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Development of a Quantitative Model in Land Use Planning Using GIS – A Case Study of Zarrin Dasht County, Iran

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Abstract. Land evaluation methods are crucial for evaluating the potentials and constraints of land for intended land use. In the procedure, environmental criteria such as topography, soil, climate, hydrology, and socioeconomic parameters are evaluated. Different technical procedures are also used for land evaluation ranging from simple methods based on expert knowledge to more complex methods based on simulation models. The main goal of this research is to evaluate land use and natural resources for future sustainable land planning using Geographic Information System (GIS). So, in this study, the Iranian ecological evaluation model was used for the analysis of the ecological and resources maps of the study area. First, ecological capability maps of different land uses such as forestry, agriculture, range management, environmental conservation, ecotourism, and development of villages, urban and industrial areas were developed by overlaying geographical maps based on Boolean overlay method (as a Multi-Criteria Evaluation Method) in GIS for the Township. The final step of this research was the prioritization of land uses considering the ecological and socio-economic characteristics (by distributing questionnaires to 63 experts) of the study area using a quantitative model. The results showed that the maximum area of proposed uses is 78.31%, which is related to rainfed agriculture, showing this land use has high potential and socio-economic demands in the study area. Meanwhile, minimum area of proposed uses is related to forest and ecotourism. One of the most important practical results of this study is that different or even modified methods should always be used in the same region to check the capability of land and the common method will not always be as best method.

Key words: Boolean Theory, Land-use planning, Modified Model, GIS, Zarrin Dasht County

1 Introduction

From the earliest times, people have performed land suitability assessments. They learnt by experience how to estimate what land will produce and how it must be managed. Land evaluation is the process of assessing the suitability of land for a specified kind of land use (van Lier 1998, Jozi 2010, Sarvazad et al. 2015, Masoudi, Zare 2019). Possibilities for land use types such as high-input arable farming, extensive grazing by dairy cattle combined with nature conservation or timber production in short-rotation forestry can be explored. The principal purpose of land evaluation is to predict the potentials and constraints of land for changing use. This may involve the introduction of a fully new land use type or the introduction of a new management practice, such as minimum soil tillage instead of conventional tillage (Dent, Young 1981, Mokarram, Zarei 2021).

Land evaluation deals with two major aspects of land, physical resources, and socio-economic resources. The physical resources include soil, topography, hydrology, and climate, whereas the socio-economic resources comprise, for instance, availability of labour, capital, size and configuration of land holdings, land ownership, and infrastructure (Alavi Panah et al. 2001, Jokar, Masoudi 2016, Yohannes, Soromessa 2018, Masoudi et al. 2020). The physical resources are relatively stable. On the other hand, the socio-economic resources are more time-dependent because they are affected by the social, economic, and political settings. The distinctly different nature of both resources has resulted in a procedure with separate evaluations, i.e., physical evaluation and economic evaluation, which may be processed subsequently or in parallel in an integral land evaluation approach (Dent, Young 1981, Masoudi, Jokar 2015, Asadifard et al. 2019, Jahantigh et al. 2019). Physical land evaluation aims to assess land qualities or the suitability of a specific land use type, as conditioned by biophysical parameters. Different technical procedures can be used for physical land evaluation (Lahmian 2016). These procedures range from expert knowledge based on farmers' experience to process-oriented simulation models based on generally applicable physical and biological laws, which are derived from extensive laboratory and field experiments (Pan et al. 2021).

In ecological evaluation, GIS is quickly becoming data management standard in planning the use of land and natural resources (Makhdoom 2001, Prato 2007, Makhdoom et al. 2009, Abu Hammad, Tumeizi 2010, Marani Barzani, Khairulmaini 2013, Jafari, Bakhshandehmehr 2013). Virtually all environmental issues involve map–based data, and real-world problems typically extend over relatively large areas (Nouri, Sharifipour 2004, Zakerinejad, Masoudi 2019). GIS is used for geography patterns (Pauleit, Duhme 2000, Bojórquez-Tapia et al. 2001, Biswas, Baran 2005, Peel, Lloyd 2007). Also, GIS is an indispensable tool for land and resource managers (Swanson 2003, Gandasasmita, Sakamoto 2007, Oyinloye, Kufoniyi 2013, Ayalew 2015). In GIS-based methods like Multi Criteria Evaluation (MCE), quantitative criteria are evaluated as fully continuous variables rather than collapsing them to Boolean constraints (e.g., Weighted Linear Combination [WLC], Ordered Weighted Averaging [OWA]) (Malczewski 2004, Fallahshamsi 2004, Sanaee et al. 2010, Kumar, Biswas 2013, Oyinloye, Kufoniyi 2013, Pourkhabbaz et al. 2014). In the WLC method, maps are combined based on linear weighting. In this method, areas can be classified according to varying degrees of suitability. The OWA is extension and generalization of the WLC. This method is a weighted sum with ordered evaluation criteria (Sanaee et al. 2010, Kumar, Biswas 2013, Pourkhabbaz et al. 2014, Jokar et al. 2021).

Current land use planning in Iran by Iranian evaluation quantitative model has some problems like difficulties in assessment of ecological and socio-economic information used in related scenarios. Also, it is possible because of the sum of scores derived from different scenarios; a model may prioritize land use without ecological capability or recommended changing urban land cover to a pasture. Therefore, the main goal of this study is to solve these problems and develop and modify the current quantitative method of the Iranian ecological model (Makhdoom 2001) to evaluate better land use planning in Iran. Our research will help to achieve the Sustainable Development Goals of the United Nations and the Land Degradation Neutrality challenges due to the proper soil and water management we propose (Keesstra et al. 2018, 2021).

2 Material and Methods

Zarrin Dasht County with an area of 4,626 km^2 is located in the Fars province and Southern parts of Iran (Figure 1). Zarrin Dasht city is located at geographical longitude 54°25′E and geographical latitudes 28°12′N. This area is located in the mountainous area of Zagros and has an arid and semi-arid climate.

The data in this paper are included in two types 1) numerical and descriptive data

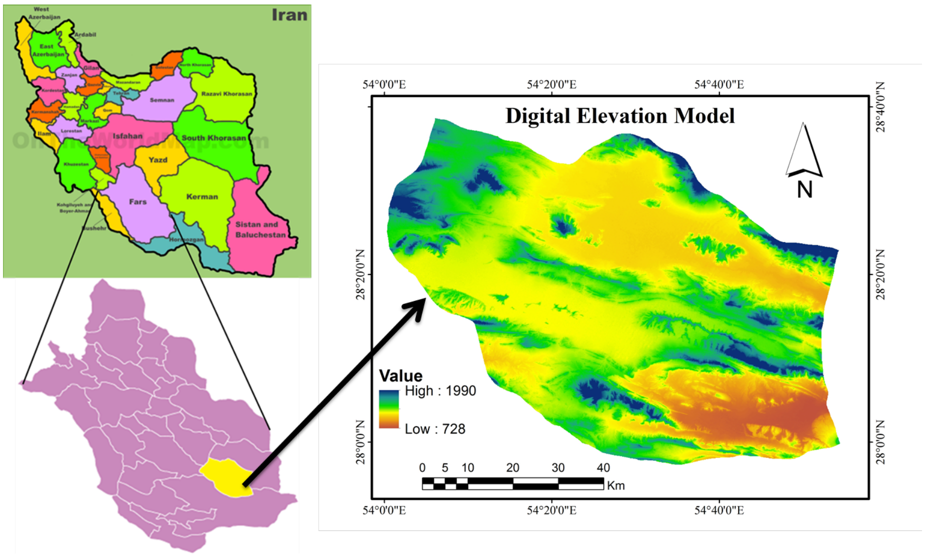

Figure 1: Position of Zarrin Dasht in Fars Province and Iran

and 2) thematic maps, but mainly in the map format (vector) with mostly semi-detailed scale (1:50000 scale) for the GIS analysis. All such relevant data (Table 1) were obtained from the local and main offices and institutes of the Ministries of Agriculture and Energy and the Meteorological Organization of Iran. Also, some soil samples and field data were gathered during field work to check and improve the maps and reports used, wherever needed. The different kinds of maps used in this research to determine the ecological resources of the area under study were Digital Elevation Model (DEM), slope and aspect, soil data, erosion, geology, iso-precipitation (iso-hyetal), iso-thermal, iso-evaporation, climate, canopy percentage and type, in addition to water resources data.

This research was done based on two main parts:

1. Ecological capability evaluation for different uses, and
2. Prioritizing the different land uses.

For ecological capability evaluation for different uses (step I), a systematic method known as the Iranian ecological evaluation model based on Boolean model (FAO 1976, Burrough et al. 1992, Davidson et al. 1994, Makhdoom 2001, Baja et al. 2002, Amiri et al. 2010) was used for the analysis of maps in relation to the ecological and socio-economic resources of the study area. The Boolean model (as an MCE Method) is an overlay method which combines parameters based on AND (intersection) and OR (union) operators in GIS.

Different ecological capability models of the Iranian ecological evaluation model based on ecological data were used to evaluate ecological capability of different land uses including forestry, agriculture, range management, environmental conservation, ecotourism, and the development of village, urban, and industry (Makhdoom 2001). We can classify an area based on these models to different capability classes. Ecological capability classes for forestry, agriculture, range management, environmental conservation, ecotourism, and the development of village, urban, and industry are 7, 7, 4, 3, 3 and 3, respectively. The best capability class in each model is class 1 and the worst capability class is the biggest number in the classification of models. The good and moderate classes of the different models were shown in Table 1.

In order to identify the effective criteria for every use in the study area, they were based on a literature review and previous studies (Makhdoom 2001, Fallahshamsi 2004, Makhdoom et al. 2009).

It should be noted that in Table 1, good and moderate classes are listed based on influence on every use. Also, poor and not suitable classes have been excluded due to their unimportant role in classification.

Table 1: Moderate and good classes of different indicators for every use (Masoudi 2018)

A) Indicators related to topography and soil criteria

Indicators	Class	Forestry (classes 1-4)	Agriculture & range management (classes 1-4)	Ecotourism (intensive) (classes 1-2)	Development (classes 1-2)
Elevation(m)	Good	0-1000	-	-	400-1200
	Good to moderate	0-1000	-	-	0-400, 1200-1800
	Moderate	0-1400	-	-	-
	Mostly moderate	400-1800	-	-	-
Slope (%)	Good	0-25	0-5	0-5	0-12
	Good to moderate	0-35	5-8	5-15	12-20
	Moderate	0-45	-	-	-
	Mostly moderate	0-55	8-15	-	-
Soil Texture & Type	Good	brown soil and forest semi humid to loam clay texture	Clay, loam clay, humus	usually moderate	moderate(often)
	Good to moderate	brown soil and forest semi humid to loam clay texture	Clay, loam clay, humus clay, sandy loam clay, sandy clay loam, clay loam, loam	Coarse, light, heavy	light(often)
	Moderate	brown soil to clay loam texture	clay loam, loam sand, loam clay sand, clay loam sandy, sand	-	-

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Indicators	Class	Forestry (classes 1-4)	Agriculture & range management (classes 1-4)	Ecotourism (intensive) (classes 1-2)	Development (classes 1-2)
	Mostly moderate	brown rendezina to clay loam texture, regosols brown soil, litosols to sand loam texture	Clay, loam clay, clay loam, loam	-	-
Drainage	Good	Moderate to perfect	perfect	Good	Good
	Good to moderate	Moderate to good	good	moderate to poor	moderate
	Moderate	Rather incomplete to good	Moderate to incomplete	-	-
	Mostly moderate	Rather incomplete to Moderate	-	-	-
Depth	Good	Deep	Deep	Deep	Deep
	Good to moderate	Deep	Moderate to good	Semi deep	Semi deep
	Moderate	Moderate to good	Low to Moderate	-	-
	Mostly moderate	Moderate to good	-	-	-
Structure	Good	Granulating fine to moderate, a bit Gravel, Evoluted	Granulating fine to moderate, none Gravel, Evoluted, low erosion	Perfect evolution	Slight erosion to Granulating Moderate and Perfect evolution
	Good to moderate	Granulating fine to moderate, by Gravel, Evoluted	Granulating fine to moderate, none Gravel, Evoluted, low to moderate erosion	moderate evolution	moderate erosion to Granulating Fine, Coarse and moderate evolution

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Indicators	Class	Forestry (classes 1-4)	Agriculture & range management (classes 1-4)	Ecotourism (intensive) (classes 1-2)	Development (classes 1-2)
	Moderate	Granulating fine to moderate, by Gravel, Evoluted	Granulating moderate to coarse, by Gravel, moderate Evolution, moderate erosion		
	Mostly moderate	Granulating fine to moderate, by Rubble, low to moderate Evolution	-	-	-
Fertility	Good Good to Moderate Moderate Mostly moderate	perfect Good Moderate to good Low to Moderate	perfect Good Moderate -	Good, Moderate Low - -	Good, Moderate - -

B) Indicators related to climate, vegetation, and water criteria

Indicators	Class	Forestry (classes 1-4)	Agriculture & range management (classes 1-4)	Ecotourism (intensive) (classes 1-2)	Development (classes 1-2)
Climate and Precipitation (mm)	Good	>800	Warm & moderate (Mediterranean to humid)	-	501-800
	Good to Moderate	>800	Warm & moderate & cold (Semi-arid to humid)		51-500, >800

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Indicators	Class	Forestry (classes 1-4)	Agriculture & range management (classes 1-4)	Ecotourism (intensive) (classes 1-2)	Development (classes 1-2)
	Moderate	>500	Warm & moderate & cold & very cold) Arid to humid		-
	Mostly moderate	>500	-		-
Temperature (∘C)	Good	18-21	-	21-24[1]	18.1-24
	Good to Moderate	18-21		18-21, 24-30	24.1-30, <18
	Moderate	<18, 18-30		-	-
	Mostly moderate	<18, 18-30		-	-
Sunny days[2]	Good to Moderate	-	-	>15	-
	Moderate			7-15	
Relative humid (%)	Good to moderate	-	-	-	40.1-70
	Moderate				<40, 70-80
Canopy Cover (%)	Good	>80	-	Forest lands (with canopy cover of >50%)	0-25
	Good to moderate	60-80		Forest lands (with canopy cover of 5-50%)	26-50
	Moderate	50-70		-	-
	Mostly moderate	40-60		-	-

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[1] in spring & summer seasons
[2] in spring & summer seasons

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Indicators	Class	Forestry (classes 1-4)	Agriculture & range management (classes 1-4)	Ecotourism (intensive) (classes 1-2)	Development (classes 1-2)
Annual Growth (m^3)	Good	>6	-	-	-
	Good to Moderate	>6			
	Moderate	>5			
	Mostly moderate	>4			
Quantity of water for everyone (Lit/day)	Good	-	6000-10000[3]	>40	<225
	Good to Moderate		4000-6000	12-39.9	150-225
	Moderate		3000-5000	-	-
	Mostly moderate		To 3000	-	-

[3] in m^3/ha

Table 2: The questionnaire sample distributed among experts

		LAND USE						
		Development	Ecotourism	Conservation	Rainfed farming	Rangeland	Forest	Irrigated farming
SCENARIO	Scenario b							
	Scenario c							
	Scenario d							

In the next step, after producing ecological capability maps, the land use map was prepared. To prioritize the different land uses (step II), the model consists of four scenarios in each land unit including: a) present land utilization of the study area, b) economic needs of the study area, c) social needs of the study area and d) ecological needs of the study area. The first scenario to make its ranking was evaluated using current land use. But for the other scenarios (b, c, and d) a questionnaire was prepared to ask experts of the study area to rank different land uses for each scenario based on their knowledge and experience from the study area. Questionnaire filling is a good method especially for finding socio-economic needs of an area that depend on many things like: socio-political characteristics, population composition, relative earning conditions, immigration condition, present land utilization, agriculture and animal husbandry conditions, hygiene, health, education, and other public services. The above socio-economic information helped the experts to rank the utilizations in economic and social scenarios (Fallahshamsi 2004, Hamzeh et al. 2014). The questionnaire sample distributed among experts is shown in Table 2.

It should be noted that 70 experts were identified from related organizations for different land uses (e.g., urban, agricultural offices, etc.) and based accessibility to them. The questionnaire was sent to 70 experts and 63 responses were received and used in the analysis. The average of the results helped us to rank different land uses for each scenario.

So, all land uses are ranked for each scenario and then scored from 10 to lower based on their ranks and ecological capability (the lowest score is 4). For example, if in one scenario, rank of forestry is third place and its ecological capability is class two in a land unit; its score in first step is given 8 and then one score is lowered for its capability reduction (class two) that makes its score number 7 for forestry in the land unit. It should say that this one-point reduction for forestry in three other scenarios is repeated because of one place of reduction compared to first class of ecological capability. If ecological capability class is class three, the reduction in each scenario would be two.

To achieve a systematic analytical model, all maps' layers are in vector format in the ArcGIS software environment. These maps were operated using ArcGIS 9.3 and the appropriate utilization of each land unit was determined and prioritized. The appropriate utilizations are those that have higher sum of scores among used scenarios. Many of the units were seen fit fortwo appropriate uses. Hence, selection for the best utilization of the area is based on socio-economic status of the area and consistency of land uses and current land use, too.

The important modifications in this paper are explained below:

Land capability evaluation: In the process of work, environmental units were not prepared (such as the Iranian ecological evaluation model). In this research, current method of systemic analysis for preparation of environmental units was not utilized for assessing the ecological capability maps and land use planning of quantitative model. It may be used only for assessing the small areas with low diversity (e.g., small watershed). Hence, for assessing the larger areas (e.g., large watersheds, counties, and provinces), preparation of environmental units eliminates a lot of information used in the ecological capability models. So, in the present study all indicator maps related to different ecological capability models were overlaid in GIS.

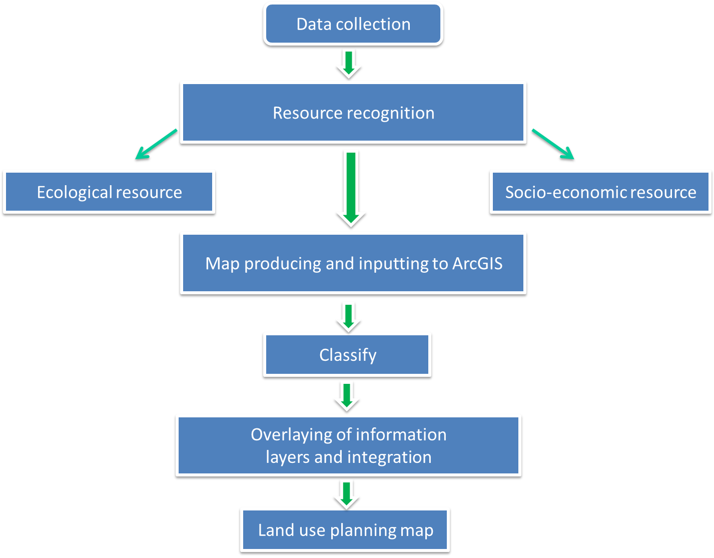


Figure 2: Process of evaluation

Land use prioritizing: Other modifications in the process of work done for assessing the land use planning model included:

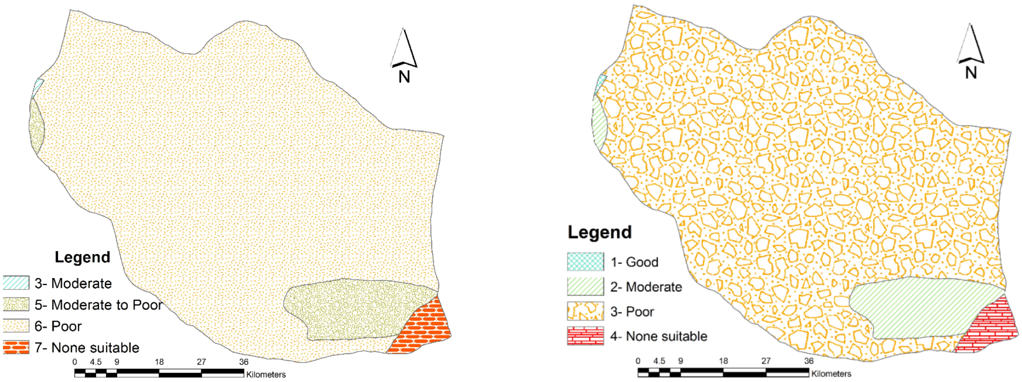
1. Prioritization of each use was based on the highest score derived after summing the scenarios' scores (ecological, economic, social, and area) (Makhdoom 2001). Also, it was considered suitable capability for the use with highest score, for example if in a land unit development has highest score among other land uses but its capability class is unsuitable we don't select it as priority in the land use planning process (this point does not appear in Iranian ecological evaluation method).
2. Using current land-use map in assessment mainly due to the socio-economic compulsions of the population especially in rural area. Also, we hold the following land utilizations in the end of land-use planning process:
   (a) Irrigated lands with suitable capability.
   (b) Settlement lands (urban, rural, and industrial area).
   (c) The Forest lands with canopy cover of more than 25% and those with conservational role.
   (d) Lake and river bed.

Finally, land use planning maps of the Zarrin Dasht County were developed considering the ecological and socio-economic characteristics of the area. Process for evaluation included the following steps presented in Figure 2.

3 Results and Discussion

In this study for each model the related indicators were overlaid. Then land capability maps were accessed. The capability maps are shown in Figures 3 to 5 and percent of area for different ecological capabilities of land uses is observed in Table 3.

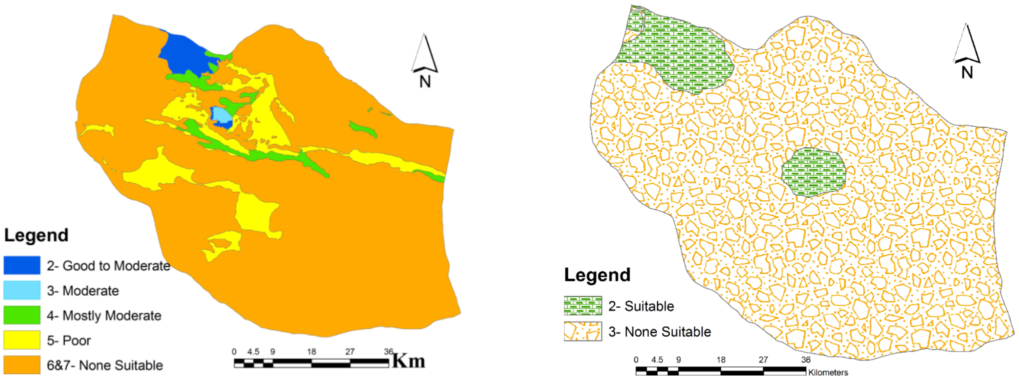
Table 3 shows percent of area for different ecological capability classes of land uses. For agriculture use, minimum and maximum areas are related to class 3 (0.16%) and class 6 (91%) respectively. For Range management & dry farming uses, minimum and maximum areas are related to class 1 (0.09%) and class 3 (90.61%) respectively. For forest use, minimum and maximum areas are related to class 3 (0.45%) and class 7 (58%) respectively. For Conservation use, minimum and maximum areas are related to class 2 (8%) and class 3 (92%) respectively. For ecotourism use, the whole area is in class 3. For



(a) Land capability classification map for irrigation agriculture

(b) Land capability classification map for range management and dry farming

Figure 3: Land capability classification maps



(a) Land capability classification map for forest

(b) Land capability classification map for environmental conservation

Figure 4: Land capability classification maps

development use, minimum and maximum areas are related to class 2 (10.53%) and class 3 (89.47%) respectively.

Also, results of uses ranking are seen below:

Area scenario: Irrigated farming > Range > Rainfed farming > Development > Forest > Ecotourism > Conservation.

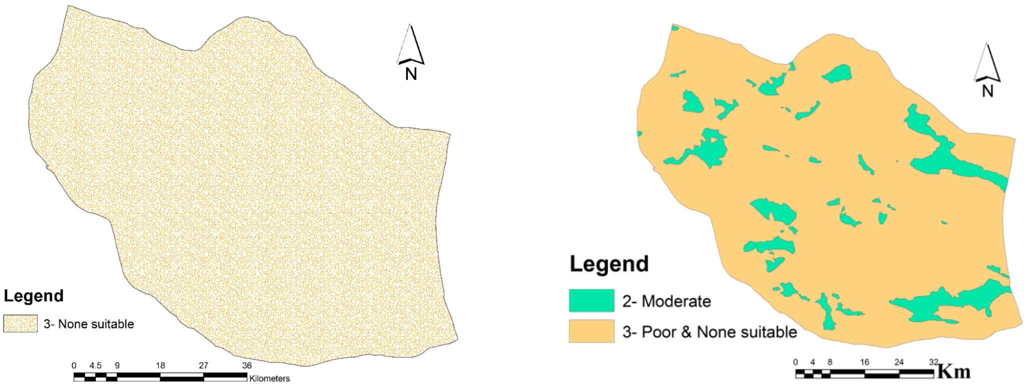
Ecological scenario: Conservation > Irrigated farming > Rainfed farming > Development > Range > Ecotourism > Forest.

Economic scenario: Development > Irrigated farming > Rainfed farming > Conservation > Range > Ecotourism > Forest.

Social scenario: Development > Irrigated farming > Conservation > Rainfed farming > Range > Ecotourism > Forest.

Table 4 also shows sum of scores for different land uses based on capability classes and quantitative method with 4 scenarios in the study area. As can be seen, agriculture and development are more important (higher scores) than other uses in study area based on sum of scores in 4 scenarios method.

The land capability maps were then overlaid and land use planning map was assessed (Figure 6) by a quantitative approach. Table 5 also shows percentage of area in current land use and proposed land use maps. The main results of this comparison indicate that



(a) Land capability classification map for ecotourism (intensive)

(b) Land capability classification map for urban, rural and industrial development

Figure 5: Land capability classification maps

current area is more than proposed area for irrigated and range management and it is showing these land uses are located more than their capabilities in the study area. While current area is less than proposed area for urban, rural, and industrial development, rainfed and environmental conservation showing these land uses are located less than their capabilities in the study area. Also Figure 6 and Table 5 show the maximum area of proposed uses is 78.31% related to rainfed agriculture showing this land use has high potential and socio-economic demands in the study area. While minimum area of proposed uses is related to forest and ecotourism.

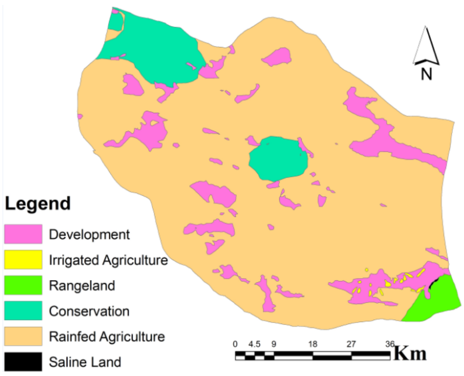


Figure 6: Land use planning map

Therefore, proposed model has higher functionality for land use planning. The Iranian ecological evaluation model and the current modified Iranian ecological evaluation model also were evaluated in Firuzabad, Shiraz and Darab Townships in southern Iran (Asadifard 2015, Masoudi, Jokar 2015, Masoudi et al. 2017); after validation of two models, results showed that the modified model has higher accuracy for land use planning in these regions. Lack of elementary classes in each model (e.g., class 1 in the model of urban development) is caused by the strict method of Boolean logic. The use of the Boolean logic theory to land evaluation methods has been criticized by many authors (Burrough et al. 1992, Davidson et al. 1994, Baja et al. 2002, Masoudi 2018). In the classic methods like the FAO model for land evaluation (FAO 1976) using maximum limitation, makes the classification quite strict. Because, in Boolean logic, only one index with lower effect is enough to reduce the suitability of lands from highly suitable classes to not suitable classes.

Babaie Kafaky et al. (2009) showed that 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.

Table 3: Percent of area for different ecological capabilities of land uses

Land Type	class	Percent
Agriculture	3	0.16
	5	7
	6	91
	7	1.84
Range management and dry farming	1	0.09
	2	7.43
	3	90.61
	4	1.87
Forestry	2	1.75
	3	0.45
	4	3.8
	5	12
	6	24
	7	58
Conservation	2	8
	3	92
Ecotourism	3	100
Development of urban, rural and industry	2	10.53
	3	89.47

Table 4: Sum of scores for different land uses based on capability classes and 4 scenarios method

Capability / Land use	1	2	3	4	5	6	7
Forest	-	14	10	6	2	-2	-6
Ecotourism	-	-	12	-	-	-	-
Development	-	30	26	-	-	-	-
Irrigated farming	-	-	29	-	21	19	13
Range	27	23	19	15	-	-	-
Rainfed farming	31	27	23	19	-	-	-
Conservation	-	25	21	-	-	-	-

Amiri et al. (2010) utilized two methods for assessing the ecological capability of forestry in Mazandaran Province. Their findings after using the conventional Boolean Model revealed that there are categories 3, 5, 6, and 7 of forest capability in the area. Our research is in good agreement with them, from a Boolean perspective.

4 Conclusion

Land evaluation based on physical resources and socio-economic resources is an essential prerequisite for rational land- use planning, which must be based on a knowledge of what land resources are available and what they are suitable for. Generally, it should be noted that current research implemented reforms in Iranian ecological evaluation model. In ecological capability evaluation part, classification of parameters was somewhat changed compared to the initial model in order to have a higher compatibility with the study area. Some modifications in the process of work were also done , such as no preparation of environmental units (as in the Iranian ecological evaluation model) and all indicator maps related to different ecological capability models were overlaid in GIS. Other modifications in the process of work done for assessing the land use planning model were prioritization

Table 5: Comparison of land percent in Current land use and proposed land use maps

Land Type	Percent of Current land use	Percent of Proposed land use
Forestry	0.03	-
Ecotourism	-	-
Urban, rural and industrial development	0.25	10.55
Irrigation agriculture	10.6	0.24
Range management	77.14	1.64
Rainfed agriculture	1.35	78.31
Environmental conservation	-	9.24
Saline land	5.75	0.02
Bare land	4.88	-

of each use was based on the highest score derived after summing the scenarios' scores (ecological, economic, social, area) with regard to suitable capability for the use with highest score (this point does not appear in Iranian ecological evaluation method). To use the current land-use map in assessment mainly due to the socio-economic compulsions of the population especially in rural area was another revision. Generally, the results of this study are suggested to managers and other stakeholders according to this land management study.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Data Availability

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

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