A QUANTITATIVE APPROACH TO LAND USE PLANNING USING GIS – A CASE STUDY OF CHABAHAR COUNTY, IRAN

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ABSTRACT

Land use planning aims to formulate activities, administer potential changes and prevent incompatible changes. The aim of this study is to prepare a land use plan for Chabahar County, Iran, based on a quantitative model using GIS. This study involves two main stages. First, the overlaying of geographical maps and preparing ecological capability maps of different land uses, like forestry, agriculture, range management, environmental conservation, ecotourism and development of villages, urban areas and industry using GIS. The second stage involves prioritizing the land uses taking into consideration the ecological and socio-economic characteristics of the study area and using a quantitative model. The results indicate that the proposed model provides better land use planning than Iran's Makhdoom model. The new model provides clearer and more suitable uses for the land than those used currently. The results also indicated that the maximum area of proposed uses (52.17%) was related to ecotourism, showing this land use had high potential and socio-economic demands in study area. Also, minimum area of proposed uses was related to development.

Keywords: Chabahar County; GIS; land use optimatization; land use planning, modified Makhdoom's model

Introduction

Land use planning is useful for planning the development of an area as it aims to formulate activities, administer potential changes and prevent incompatible changes, and so ensure sustainability (FAO 1993; Van Lier 1998; Makhdoom 2001; Cools et al. 2003; Jozi 2010).

In addition to increasing food production, the loss of valuable land by degradation and deterioration should be restricted as much as possible. Due to potentially rapid degradation rates and slow regeneration, land is a limited non-renewable natural resource. Degradation results in a loss of production and a reduction in the capabilities of land to perform its functions (Ward et al. 1998; NEMA 2004; Abu Hammad and Tumeizi 2010; Barzani and Khairulmaini 2013; Jafari and Bakhshandehmehr 2013).

Although perfect land use planning is a complex decision making process, modern GIS technologies have made this task easier in two ways: (i) They allow one to work simultaneously on a large number of datasets, (ii) Some of the methods, techniques or models can be embedded in GIS used for the suitability analysis of areas of land (Pauleit and Duhme 2000; Swanson 2003; Nouri and Sharifipour 2004; Gad 2015; Atalay 2016). For a more accurate land use planning a wider range of social, economic, physical and environmental indicators need to be included. Inclusion of geographical data in GIS allows these indicators to be used in a more sophisticated way in the decision making process of land use planning. However, for handling the datasets in a GIS environment it is necessary to include a geographical database management system – especially, when the datasets are robust and complex. To build such a geographical database it is essential, first to prepare a conceptual model so that the data requirements and their interrelations are well defined and that the database can be used to store, modify and query the security of the data. Then, a number of Multi-Criteria Decision Making (MCDM) models or techniques embedded in the GIS can be used for land use suitability analysis, where the importance of each indicator of land use is determined in a more sophisticated way based on subjective and or objective judgments. The literature indicates that Boolean and AHP methods, which are kinds of MCDM techniques, can be used for land use planning within a GIS (Bojo'rquez-Tapia et al. 2001; Biswas and Baran Pal 2005; Peel and Lloyd 2007; Gandasasmita and Sakamoto 2007; Oyinloye and Kufoniyi 2013; Farashi et al. 2016; Allaouia et al. 2018).

Taking the above into consideration, the aim of this research is to prepare a quantitative method for the land use planning of the area studied within a GIS.

Materials and Methods

Chabahar County covers an area of 24,729 km² and is located in the Sistan and Baluchistan province in the southeastern part of Iran (Fig. 1). Chabahar city is located between longitude 60°37´E and latitude 25°17´N. This county is located near the warm waters of the Oman Sea and has a humid and warm climate. A systematic method known as the Makhdoom Model (Makhdoom 2001) was used for the analysis of maps in relation to the ecological and socio-economic resources of the area studied. This model is based on an applied and simple Boolean (binary) model.

Several maps were used to evaluate the ecological resources of the area studied, the Digital Elevation Model (DEM), slope and aspect, soil data, erosion, geology, iso-precipitation (iso-hyetal), iso-thermal, iso-evapora-

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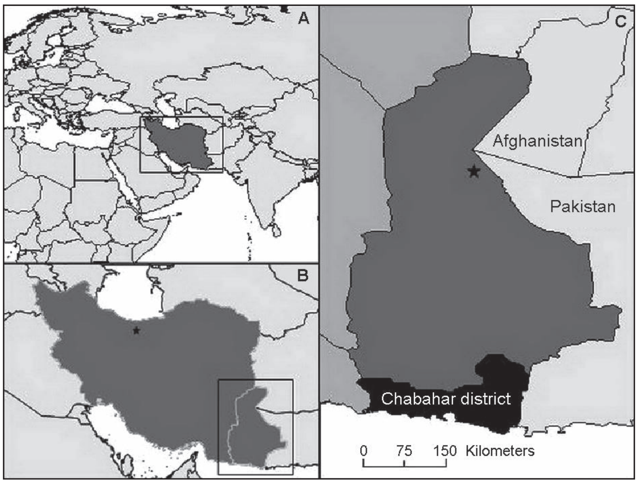

Fig. 1 Map showing the location of Chabahar Province in Iran.

tion, climate, canopy percentage and type and water resources data. These data were gathered from the records of different departments of the Ministries of Agriculture and Energy and Meteorology in Iran. The data obtained consists of two types: 1) attributed data and 2) GIS maps.

Fig. 2 shows the conceptual framework of land use planning for the proposed model. In fact, different ecological capability models based on the Makhdoom method were used to evaluate ecological capability of different land uses including forestry, agriculture, range management, environmental conservation, ecotourism and development of villages, urban areas and industry (Makhdoom 2001). Based on these models, ecological suitability for forestry, agriculture, range management, environmental conservation, ecotourism and development of villages, urbans and industry were 7, 7, 4, 3, 3 and 3, respectively. The best and worst suitability's are the first and the last in each model, respectively. Note that the ecological suitability assessment was based on Boolean algebra. The good and moderate ranges are shown in Table 1.

Based on Fig. 2 and ecological suitability maps, a land use planning map was prepared, which was done by intersecting capability maps. Then the process of land use planning was done by evaluating four scenarios including: a) present land utilization in the area studied and b) the economic, c) social and d) ecological needs of this area. All land uses were ranked for each scenario and then scored from 10 to lower base on their ranks and ecological capability. For example if in one scenario, rank of forestry was placed in the third rank and its ecological capability was class two in a land unit; its score in first step was 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. This means that this one point reduction for forestry in three other scenarios was repeated because of one place of reduction compared to first class of ecological capability. If ecological capability class was class three, the reduction in each scenario would be two.

Ranking in the first scenario was done on the basis of current land use. For other scenarios a questionnaire was completed by 81 experts who ranked the different land uses for each scenario based on their knowledge and experience of the area studied. Averages of the results were used to rank different land uses in each scenario. Questionnaire filling is a good method for determining the socio-economic needs of an area, which depend on many things: socio-political characteristics, population composition, relative earnings, immigration, present land utilization, agriculture and animal husbandry, hygiene, health, education and other public services.

To achieve a systematic analytical model, all maps were layered using a vector format in an ArcGIS software environment. These maps were operated using ArcGIS and the appropriate utilization of each land unit was determined and prioritized. The appropriate utilizations are those that have the highest scores in the different scenarios.

Some of the processes were modified such as preparation of the environmental units and using the current land use map. In this research, the current systemic analysis for preparing environmental units was not utilized for assessing the ecological capability maps and land use planning by the quantitative model. It may be used only

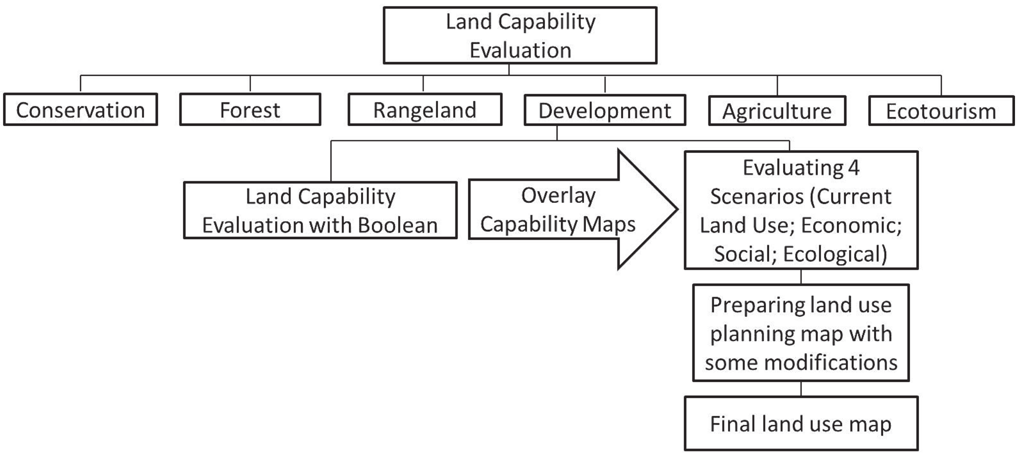

Fig. 2 The conceptual framework of the proposed model for land use planning.

Table 1 Moderate and Good classes for every use.

Indicators	Class	Forestry (class 1–4)	Agriculture and range management (class 1–4)	Ecotourism (intensive) (class 1–2)	Development (class 1–2)
Altitude (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	–	–
Precipitation (mm)	Good	>800	Warm and moderate (Mediterranean to humid)	–	501–800
	Good to moderate	>800	Warm, moderate and cold (semi–arid to humid)		51–500, >800
	Moderate	>500	Warm, moderate, cold and super cold (arid to humid)		–
	Mostly moderate	>500	–		–
Temperature (°C)	Good	18–21	–	21–24*	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*	Good to moderate	–	–	>15	–
	Moderate			7–15	
Relative humidity (%)	Good to moderate	–	–	–	40.1–70
	Moderate				<40, 70–80
Soil Texture & Type	Good	Brown soil and forest semi humid to loam clay texture	Clay, loamy clay, humus	Usually moderate	Moderate (often)
	Good to moderate	Brown soil and forest semi humid to loam clay texture	Clay, loamy clay, humus clay, sandy loamy clay, sandy clay loam, clay loam, loam	Coarse, light, heavy	Light (often)
	Moderate	Brown soil to clay with loamy texture	Clay loam, loamy sand, loam clay sand, clay loam sandy, sand	–	–
	Mostly moderate	Brown rendezina to clay with loamy texture, regosols brown soil, litosols to sand with loamy 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	Granulations fine to moderate with a bit of gravel	Granulations fine to moderate with no gravel, with little erosion	Perfect evolution	Slight erosion with granulation moderate
	Good to moderate	Granulations fine to moderate with gravel	Granulating fine to moderate, no gravel, low to moderate erosion	Moderate erosion	Granulations fine, coarse and moderate with moderate erosion

Structure	Moderate	Granulations fine to moderate with gravel	Granulations moderate to coarse with gravel, moderate erosion	Moderate erosion	Granulations fine, coarse and moderate with moderate erosion
	Mostly moderate	Granulations fine to moderate with rubble, low to moderate erosion	–	–	–
Fertility	Good	Perfect	Perfect	Good to moderate	Good
	Good to moderate	Good	Good	Low	Moderate
	Moderate	Moderate to good	Moderate	–	–
	Mostly moderate	Low to moderate	–	–	–
Canopy Cover (%)	Good	>80	–	Forest lands (with canopy cover > 50%)	0–25
	Good to moderate	60–80	–	Forest lands (with canopy cover 5–50%)	26–50
	Moderate	50–70	–	–	–
	Mostly moderate	40–60	–	–	–
Annual Growth (m^3)	Good	> 6			
	Good to moderate	To 6	–	–	–
	Moderate	To 5			
	Mostly moderate	To 4			
Quantity of water for everyone (l/day)	Good	–	6000–10000**	> 40	< 225
	Good to moderate	4000–6000	12–39.9	150–225	
	Moderate	3000–5000	–	–	
	Mostly moderate	To 3000	–	–	
Lithology	Good	Limestone and dolomite, shale, clay stone, Conglomerate and marl type 1		Pyroclastic rocks, granite ophiolite of a mixture of colours, sand dunes, continental shelf sediments	Sandstone, Ophiolite of a mixture of colours, continental shelf sediments
	Good to moderate	Limestone and dolomite, intermediate pyroclastic rocks of eocene, shale, clay stone, conglomerate and marl type 1, floodplain, ophiolite of a mixture of colours		Limestone and Dolomite, sandstone, loess, schist and gneiss and amphibolite, quartzite, alluvial fans, flood plain	Limestone and dolomite, intermediate pyroclastic rocks of eocene, granite, alluvial fans, shale, clay stone, conglomerate, loess, alluvial terraces
	Moderate	Limestone and dolomite, intermediate pyroclastic rocks of eocene, shale, clay stone, conglomerate and marl type 1, granite, schist and gneiss and amphibolite, floodplain, ophiolite of a mixture of colours	–	–	–
	Mostly moderate	Limestone and dolomite, intermediate pyroclastic rocks of eocene, sandstone, shale, clay stone, conglomerate and marl type 1, granite, schist and gneiss and amphibolite, floodplain, ophiolite of a mixture of colours, loess		–	–

* in spring & summer seasons; ** m^3/ha

for assessing small areas with a low diversity (e.g. small watershed). Hence, for assessing larger areas (e.g. large watersheds, counties and provinces), preparation of environmental units involves not using the same amount 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. Other modifications of the processes that were done for assessing the land use planning model included:

a) Prioritization of each use based on the highest score obtained by summing the scenarios' scores (ecological, economic, social, area) (Makhdoom 2001).

b) Because of the socio-economic position of the population, especially in rural areas, the following land uses were included in the land use planning process:
   1) Irrigated land.
   2) Settlement lands (urban, rural and industrial area).
   3) Dense forests taking into consideration compatibility of uses (e.g. conservation).
   4) Lakes and river beds.

Finally, land use planning maps for Chabahar County were developed considering the ecological and socio-economic characteristics of the area. The process of evaluation included the steps presented in Fig. 2.

Results

For each model, the related indicators were overlaid and then the land capability maps were assessed. The capability maps are shown in Figs 3 to 8 and the percentage of the area suitable for different uses is presented in Table 2.

After that, land capability maps were overlaid and land use planning map (Fig. 9) by quantitative approach was assessed. A comparison of the percentage of the land currently in different land use categories and that proposed by the land use maps is presented in Table 3. The main results of this comparison is that the areas currently assigned to forestry and range management are greater than that proposed by the land use model. A lot of barren land in this area could potentially be used for other purposes, such as ecotourism and environmental conservation. Fig. 9 and Table 2 also show a maximum percentage area of 52.17% is suitable for ecotourism. Also, little of area is currently used and suitable for future development.

Table 2 Percentage of area suitable for different uses.

Land Type	Class	Percent
Agriculture	2	0.03
	3	2.72×10^{-5}
	4	0.12
	5	79.90
	6	19.96
	7	4.47×10^{-7}
Range management & dry farming	1	0.14
	2	79.90
	3	19.96
	4	4.47×10^{-7}
Forestry	4	0.89
	5	15.90
	6	11.70
	7	71.48
Conservation	1	35.79
	2	22.30
	3	41.90
Ecotourism	1	2.83
	2	85.82
	3	11.34
Development of urban and rural areas, industry	2	0
	3	100

Table 3 Comparison of the percentage of the land currently under different types of land use and that proposed by the land use maps.

Land Type	Percentage of current land use	Percentage of proposed land use
Forestry	4.80	0.85
Ecotourism	–	52.17
Urban, rural and industrial development	0.03	0.03
Irrigated	0.47	0.22
Range management	48.33	2.66
Dry farming	10.30	0.27
Environmental conservation	35.79	6.50
Ecotourism-conservation	–	35.44
Saline land	–	–
Bare land	35.30	1.05

Discussion and Conclusions

Arid and semi-arid regions in Iran are undergoing rapid desertification in response to climate warming and anthropogenic disturbances. Hence, it should be noted that the establishment of the best land use is needed for land improvement. Thus, there is a need to improve land use planning. Land degradation can be due to natural hazards, direct and indirect causes. Direct causes include unsuitable land use and inappropriate land management practices, for example cultivation of steep slopes (Masoudi 2010; Masoudi et al. 2018). Some anthropogenic activities like deforestation, using rangelands for cultivation, mining and urbanization, destroy the natural vegetation and degrade the land. All these activities have to be controlled by incorporating the capacity of natural vegetation to sustain them (Masoudi 2010; Atalay 2016). In regions such as the eastern part of the Mediterranean, factors affecting changes in land use (e.g. Population and Urban Expansion) result in the degradation of the land (Abu Hammad and Tumeizi 2010; Masoudi et al. 2018), which also applies to Iran and, in particular, the area studied. Determination of the appropriate use of land and preventing further destruction of resources due to population increase should be included in strategies proposed for stable expansion (Bocco et al. 2001; Prato 2007).

By employing GIS and combining the various vector layers of the area, which represent its ecological resources, one can obtain a map showing the most appropriate

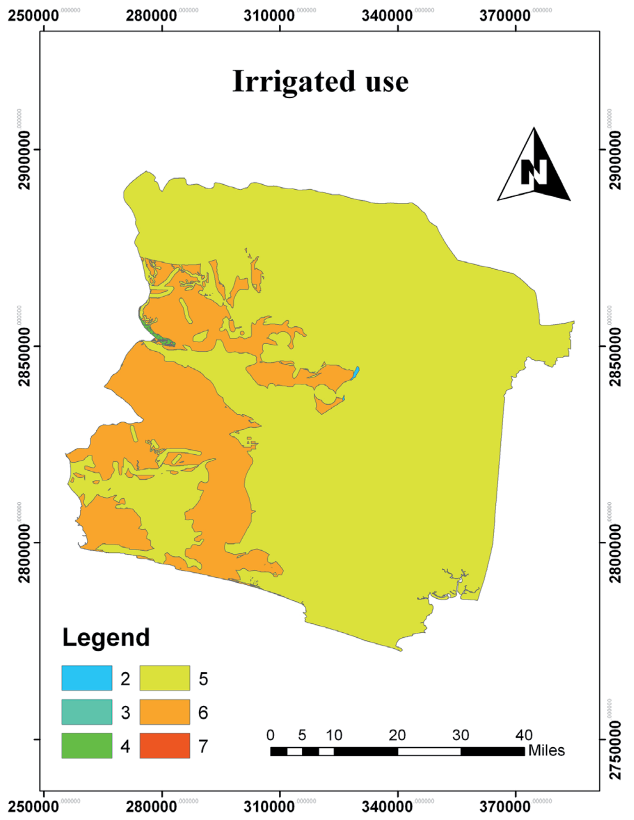

Fig. 3 Land map showing suitability of areas for irrigation agriculture (Note: class 2 → Good to moderate; class 3 → Moderate; class 4 → Mostly moderate; class 5 → Moderate to poor; class 6 → poor; class 7 → unsuitable).

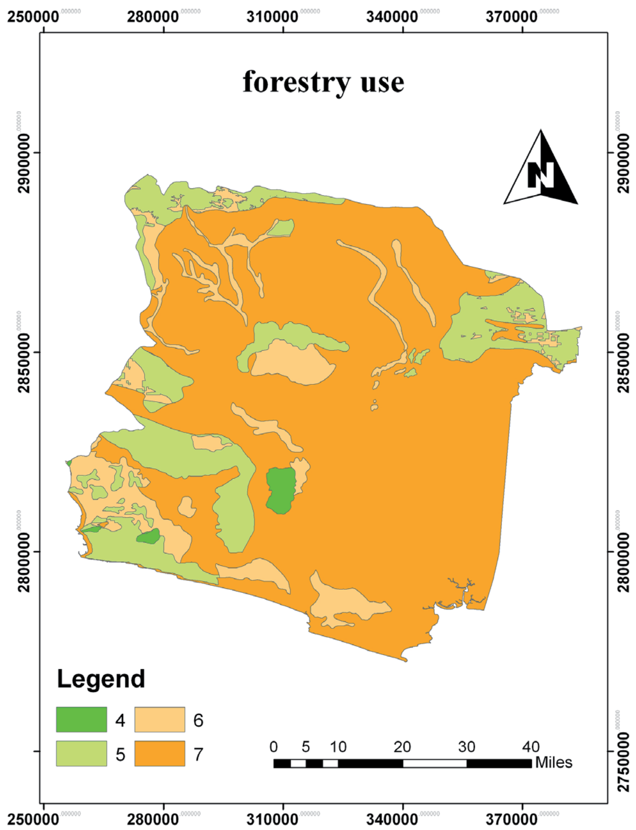

Fig. 5 Land map showing suitability of areas for forestry (Note: class 4 → Mostly moderate; class 5 → poor; classes 6 and 7 → unsuitable).

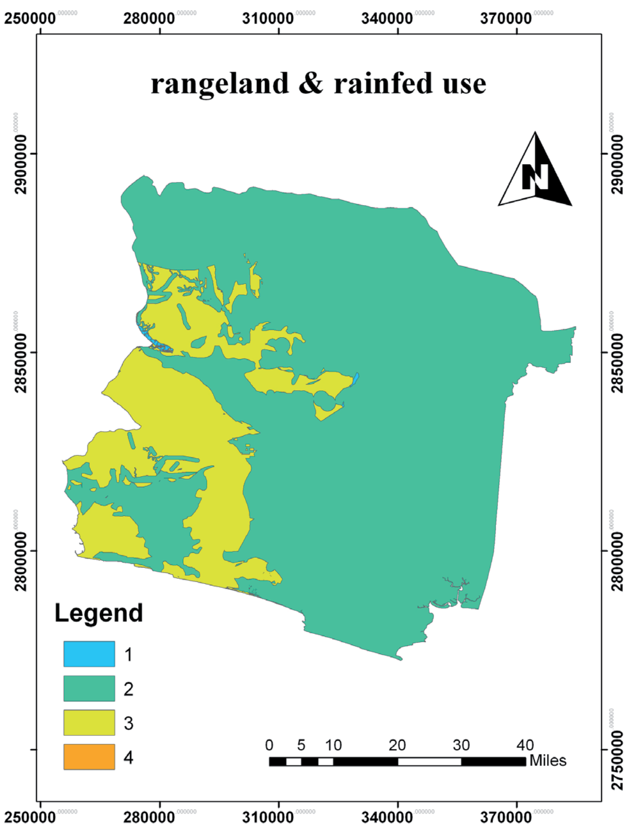

Fig. 4 Land map showing suitability of areas for range management and dry farming (Note: class 1 → Good; class 2 → Moderate; class 3 → Poor; class 4 → unsuitable).

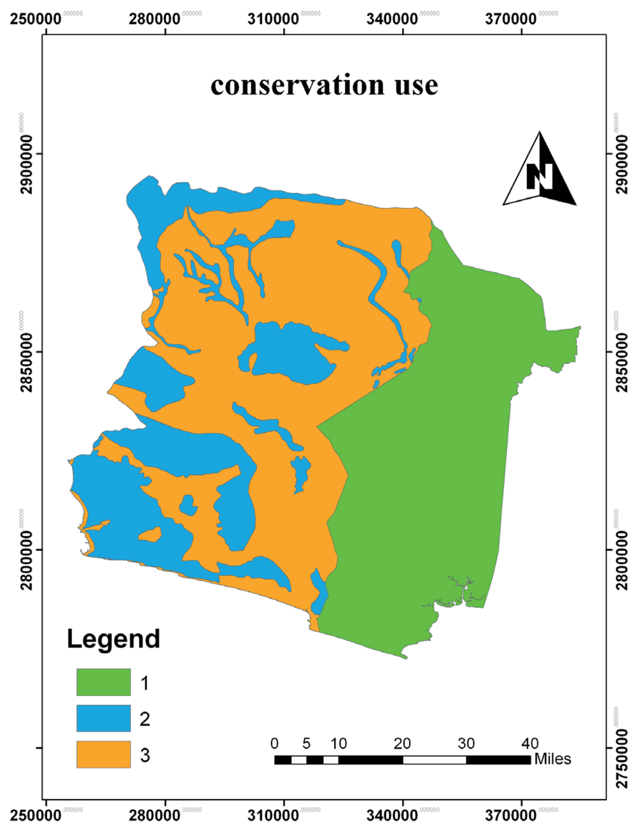

Fig. 6 Land map showing suitability of areas for environmental conservation (Note: class 1 → Good; class 2 → Moderate; class 3 → unsuitable).

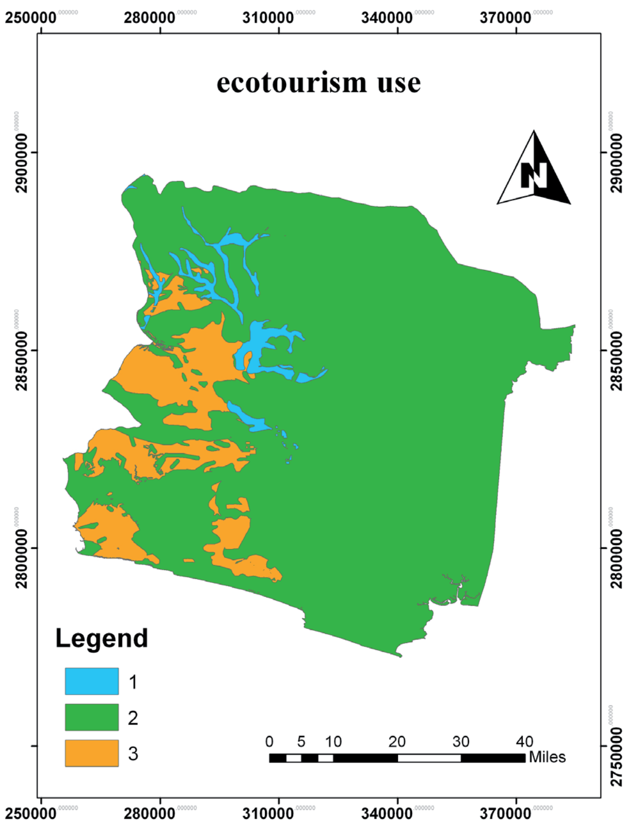

Fig. 7 Land map showing suitability of areas for ecotourism (Note: class 1 → Good; class 2 → Moderate; class 3 → unsuitable).

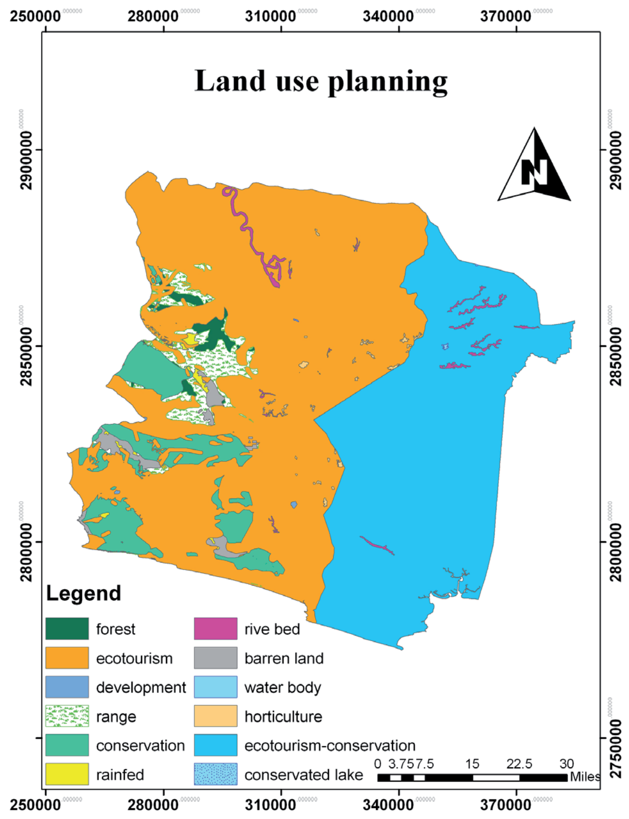

Fig. 9 Land use planning map.

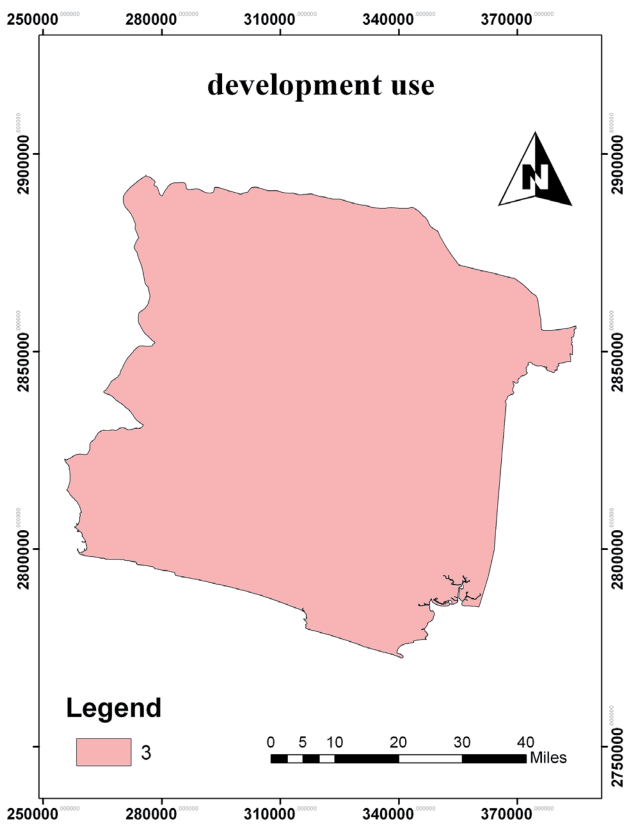

Fig. 8 Land map showing suitability of areas for urban, rural and industrial development (class 3 → poor and unsuitable).

use of the land in an area. However, determination of the priorities for the most appropriate uses of land in these maps must take into consideration the socio-economic conditions in an area or the tendency of residents to utilize the land for certain specific uses.

The capability of areas to sustain particular uses can be reduced by taking into consideration their ecological suitability. This is included in the agricultural and forestry maps with 7 classes, and urban development and ecotourism maps with 3 classes. Use for ecotourism was included because ecotourism is very important in the area studied. Based on the results, the minimum and maximum percentages of area that should be used for development and ecotourism, respectively, can be defined.

The application of Boolean logic to land use evaluation has been criticized by many authors (Burrough et al. 1992; Davidson et al. 1994; Baja et al. 2006; Amiri et al. 2010). In the classic methods like the FAO model for evaluating land use (FAO 1976) the use of maximum limitation make the classification quite rigorous. Because, in Boolean logic, only one index with a lower effect is enough to reduce the suitability of land from highly suitable to unsuitable.

Amiri et al. (2013) utilized methods for assessing the ecological capability of forestry in Dohezar and Sehezar (33, 34), a watershed of Tonekabon city in the Mazandaran Province in Iran. Their findings indicate that the Analytical Hierarchy Process (AHP) and the OWA method was better than other models, even those based on Boolean logic, which is supported by the results presented here.

Babaie-Kafaky et al. (2009) show that if the importance of the multiple-use of Zagros forests is not recognized in the management of this forest it will lose many of its recreational, natural ecosystem characteristics and countless other values.

Examining the land planning maps proved that besides being useful for a single purpose, they can be potential used for many purposes. However, in any one unit, no more than a single type of utilization can ultimately be implemented (Makhdoom 2001). The best use for each unit should be determined by prioritizing the socio-economic conditions in an area and the resident's way of life and their tendency to use land in a specific way. To this end, it is best to consider the following points in prioritizing our findings. In units where there are no socioeconomic limitations, the priority is the one with the highest potential (Espejel et al. 1999). The priority of land use in some of the units is determined based on political needs, and there is no possibility of changing it (Pierce et al. 2005). In some units, where one use has no advantage over another, multiple uses may be proposed (Makhdoom 2001). Generally, current research implemented reforms in Makhdoom's model, which is now more suitable for land use planning. Makhdoom's model and the modified Makhdoom's model have been evaluated in Jahrom and Firuzabad Townships in southern Iran (Asadifard 2015; Masoudi and Jokar 2016; Razaghi 2016). After validation of the two models, the results showed that the modified model was more accurate for land use planning in the areas studied.

Due to the importance of natural hazards, such as drought and climate change, they should be considered in future research. To increase the model's accuracy, methods such as AHP and ANP for Weighting and Fuzzy methodology are also recommended.

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