaty and Vargas, 2001). AHP is based on three principles: decomposition of the overall goal (suitability), comparative judgment of the criteria, and synthesis of the priorities (Baniya, 2008; Nazari Viand *et al.,* 2019). In contrast to above methodologies, this research showed that proposed method is easier than AHP and saves time and cost.

Also, the proposed method using geometric mean and different criteria reduces the high effect of certain criteria like soil with ten indicators as compared to other important criteria with fewer indicators. Therefore, climate and topography with only two indicators have an equal weight as the soil factor. Also, there is a range of ecological conditions that create restrictions in the land such as very severe salinity. By placing the number zero in an equation and multiplying, these regions were not considered to be suitable.

3.2. Land Use Planning Maps

Land use planning methods were applied in every polygon after intersecting ecological capability maps of different land uses with the current land use. Final results of validation for land use planning methods are observed in Table 5. The basic method is based on primary methods: Nakos (1984) and Makhdoum (2006).

Table 5. Validation of land use planning methods.

Model / **Index**	**Basic**		**Modified**		
	Qualitative	Quantitative	Qualitative	Quantitative	
				4 scenarios	2 scenarios
EPM (Average)	0.23	0.01	0.25	0.29	0.31

Results generally show that modified methods (with EPM index for modified qualitative = 0.25, for modified quantitative with 4 scenarios = 0.29 and for modified quantitative with 2 scenarios = 0.31) are better than basic models (with EPM index for basic qualitative = 0.23 and for basic quantitative with 4 scenarios = 0.01) due to reforms; and revised quantitative methods are better than qualitative models due to quantitative calculations, existing scenarios, and modifications. Also, the modified quantitative method with two scenarios (EPM index = 0.31) is the best among the different used models. Actually, the quantitative method with two scenarios is even better than the quantitative method with four scenarios. It shows that the area and ecological scenarios are not suitable for land use planning. These results agree well with Babaee and Ownegh (2006), Jokar (2015), Asadifard (2016) and Masoudi *et al.* (2020). Additionally, it was found that the quantitative method with two scenarios (Figure 6) has more land for future conservation (in accordance to the mentioned regions). In other words, the existing scenarios of area and ecology led to the use of conservation being seen as less than range or forest (Masoudi and Jokar, 2015). The areas defined in Figure 6 represent future conservation. On the whole, Figure 6 and Table 5 show that 31% of the study area will be improved by the two scenarios method, using socio-economic and ecological information.

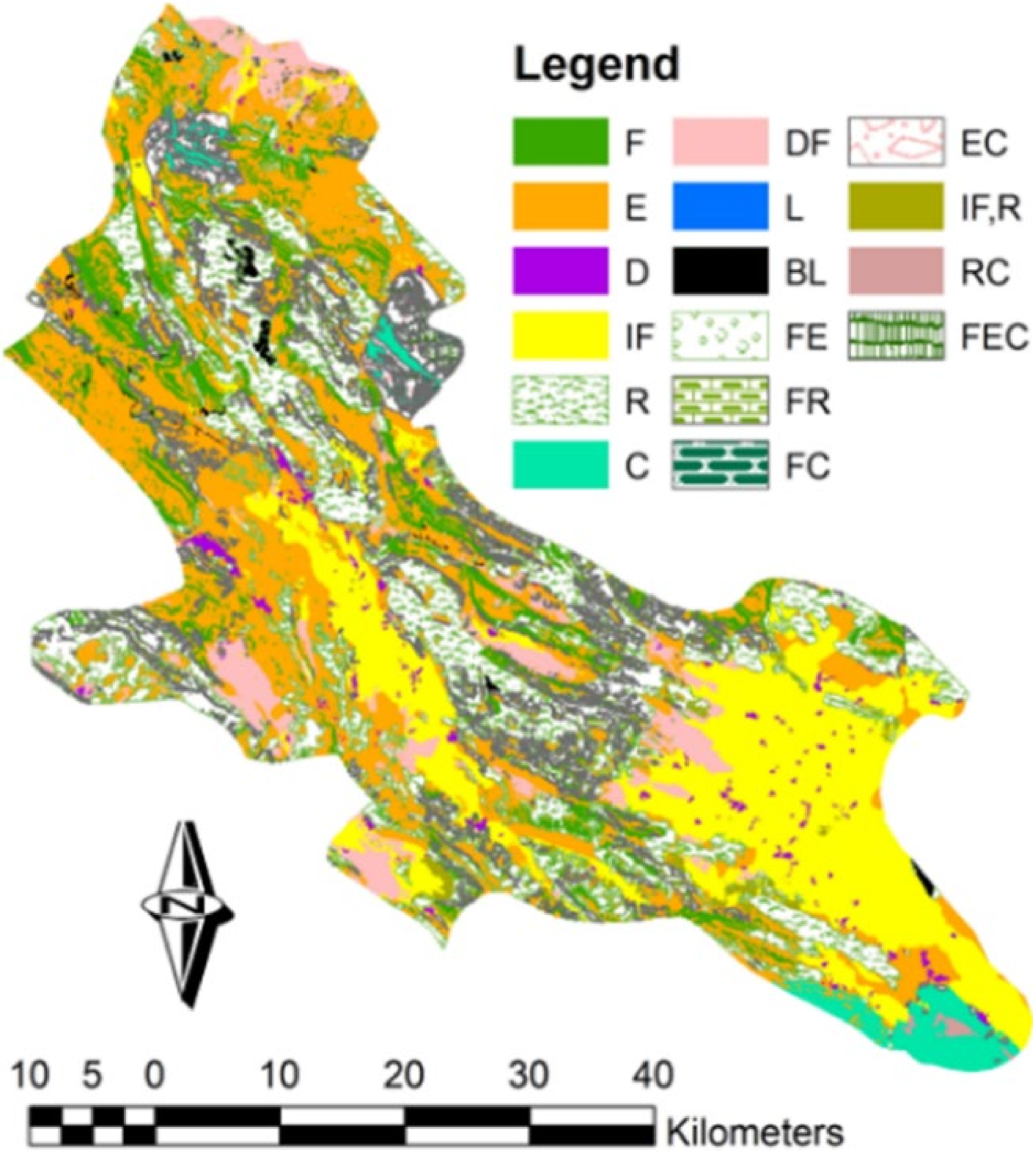

Figure 6. Final map of land use planning by two scenarios. [Note: Proposed land use: F (Forest), E (Ecotourism), R (Rangeland), IF (Irrigated Farming), DF (Dry Farming), D (Settlement & Development), E (Ecotourism), C (Conservation), BL (Bare Land), L (Lake and water body)].

The total results obtained in Table 6 are as follows:

1. To keep most forest lands and rangelands (especially R1, R2, and most of R_3) in the optimized land use map.
2. To keep most irrigated lands in the optimized land use map.
3. To increase conservation lands in optimized land use as compared to current land use.
4. To increase development, use due to socio-economic issues, taking into consideration environmental conservation and EIA (Environmental impact assessment).
5. To convert few parts of deserts to natural resources in optimized land use.
6. To perform ecotourism in some forest lands.

Table 6. Percent are of current and optimized land uses.

Land use	Current land use (%)	Optimized land use
Forest	35.47	9.28 (F)
		0.25 (FC)
		0.56 (FEC)
		5.79 (FR)
		5.41 (FE)
Rangeland	24.12	16.04 (R)
		0.15 (RC)
Irrigated farming	27.41	20.35
Ecotourism	-	30.43
Rainfed farming	10.84	5.61
Development	1.12	1.22
Desert	0.68	0.52
Conservation	-	2.79 (C)
		1.48 (EC)
Sum	100	100

4. Conclusion

In this paper, different evaluation methods such as the Boolean and average were investigated. Results showed that the suitability of every use and the selection of suitable evaluation methods could be estimated by current land use. Since current land use is an important parameter, the socio-economic conditions in a region were stated (Di Gregorio and Jansen, 1998).

The modified classification of parameters has helped to increase the accuracy of the new model in land use planning. This indicates that in each specific area, a special classification appropriate to the conditions of the area is required. The geometric mean method has also improved the accuracy of the models, which shows this method has higher flexibility and accuracy. Another important advantage of this method is the simplicity of implementation compared to other methods.

In this paper, it was found that the quantitative method with two scenarios (social and economic) is the best method for land use planning. It should be noted that the proposed method considers ecological as well as socio-economic issues. Of course, if socio-economic information is not available, we can use the revised qualitative method.

We conclude that land management study based on geo-mean, its calibration and validation methods, and modification methods of land use planning (especially quantitative method with two scenarios) are suggested to managers. Also, we denominate this kind of ecological capability evaluation and land use planning for different land uses with a proposed model of EMOLUP (Eco-Socioeconomic Model of Land Use Planning) to the scientific societies.

Acknowledgements

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Data Availability Statement

The datasets used and/or analyzed during the current study are available from the first author on reasonable request.

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Anex 1. The indicators used in the model of land evaluation for agriculture and natural resources or four classes' models (a) and for Development and Ecotourism or three classes' models (b) and Conservation Use (c).

(a)

Criteria	**Parameter**	**Irrigated Farming**	**Rainfed Farming**	**Forest**	**Rangeland**	**Class**
Topography	Slope (%)	0-8[1]	0-5	0-35	0-15	1
		8-15	5-15	35-55	15-25	2
		15-30	15-25	55-65	25-40	3
		>30	>25	>65	>40 (in mountains)	4
	Elevation (m) or Land type	Plain	Plain	0-1000	-	1
		-	-	1000-1800		2
		Hill	Hill	1800-2600		3
		Mountain	Mountain	>2600		4
Climate	Drought	Slight	Slight	-	Slight	1
		Moderate	Moderate		Moderate	2
		Severe & very severe	Severe & very severe		Severe & very severe	3
		-	-		-	4
	Rain (mm)	-	>400	>800	>400	1
			200-400	500-800	200-400	2
			50-200	200-500	50-200	3
			<50	<200	<50	4
	Temperature (°c)	-	-	18 - 21	-	1
				<18, 21.1-30		2
				>30		3
				-		4
	Current state of climate	Semi-arid to Humid	-	-	-	1
		Arid				2
		Very arid				3
		-				4
Soil	Texture	Heavy, moderate, light	Heavy, moderate, light	Heavy, moderate, light	Heavy, moderate, light	1
		Coarse	Coarse	Coarse, very coarse	Coarse	2
		Very coarse	Very coarse	-	Very coarse	3
		-	-	-	-	4
	Depth (cm)	Deep (>80)	Deep (>80)	Deep (>80)	Semi deep to deep (>50)	1
		Semi deep (50-80)	Semi deep (50-80)	Semi deep (50-80)	Shallow (25-50)	2
		Shallow (25-50)	Shallow (25-50)	Shallow to very shallow (<50)	Very shallow (<25)	3
		Very shallow to no soil (0-25)	Very shallow to no soil (0-25)	No soil (0)	No soil (0)	4
	pH	6.1-8.5	≤ 8.5	4.2-7	≤ 9	1
		4.2-6,8.5-9	8.5-9	7.1-8.5	-	2
		9-9.5	9-9.5	8.6-10	>9	3
		>9.5	>9.5	>10	-	4
	Gravel percent	0-35	0-35	≥15	0-35	1
		35-75	35-75	16-50	35-75	2
		>75	-	>51	>75	3
		-	>75	-	-	4

	Drainage (cm/hr)	Good to moderate (0.1-25)	Good to moderate (0.1-25)	Good to moderate (0.1-25)	Good to moderate (0.1-25)	1
		Poor (<0.1, >25)	Poor (<0.1, >25)	Poor (<0.1, >25	Poor (<0.1, >25)	2
		-	-	-	-	3
		-	-	-	-	4
	Erosion	None, slight	None, slight	None, slight	None, slight	1
		Moderate	Moderate	Moderate	Moderate	2
		Severe	Severe	Severe, very severe	Severe, very severe	3
		Very severe	Very severe	-	-	4
	Granulating	Fine to Moderate	Fine to Moderate	Fine	Fine to Moderate	1
		Coarse	Coarse	Moderate	Coarse	2
		-	-	Coarse	-	3
		-	-	-	-	4
	Evolution (Structure)	Perfect (granular)	-	Perfect (granular)	-	1
		Moderate		Moderate		2
		Low		Low		3
		None (no structure)		None (no structure)		4
	Salinity (EC in ds/m)	<8	<8	-	<8	1
		8-16	8-16		8-18	2
		16-32	16-32		18<	3
		>32	>32		-	4
	ESP	<15	<15	-	<15	1
		15-30	15-30		15-30	2
		30-50	30-50		>30	3
		>50	>50		-	4
	Fertility (organic matter %)	Good (>1.5)	Good to Moderate (>1)	Good (>1.5)	Good to Moderate (>1)	1
		Moderate (1-1.5)	Low (1)	Moderate (1-1.5)	Low (1)	2
		Low to Very Low (<1)	Very Low (<1)	Low (1)	Very Low (<1)	3
		-	-	Very Low (<1)	-	4
Geology	Geology	-	-	Limestone and Dolomite, Intermediate pyroclastic rocks of Eocene, Shale, Clay Stone, Conglomerate and marl type 1, Ophiolite of melange color, floodplain	-	1
				Granite, sandstone, loess, schist and gneiss and amphibolite		2
				marl Type 2, alluvial fans, alluvial terraces, sand dunes, continental shelf sediments		3

				Salt domes, gypsum dome, calcite and dolomite marble, quartzite		4
Vegetation	Canopy Cover (%)	-	-	75-100	≥50	1
				25-74	25-50	2
				<25	5-25	3
				-	<5	4
	Wood Value[2]	-	-	Wood with grade1	-	1
				Wood with grade 2		2
				Wood with grade 3		3
				None Commercial		4
	Vegetation Type	-	-	Forest lands	-	1
				-		2
				Rangelands		3
				Poor Rangelands (canopy cover <25%), Desert		4
	Annual Growth (m^3)[3]	-	-	>5	-	1
				2.1-5		2
				<2		3
				-		4
	Dry Forage (kg/ha)	-	-	-	>500	1
					350-500	2
					<350	3
					-	4
Water	Quantity of water (m^3/year)	>3000[4]	-	-	-	1
		1500-3000				2
		<1500				3
		Without water resources				4
	Lowering of water table(cm/y)	0-20	-	-	-	1
		20-30				2
		>30				3
		-				4
	EC(µmhos/cm)	0-750	-	-	-	1
		750-2250				2
		>2250				3
		-				4
	SAR	0-18	-	-	-	1
		18-26				2
		>26				3
		-				4

(b)

Criteria	**Parameter**	**Development**	**Ecotourism**	**Class[5]**
Topography	Slope (%)	0-15	0-15	1
		15-30	15-30	2
		>30	>30	3
	Land type	Plains except of flood plains	-	1
		Plateau & upper terraces, alluvial- colluvial fans		2
		Mountains, Hills, Flood Plains		3

Climate	Rain (mm)	501-800	-	1
		51-500, >800		2
		<50		3
	Temperature[6] (°c)	18.1-24	21-24	1
		24.1-30, <18	18-21, 24-30	2
		>30	>30, <18	3
	Number of sunny days (in spring & summer months)	-	>15	1
			7-15	2
			<7	3
	Relative humid (%)	40.1-70	-	1
		<40, 70-80		2
		>80		3
	Wind speed(km/h)	1-35	-	1
		36-60		2
		>60		3
Soil	Texture	Moderate (often)	Usually moderate	1
		light(often)	Coarse, light, heavy	2
		Heavy(often), Regosols, Lithosols	Very heavy	3
	Depth	Deep	Deep	1
		Semi deep	Semi deep	2
		Shallow to very shallow	Shallow to very shallow	3
	Gravel percent	0-25	-	1
		26-50		2
		>50		3
	Drainage (cm/hr)	Good (2-6)	Good (2-6)	1
		Moderate (0.1-2, 6-25)	moderate to poor (0.1-2, 6-25)	2
		Poor (<0.1, >25)	Incomplete (<0.1, >25)	3
	Erosion	None, slight	-	1
		Moderate		2
		Severe, very severe		3
	Granulating	Moderate	-	1
		Fine, coarse		2
		Very fine		3
	Evolution (Structure)	Perfect (granular)	Perfect (granular)	1
		Moderate	Moderate	2
		Low	Low	3
	Fertility (Organic matter %)	-	Good, moderate (>1)	1
			Low (1)	2
			Very low (<1)	3
Geology	Lithology	Sandstone, Ophiolite of melange color, sediments of continental shelf	pyroclastic rocks, Granite Ophiolite of melange color, sand dunes, continental shelf sediments	1
		Limestone and Dolomite, Intermediate pyroclastic rocks of Eocene, Granite, alluvial fans, Shale, Clay Stone, Conglomerate, loess, alluvial terraces	Limestone and Dolomite, sandstone, loess, schist and gneiss and amphibolite, quartzite, alluvial fans, flood plain	2
		marl, schist and gneiss and amphibolite, sand dunes, Salt domes, Gypsum dome, calcite and dolomite marble, quartzite, floodplain, Buffer[7] (Fault, River)	marl, Shale, Clay Stone, Conglomerate, Salt domes, gypsum dome, calcite and dolomite marble	3

Vegetation	Canopy Cover (%)	0-25	Forest lands with canopy cover of 50-80 %	1
		26-50	Forest lands with canopy cover of 5-50%	2
		>50	Poor Rangelands, Forest lands with canopy cover>80%, Desert	3
Water	Quantity of water for everyone (Lit/day)	>225	>40	1
		150-225	12-39.9	2
		<150	<12	3
Conservation	Protected area	-	Forest park of Natural and planted, Nature Park, National Park, Protected Area, Biosphere Reserve, World Heritage, Historical artefacts and national and pilgrimage	1
			-	2
			Reserve forest, Wildlife Sanctuary, National natural monuments	3

(c)

Parameter		**Class**
Value of Species (Mammals)	Cheetah, Zebra, Fallow deer, Ibex, Chamois, Panther, gazelle, Chinkara, Wild goat, Ovis, Wolf, Sable, Wild Cats, Bear	Suitable
	Fox, Badger, Hyena, Weasel, Pig, Porcupine, Squirrel, Jackal, Pika, Hedgehog, Bat, Rabbit, Rodents	None Suitable
Species Biodiversity	≥5	Suitable
	<5	None Suitable
Sensitive Habitats	Mangroves, estuaries, ponds	Suitable
	Other	None Suitable
Protected Area	Reserve forest, Forest Park of Natural and planted, National Park, Nature Park, Protected Area, Biosphere Reserve, Wildlife refuges, National natural monuments	Suitable
	Other	None Suitable

[1] This slope classification is assigned for horticulture and Class 1: 0-5, Class 2: 5-8, Class 3: 8-15 and Class 4: >15 is assigned for Irrigated cultivation.
[2] It is evaluated for only Commercial Forestry suitability
[3]It is evaluated for only Commercial Forestry suitability
[4]This classification is assigned for horticulture and Class 1: >4000, Class 2: 1500-4000, Class 3: <1500 and class 4: Without water resources is assigned for Irrigated cultivation
[5]Poor & not suitable situation for third class
[6]For ecotourism in spring & summer seasons
[7]Major Fault= 1km, Minor Fault =300m; River= 1km (Gharakhlou *et al.,* 2008, based on guidelines of Department of Energy and Department of Housing and Urban Development in Iran)