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Land Use Planning Using a Quantitative Model and Geographic Information System (GIS) In Sistan Region, Iran

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Background: Land use planning is a science that determines the type of land use through studying the ecological and socio-economic characteristics of the land.
Materials and Methods: A systematic method known as the Makhdoom Model was used for the analysis of maps to evaluate the land use and natural resources for future sustainable land planning of an area in Sistan region, using GIS as a tool. For this purpose, the ecological capability maps of different land uses, including forest and range, agriculture, ecotourism, rural and urban development were initially prepared by overlaying geographical maps in GIS for the study area. Then, the prioritization of land uses was assessed using a quantitative model by considering the ecological and socio-economic characteristics of the study area.
Results: The results indicated that the maximum area of the proposed uses (28.7%) was related to conservation, showing this land use had high potential in the study area. Also, the minimum area of proposed uses was related to dry farming.
Discussion and Conclusions: This research proved that quantitative methods can be more useful than classic methods (qualitative).

Keywords: Land use planning, Modified, GIS, Sistan Region

1. Background

Land-use planning is one of the best methods for evaluating land-use, economic and social conditions in adopting the best land-use options (1). Unplanned development is a basic problem in developing countries. Through land use planning, which is based on regulations and capabilities for different land use, the waste of natural resources and ruining of the environment can be stopped. Land use, in general, consists of the coordination of the relation between humans and the land for the proper and long-term use of provisions (2). Hence, one must base the ecological potential of an area for a certain use on the socio-economic ability of that area in addition to its ecological conditions. On the other hand, the lack of necessary knowledge of land potential and the irrational use of the land have reduced land resources (3). So, evaluation of ecological capability, as a basic study and foundation of land use planning, is necessary.

Arid and semi-arid lands cover more than 70% of Iran and are very prone to desertification (4). In fact, as the results of increased population, increased agricultural activities, overgrazing and several other factors, land degradation has increased in Iran in recent decades (5).

In ecological evaluation, GIS is quickly becoming data management standard in planning the use of land and natural resources (6). Actually the GIS is used to access for geography patterns (7) and has become an indispensable tool for land and resource managers (8), with a wide application in land development and agricultural purposes around the world (9, 10, 11, 12, 13, 14, 15 and 16).

The current land use planning in Iran by Makhdoom Quantitative Method (2) has some problems in assessment of ecological and socio-economic information in relation to scenarios. Also it can be due to sum of scores scenarios in current model; a land use without ecological capability is prioritized or part of settlement is suggested to another use. So, the main target of this research was to solve these problems and develop and modify the current quantitative method of Makhdoom Model to evaluate better land use planning in Iran.

2. Materials and Methods

Sistan region with an area of 16947 km^2 is located in the northern part of the eastern province of Sistan-Baluchistan (61° 10´ to 61° 50´E and 30° 18´ to 31° 27´ N) (Figure 1). The area has an arid and dry climate.

A systematic method known as the Makhdoom Model (2) was used for the analysis of maps in relation to the ecological and socio-economic resources of the study area. This model is based on an applied and simple Boolean (binary) model.

Several maps were used to evaluate the ecological sources of the area under study, including slope and aspect, soil data, erosion, geology, iso-precipitation (iso-hyetal), iso-thermal, iso-evaporation, climate, canopy percentage and type, and water resources data. These data were gathered from the records by different departments in the Ministries of Agriculture, Energy, and the Meteorological Organization. The data obtained were of two types: 1) attribute data and 2) GIS maps, mainly with curt scale useful for the GIS analysis.

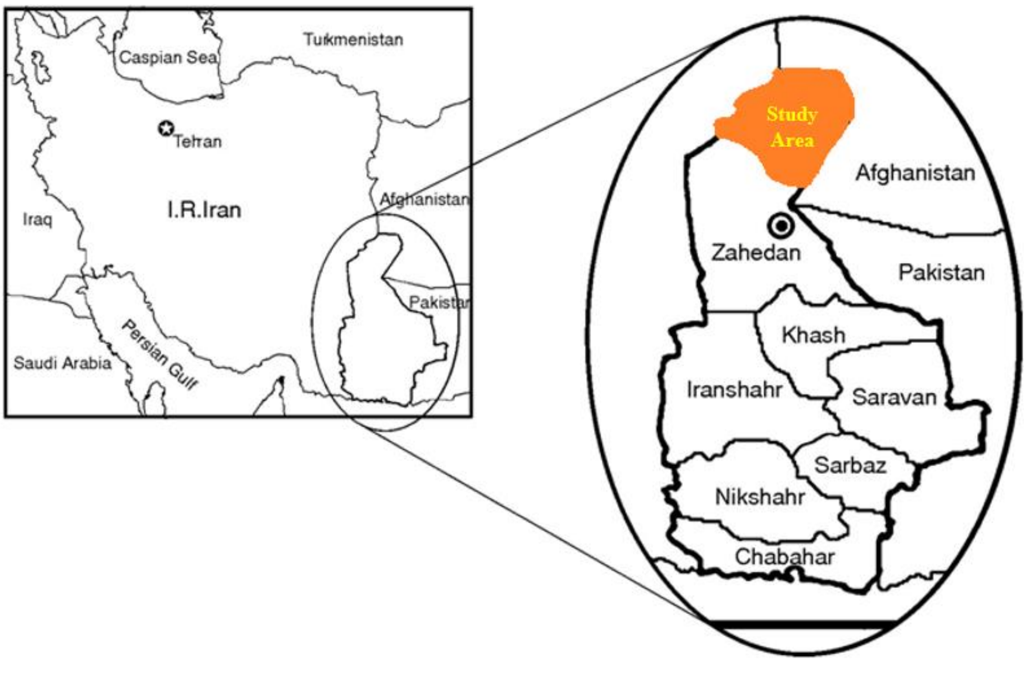

Figure 1 Position of Sistan region in Sistan-Baluchistan Province and Iran

Different ecological capability models of Makhdoom’s method have been used to evaluate ecological capability of different land uses, including forestry, agriculture, range management, environmental conservation, ecotourism and development of village, urban and industry (2). Based on these models, ecological capability classes for forestry, agriculture, range management, environmental conservation, ecotourism and development of village, urban and industry were 7, 7, 4, 3, 3 and 3, respectively. The best capability class and the worst one are class one and the last class in each model, respectively. Ecological Capability classes for aquaculture are suitable and non-suitable, too. The good and moderate ranges were shown in Table 1.

Table 1 Moderate and good classes for every uses (2)

Indicators	**Class**	**Forestry (class 1-4)**	**Agriculture & range management (class 1-4)**	**Ecotourism (intensive) (class 1-2)**	**Development (class 1-2)**
Elevation (m)	Good	0-1000	-	-	400-1200
	Good to Moderate	0-1000			0-400, 1200-1800
	Moderate	0-1400			-
	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	-	-	-
	Moderate	0-55	8-15	-	-
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
	Moderate	>500	Warm & moderate & cold & super cold) Arid to humid		-
	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		-	-
	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

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

Table 1 (Continued)

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	-	-
	Moderate	brown rendezina to clay loam texture, regosols brown soil, litosols to sand loam texture	Clay, loam clay, clay loam, loam	-	-
Soil 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	-	-
	Moderate	Rather incomplete to Moderate	-	-	-
Soil Depth	Good	Deep	Deep	Deep	Deep
	Good to Moderate	Deep	Moderate to good	Semi deep	Semi deep
	Moderate	Moderate to good	Low to Moderate	-	-
	Moderate	Moderate to good	-	-	-

Table 1 (Continued)

Soil Structure	Good	Granulating fine to moderate, a bit Gravel, Evolved	Granulating fine to moderate, none Gravel, Evolved low erosion	Perfect evolution	Slight erosion to Granulating Moderate and Perfect evolution
	Good to Moderate	Granulating fine to moderate, by Gravel, Evolved	Granulating fine to moderate, none Gravel, Evolved low to moderate erosion	moderate evolution	moderate erosion to Granulating Fine, Coarse and moderate evolution
	Moderate	Granulating fine to moderate, by Gravel, Evolved	Granulating moderate to coarse, by Gravel, moderate Evolution, moderate erosion		
	Moderate	Granulating fine to moderate, by Rubble, low to moderate Evolution	-	-	-
Soil Fertility	Good	perfect	perfect	Good, Moderate	Good,
	Good to Moderate	Good	Good	Low	Moderate
	Moderate	Moderate to good	Moderate	-	-
	Moderate	Low to Moderate	-	-	-
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		-	-
	Moderate	40-60		-	-
Annual Growth (m^3)	Good	>6	-		
	Good to Moderate	To 6			
	Moderate	To 5			
	Moderate	To 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	-	-
	Moderate		To 3000	-	-

In the next step, after producing ecological capability maps, the land use map was prepared. The model consisted of four scenarios in each land unit including: (a) current 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 (2). All land uses were ranked for each scenario, and then scored from 10 to lower, based on their ranks and ecological capability. For example, if in one scenario, forestry is placed in the third rank and its ecological capability is class two in a land unit, its score in the 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. This one point reduction for forestry is repeated in three other scenarios 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.

Ranking of the first scenario was evaluated using current land use. For other scenarios, questionnaires were filled by 81 experts to rank different land uses, based on their knowledge and experience from study area.

To achieve a systematic analytical model, all map layers were used by a vector format in the ArcGIS software environment. These maps were operated using ArcGIS and the appropriate utilization of each land unit was determined and prioritized, including those utilizations that had higher sum of scores among the scenarios. Many of the units were seen fit for two appropriate uses considering the socio-economic status of the area, consistency of land uses and current land use.

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 eliminate 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. Other modifications in the process of assessing the land use planning model included:

a) Prioritization of each use was based on the highest score derived after summing the scenarios' scores (ecological, economic, social, area) (2).

b) The current application of the land use map in assessment is mainly due to the socio-economic obligations, especially in rural area to retain the following land utilizations in the land use planning process:

1) Irrigated lands with suitable capability.

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

3) Dense forests with taking into consideration of compatibility of uses (e.g. conservation).

4) Lake and river bed.

Finally, land use planning maps of Sistan region were developed with the consideration to the ecological and socio-economic characteristics of the area. Process for evaluation included the following steps presented in Figure 2.

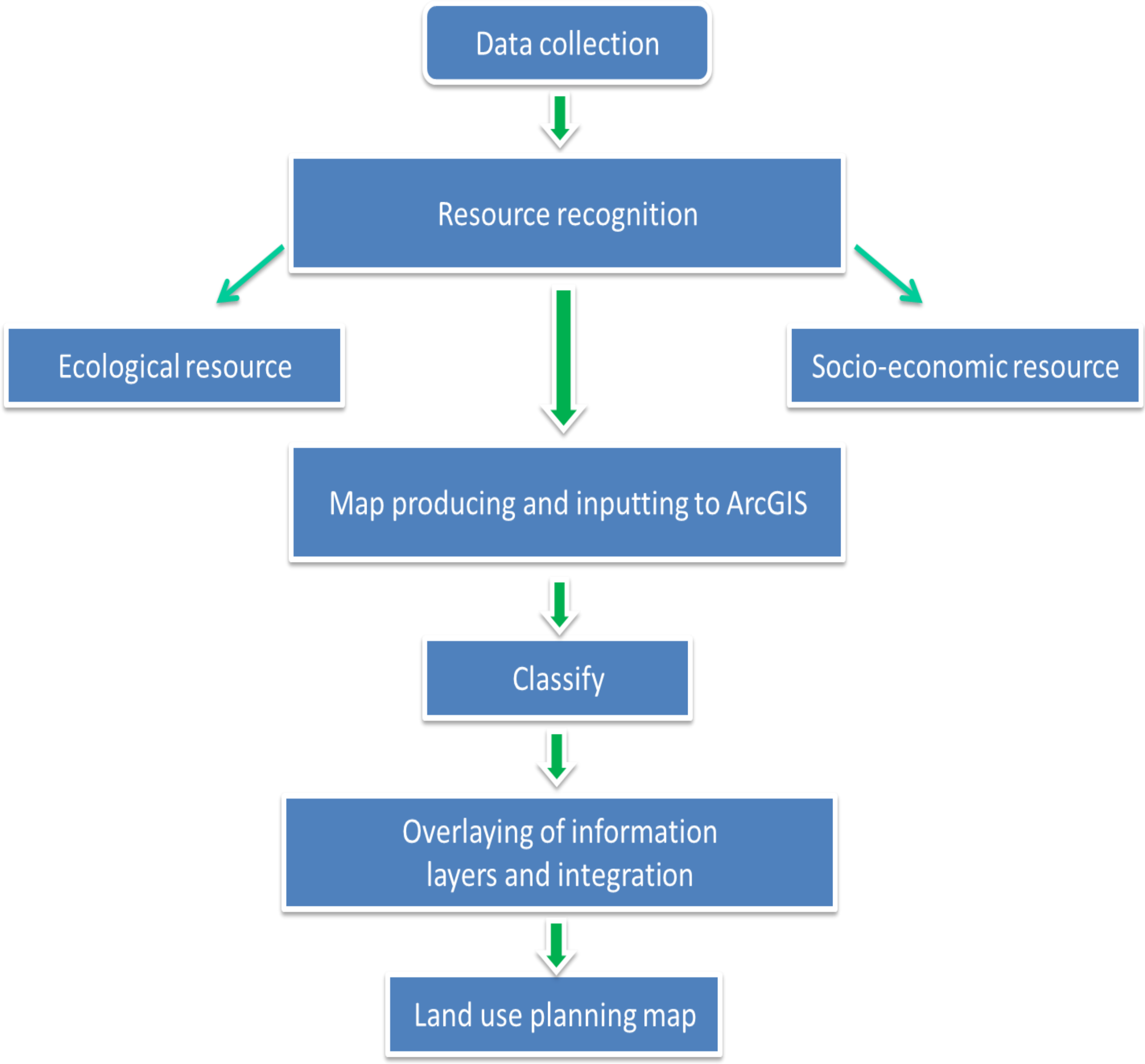

Figure 2 Flowchart showing the methodology for land-use planning adopted in the study

4. Results

For each model the related indicators were overlaid, and then the land capability maps were accessed. The capability maps are shown in Figures 3 to 9 and percent of area for different ecological capabilities of land uses is shown in Table 2.

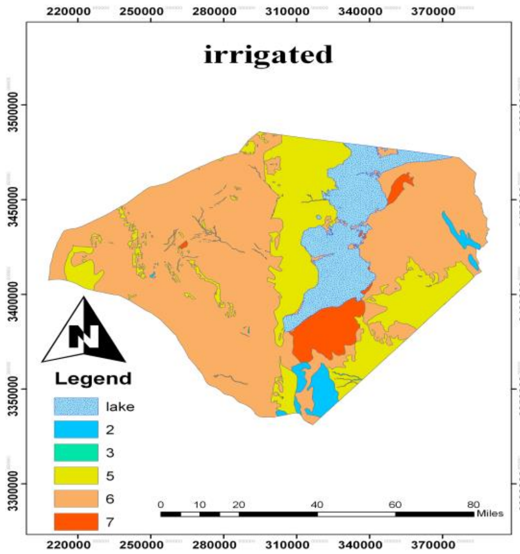

Figure 3 Land capability map for irrigation agriculture in Sistan region

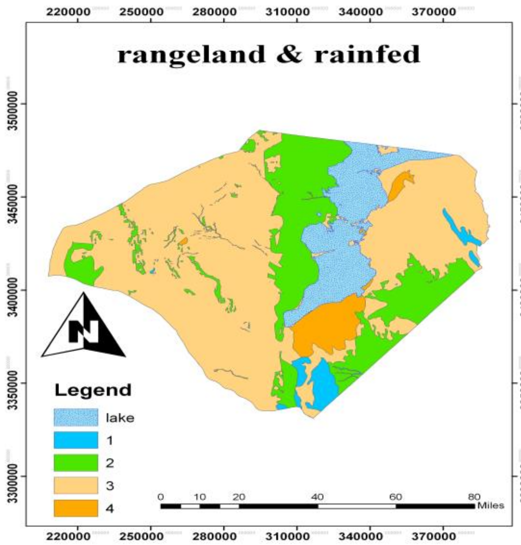

Figure 4 Land capability map for range management and dry farming in Sistan region

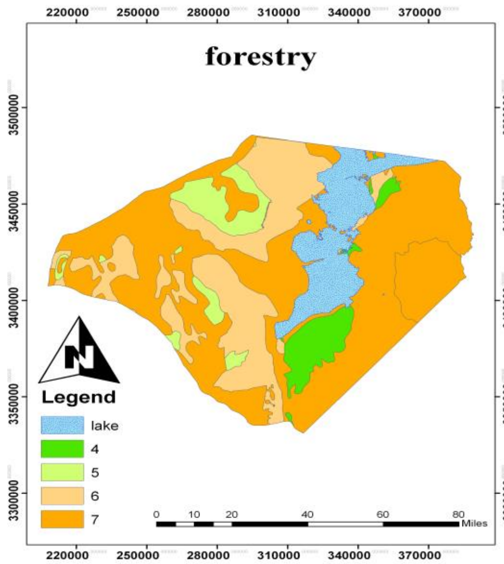

Figure 5 Land capability map for forest in Sistan region mental

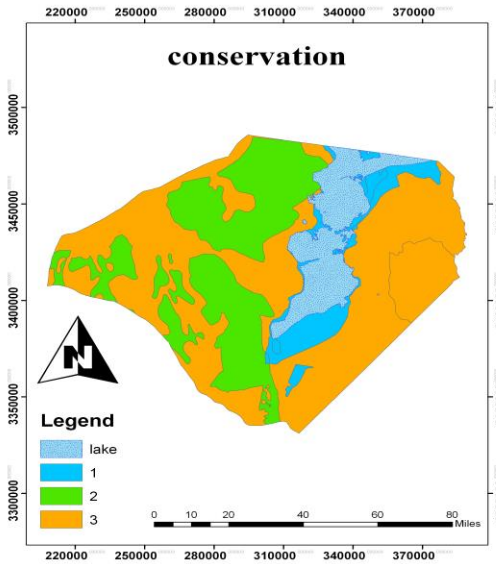

Figure 6 Land capability map for environ conservation in Sistan region

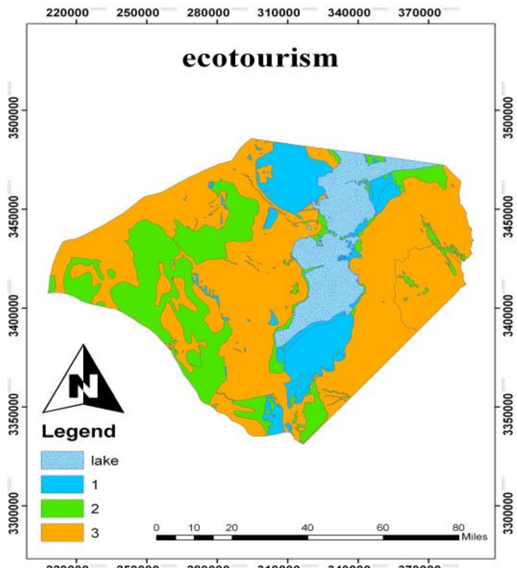

Figure 7 Land capability map for ecotourism in Sistan region

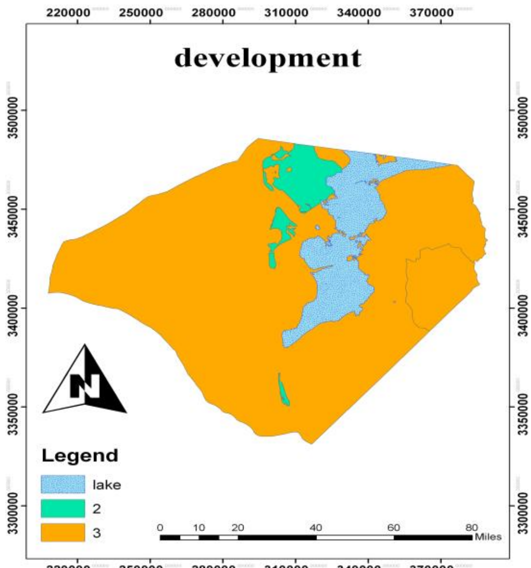

Figure 8 Land capability map for urban, rural and industrial development in Sistan region

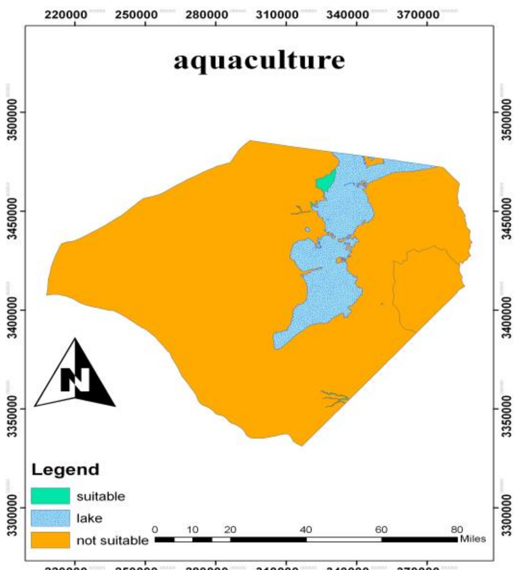

Figure 9 Land capability map for aquaculture in Sistan region

Then land capability maps were overlaid and land use planning map by quantitative approach was assessed (Figure 10). A comparison of land percent in current land use and proposed land use maps is observed in Table 3. The main results from this comparison indicate that current area is more than proposed area for forestry and range management, showing these land uses have been more than their estimated capabilities in the study area. In saline and barren lands also current area is more than proposed area, showing this use can change to other uses. While the current area is less than proposed area for irrigation agriculture, environmental conservation and ecotourism, showing these land uses have been less than their estimated capabilities in the study area. The maximum area of proposed uses was 28.69% that was related to conservation showing this land use has high potential and socio-economic demands in the study area; the minimum area of the proposed uses was related to dry farming. The most important implication of the proposed land use map is related to study area with arid to semi-arid conditions. Hence, due to shortage of water and rain, it is proposed that dry farming must not be done. Instead, conservation and ecotourism uses can be developed in the study area.

Table 2 Percent of area for different ecological capabilities of land use

Percent	class	Land Type
Agriculture	2	2.26
	3	0.07
	5	25.99
	6	66.61
	7	5.06
Range management and dry farming	1	2.34
	2	25.99
	3	66.61
	4	5.06
Forest	4	5.94
	5	5.58
	6	28.59
	7	59.89
Conservation	1	16.77
	2	31.29
	3	51.92
Ecotourism	1	19.22
	2	26.43
	3	54.34
Development of urban, rural and industry	2	8.66
	3	91.33
Aquaculture	1	0.36
	2	99.63

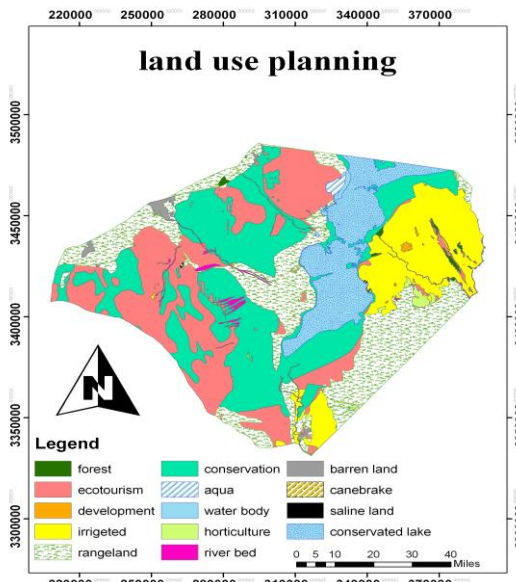

Figure 10 Land use planning map by the proposed quantitative model in Sistan region

Table 3 Comparison of land percent in Current land use and proposed land use maps

Land Type	Percent of Current land use (with current conservation)	Percent of Proposed land use
Forest	1.46	0.39
Ecotourism (with forest)	-	22.05
Urban, rural and industrial development	0.13	0.13
Irrigated agriculture (with horticulture)	12.2	13.82
Rangeland	70.68	22.1
Dry farming	-	-
Environmental conservation	16.77	28.69
Water body (lake, Aquaculture and river bed)	12.15	0.31 (Aquaculture), 0.86 (river bed) and 10.98 (conserved lake)
Barren and Saline land	3.38	0.65

5. Discussion and Conclusions

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 in steep slopes (17). Some anthropogenic activities like deforestation, encroachment to rangelands for cultivation, mining and urbanization harm the natural vegetation cover and degrade land. All these activities have to be controlled based on the capacity of natural vegetation cover and land use planning (17) In regions such as the eastern part of the Mediterranean, factors affecting land use changes (e.g. Population and Urban Expansion) cause land degradation (18), which also applies to Iran and the study area, too. Determination of the appropriate land use for the purpose of a better utilization of land in a country and preventing further destruction of resources due to population increase can and will be an effective step in devising strategies for stable expansion (19, 20). However, determination of priorities for appropriate land use from the obtained maps can't be adequate without considering the socio-economic condition of the area or the tendency of the residents to utilize the land for certain specific uses.

The capabilities maps of different uses, which represent the natural features of the land and class, can be reduced by increasing the ecological capability. This is displayed in agricultural and forestry maps with 7 classes, urban development and ecotourism maps with 3 classes. Use of ecotourism has been investigated based on intensive ecotourism, because of its importance in the study area. Based on the results, the minimum and maximum percentages of the final maps of land use planning belonged to dry farming and conservation, respectively.

Lack of elementary classes in each model (e.g. class 1 in urban development) is resulted from evaluation approach with Boolean logic. With this approach, a parameter is sufficient to lead to a lower class. The use of the Boolean logic theory to land evaluation methods has been criticized by many authors (21, 22, 23 and 24). In the classic methods like the FAO model for land evaluation (21), using maximum limitation make the classification quite strict. Amiri *et al.* (22) utilized two methods for assessing the ecological capability of forestry in Mazandaran Province, the findings of which revealed the categories 3, 5, 6, and 7 with the conventional Boolean Model for the forest capability in the area, which was in agreement with our results. Babaie-Kafaky *et al.* (24) showed that overlooking the importance of the multiple-use in the Zagros forests management would result to loss of many of the recreational, natural ecosystem characteristics and countless values.

Examining the prepared land planning maps proved that besides being useful for a single purpose, it has the potential for multiple uses. However, in any one unit, no more than a single type of utilization can, ultimately, be implemented (2). The best use for each unit should be determined through prioritizing the socio-economic conditions of the area and its resident's way of life as well as their tendency to use the land for specific utilization. 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 with the one demonstrating the highest potential (25). The priority of land use in some of the units is determined based on political needs, and the possibility for changing it does not exist [26]. In some units where one use has no advantage over another and where the priority point of view are close, multiple uses may be proposed (2). The current research implemented reforms in Makhdoom's model, the result of which showed higher functionality for land use planning, which was in agreement with the results of its application in other parts of Iran (27, 28, 29 and 30). After validation of two models, results showed that the modified model had a higher accuracy for land use planning in the study areas.

Due to the importance of natural hazards, such parameters as drought and climate change should be considered the in future research. To increase the model accuracy, methods such as AHP and ANP and Fuzzy methodology may be recommended, too.

Conflict of Interest

The authors declare that they have no competing interests.

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Authors' Contributions

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آمایش سرزمین با استفاده از یک مدل کمی و سامانه اطلاعات جغرافیایی (GIS) در منطقه سیستان، ایران

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مقدمه: آمایش سرزمین علمی است که با توجه به ویژگی‌های اکولوژیکی و اقتصادی اجتماعی سرزمین نوع بهینه کاربری اراضی را تعیین می‌کند.

مواد و روش‌ها: در این تحقیق از مدل سیستمی دکتر مخدوم برای تجزیه و تحلیل نقشه‌ها استفاده شد و کاربری‌های اراضی و منابع طبیعی منطقه سیستان به‌منظور برنامه‌ریزی و استفاده پایدار از سرزمین در آینده و با کمک سامانه اطلاعات جغرافیایی (GIS) ارزیابی گردید. در گام اول نقشه‌های توان اکولوژیک کاربری‌های مختلف شامل جنگل، کشاورزی، مرتع، حفاظت محیط، اکوتوریسم، توسعه شهری، روستایی و صنعتی با ادغام نقشه‌های مکانی در GIS برای منطقه مورد مطالعه تهیه شد. گام نهایی تحقیق، اولویت‌بندی کاربری‌ها با در نظرگیری خصوصیات اکولوژیکی و اقتصادی اجتماعی منطقه توسط یک مدل کمی بود.

نتایج: نتایج نشان داد که بیش‌ترین مساحت کاربری پیشنهادی (بهینه) با ۲۸/۷ درصد متعلق به حفاظت محیط بود که بیانگر این نکته است که منطقه مورد مطالعه به لحاظ شرایط حفاظتی در اولویت می‌باشد. هم‌چنین کم‌ترین مساحت کاربری بهینه پیشنهادی متعلق به کاربری کشاورزی دیم بود.

بحث و نتیجه گیری: این تحقیق ثابت کرد که روش‌های کمی می‌توانند کارآمدتر از روش‌های سنتی (کیفی) باشد.

کلمات کلیدی: برنامه‌ریزی استفاده از زمین مدل، اصلاح شده، GIS، منطقه سیستان