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Land-use Planning using a Quantitative Model and Geographic Information System (GIS) in Shiraz Township, Iran

Masoud Masoudi[1]* and Parviz Jokar[2]

[1] *Associate Professor, Department of Natural Resources and Environment, Shiraz University, Iran*

[2] *Former M.Sc. Student, Department of Natural Resources and Environment, Shiraz University, Iran*

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ABSTRACT Land-use planning is a science that determines the type optimum of land-use through studying the ecological characteristics of the land as well as its socio-economic structure. The primary objective of this study is to evaluate the land-use and natural resources for future sustainable land planning using GIS. In this study, the Makhdoom's systematic method was used to analyze the ecological and resources maps of the study area. At first, ecological capability maps of different land-uses including forest, agriculture, rangeland, environmental conservation, ecotourism and development of village, urban and industry were developed by overlaying geographical maps in GIS for the township. The final step of this study was the prioritization of land-uses considering the ecological and socio-economic characteristics of the study area using a quantitative model. The results indicated that the maximum area of proposed use was 39.30 % that was related to range and dry farming and minimum area of proposed use was 3.3 % which was related to irrigation agriculture with range.

Key words: *Boolean Theory, Land management, Land-use optimization, Modified Makhdoom's model*

1 INTRODUCTION

Land-use planning is the systematic assessment of land and water potential, alternatives for land-use and economic and social conditions in order to select and adapt the best land-use options (FAO, 1993). This definition embraces the systematic approach of possibilities for different land-uses in the future, and also the need for changes and the willingness to execute the plan all present land-use planning is caught up between two seemingly contradictory dimensions: ecological conservation and economic existence. Both dimensions are, in some way or another, related to sustainability in Land-use planning. Sustainability as a goal is often criticized as being vague and a paradox. The conflicting problem of economic development and ecological conservation is often mentioned as following: ''we cannot save the environment without development and that we cannot continue to develop anywhere unless we save the environment'' (Van Lier, 1998).

In other hand, unplanned and ungoverned development is one of the main problems in developing countries. To achieve sustainable development goals, evaluation of ecological

**Corresponding author: Associate Professor, Department of Natural Resources and Environment, Shiraz University, Iran, Tel: +98 917 339 9877 E-mail: masoudi@shirazu.ac.ir*

capability as a basic study and foundation of land-use planning, is a requisite action to accomplish development process in accordance with environmental capabilities. Besides, human-nature relation has achieved the real understanding of "human with nature" notion with gradual disappearing of old thoughts of "human on nature" (Jozi, 2010).

Nowadays, the idea of interactions between human and nature has been extended. These interactions have influenced different fields such as economy, social, industry, politics and culture; hence, standpoint of most of decision makers has been based on the fact that development plans do not conflict with principals of environmental protection (Jozi, 2010).

Land degradation and the loss of land productivity are two of the foremost environmental problems of our time. These problems relate to the reduction of land resource potential by either one or a combination of processes acting on the land such as water and wind erosion, sedimentation, loss of soil structure and fertility, salinization and other acts of nature that result in long-term reduction of diversity of vegetation and net primary production (Ward *et al.*, 1998; Masoudi, 2010). Arid and semi-arid lands cover more than 70% of Iran and are very prone to desertification (Jafari and Bakhshandehmehr, 2013). As a result of the following factors, land degradation and desertification have accelerated in Iran during the recent decades: first, the population has doubled over the last 25 years (Since 1979; Amin Mansour, 2006); second, increased agricultural and pastoral products have forced people to use land extensively or convert forest and rangelands to cultivated land; third, overuse of wood and plants as fuel for household cooking and heating, and use of natural regulations tend to denude the soil and intensify the desertification (Marani Barzani and Khairulmaini, 2013). Abu Hammad and Tumeizi (2010) investigated the socioeconomic factors and causes of land degradation (e.g., population growth and urbanization, poverty, overgrazing, pollution, biodiversity, erosion) in the eastern part of the Mediterranean region. Results revealed a significant land-use change from agricultural and natural vegetation to urbanized areas due to the high population increase during the last 80 years. Research of Babaie-Kafaky *et al.* (2009) showed that land- use planning is an important characteristic for preventing land degradation.

In this regard, land-use planning is a kind of long-term planning that considers the land as a determined factor in supplying development goals. Land-use planning based on regulations with permanent and suitable return view, according to the qualitative and quantitative capabilities and talents for different use of human from the land shall render type of utilization. Thus waste of natural resources and ruining of the environment will be stopped.

In ecological evaluation, GIS is quickly becoming data management standard in planning the use of land and natural resources. Virtually all environmental issues involve map–based data, and real world problems typically extend over relatively large areas (Nouri and Sharifipour, 2004). Actually a geographical information system (GIS) was used to access for geography patterns (Pauleit and Duhme, 2000) as well as Nowadays, GIS have become an indispensable tool for land and resource managers (Swanson, 2003).

Land-use, in general, consists of the coordination of the relation between humans and the land and their activities on the land for the proper and long-term use of provisions for the betterment of the material and spiritual condition of the society over time. Land planning requires extensive infrastructural research and keeping the economic condition of the area under study in mind. It can be undeniably stated that land-use planning of an area without considering the socio-economic condition of that area is virtually impossible (Makhdoom, 2001). While a part of an

area in theory possibly has the potential for a certain use, it may be practically impossible to implement. Hence, socio-economic characteristics must be added to ecological potential of an area for certain uses, too. Some Scientists took into consideration both socio economic and ecological capability in land- use planning (Espejel *et al.*, 1999; Bocco *et al.*, 2001; Pierce *et al.*, 2005; Prato, 2007)

On the other hand, the lack of necessary knowledge of land potential and the irrational use of the land by humans bring about further reduction of land resources. In other words, The sustainable development or best use of the land will be carried out by assigning the land-use zones on the basis of capability, compatibility, use of proper technology and measures to protect environmental degradability (NEMA, 2004).

Bojo´rquez-Tapia *et al.* (2001) presented a GIS-based multivariate application for land suitability assessment with a public participation base was also a typical case. Oyinloye and Kufoniyi (2013) analyzed the urban land-use change, 2000 and 2010 IKONOS images were used in a post classification comparison analysis to map the land-use changes and identify the conversion process in Ikeja, GRA, Lagos. The results showed increase in commercial land-uses between the same periods. Also, the application of urban satellite images with higher ground resolution was found to be effective in monitoring the land-use changes and providing valuable information necessary for planning and research.

Peel and Lloyd (2007) consider four contemporary challenges facing land-use planning practice, and suggest that a new ethos for land-use policy making is emerging. Biswas and Baran Pal (2005) in the District Nadia, West Bengal, investigated that how fuzzy goal programming can be efficiently used for modeling and solving land-use planning problems in agricultural systems for optimal production of several seasonal crops in a planning year. Gandasasmita and Sakamoto (2007) addressed a multi-criteria analysis approach to agricultural landscape planning. This case study was conducted in the Cianjurwatershed, West Java, Indonesia. Results showed that proposed agro-ecological land-use was planned under which the land-utilization types would not cause more than tolerable soil loss, would be at least marginally suitable with regard to land resources quality, and would be economically feasible.

Current land-use planning in Iran by Makhdoom's Quantitative Method has some problems like difficulties in assessment of ecological and socio-economic information used in related scenarios. Also it is possible because of sum of scores derived from different scenarios in current model; a land-use without ecological capability is prioritized or part of city is recommended to change to a pasture. Therefore the main goal of this study is to solve these problems and develop and modify the current quantitative method of Makhdoom's Model to evaluate better land-use planning in Iran.

2 MATERIAL AND METHODS

Shiraz Township with an area of 1043380 ha is located in Fars Province and southern parts of Iran (Figure 1). This area is located between longitudes of 51° 41´ 44" and 53° 15´ 23" east and geographical latitudes of 28° 56´ 12" and 29° 51´ 06" north and with the mean height of 1540 meter above mean sea level. This area is located in mountainous area of the Zagros and has a semi-arid climate.

In this study, a systematic method known as the Makhdoom's Model based on Boolean model (FAO, 1976; Burrough *et al.*, 1992; Davidson *et al.*, 1994; Makhdoom, 2001; Baja *et al.*, 2006; Amiri *et al.*, 2010) was used for the analysis of maps in relation to the ecological and socio-economic resources of the study area. Boolean (binary) model is an overlay methodology intersected parameters based on AND (intersection) and OR (union).

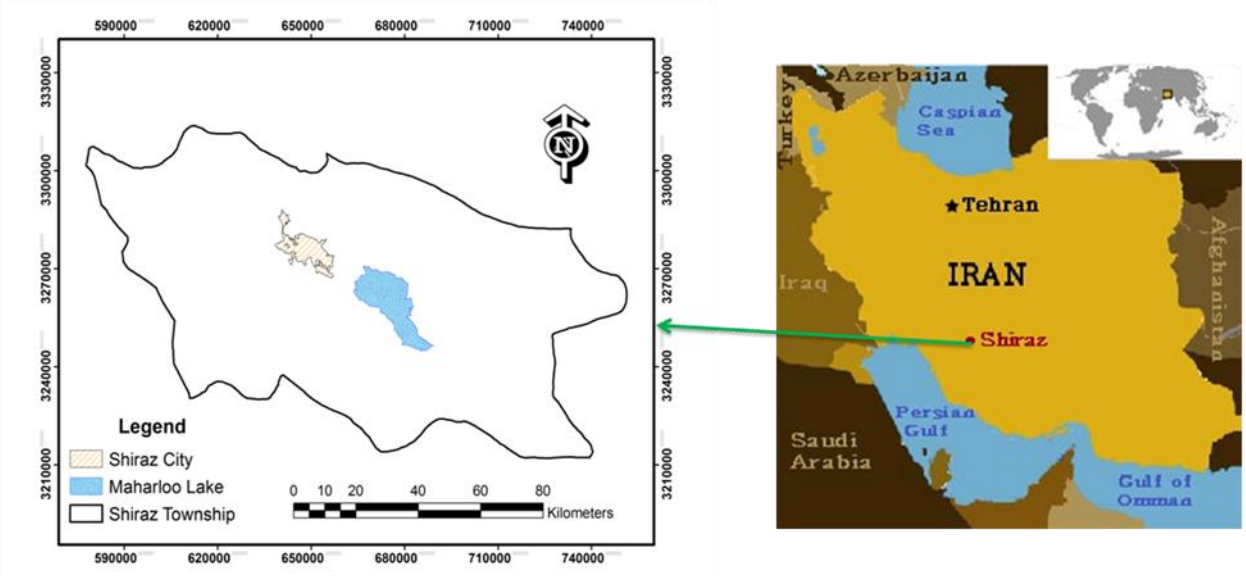

Figure 1 Position of Shiraz Township in Iran

The different kinds of maps were 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 and water resources data. These data for this study have been gathered from the records and reports published by the different departments of the Ministries of Agriculture and Energy and the Meteorological Organization of Iran. The data obtained were of two types 1) numerical and descriptive data and 2) thematic maps, but mainly in the map format with curt scale useful for the GIS analysis.

Different ecological capability models of Makhdoom's method based on ecological data were used to evaluate ecological capability of different land-uses including forest, agriculture, range, environmental conservation, ecotourism and 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 forest, agriculture, range, environmental conservation, ecotourism and development of village, urban and industry are 7, 7, 4, 3, 3 and 3, respectively. The best capability class is class one and the worst capability class is the last class in each model.

In the next step, after producing ecological capability maps, the land-use map was prepared. 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 d) ecological needs of the study area. All land-uses are ranked for each scenario and then are scored from 10 to lower based on their ranks and ecological capability. For example if in one scenario, rank of forest 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 forest in the land unit. It should say that this one point reduction for forest 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.

First scenario to make its ranking was evaluated using current land-use. But for other scenarios a questionnaire was prepared to ask from experts of study area to rank different land-uses for each scenario based on their knowledge and experience from study area. In this study, 55 experts in different studied land-uses in related organizations and offices of study area filled out questionnaires. Average related to experts' scores to every use and in every scenario, helped to rank different land-uses for each scenario. It should be noted that questionnaire method is used in order to estimation of parameters weight in AHP method, too (Hamzeh *et al.,* 2014). Questionnaire filling is a good method especially for finding socio-economic needs of an area that depends to 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 for ranking of utilizations in economic and social scenarios. On the other hand expertism evaluation of socio-economic of agriculture and natural resources and other utilizations make study very difficult.

To achieve a systematic analytical model, all maps 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. The appropriate utilizations are those utilizations that have higher sum of scores among used scenarios. Many of the units were seen fit for two appropriate uses by the systematic model to first determine and subsequently select the best utilization for the area considering the socio-economic status of the area, consistency of land-uses and current land-use.

It is necessary to say some modifications in the process of work were done like no preparation of environmental units and using current land-use map. 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 work done for assessing the land-use planning model included:

a) Prioritization of each use was done based on the highest score derived after summing the scenarios' scores (ecological, economic, social, area) (Makhdoom, 2001). But, it should be considered appropriate (suitable) capability for the utilization with highest score.

b) To use current land-use map in assessment mainly because of the socio-economic compulsions of the population especially in rural area. Like to hold the following land utilizations in the end of land-use planning process:

1) Irrigated lands with suitable capability.
2) Settlement lands (urban, rural and industrial area).
3) The Forest lands with canopy cover more than 25% and those with conservational role.
4) Lake and river bed.

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

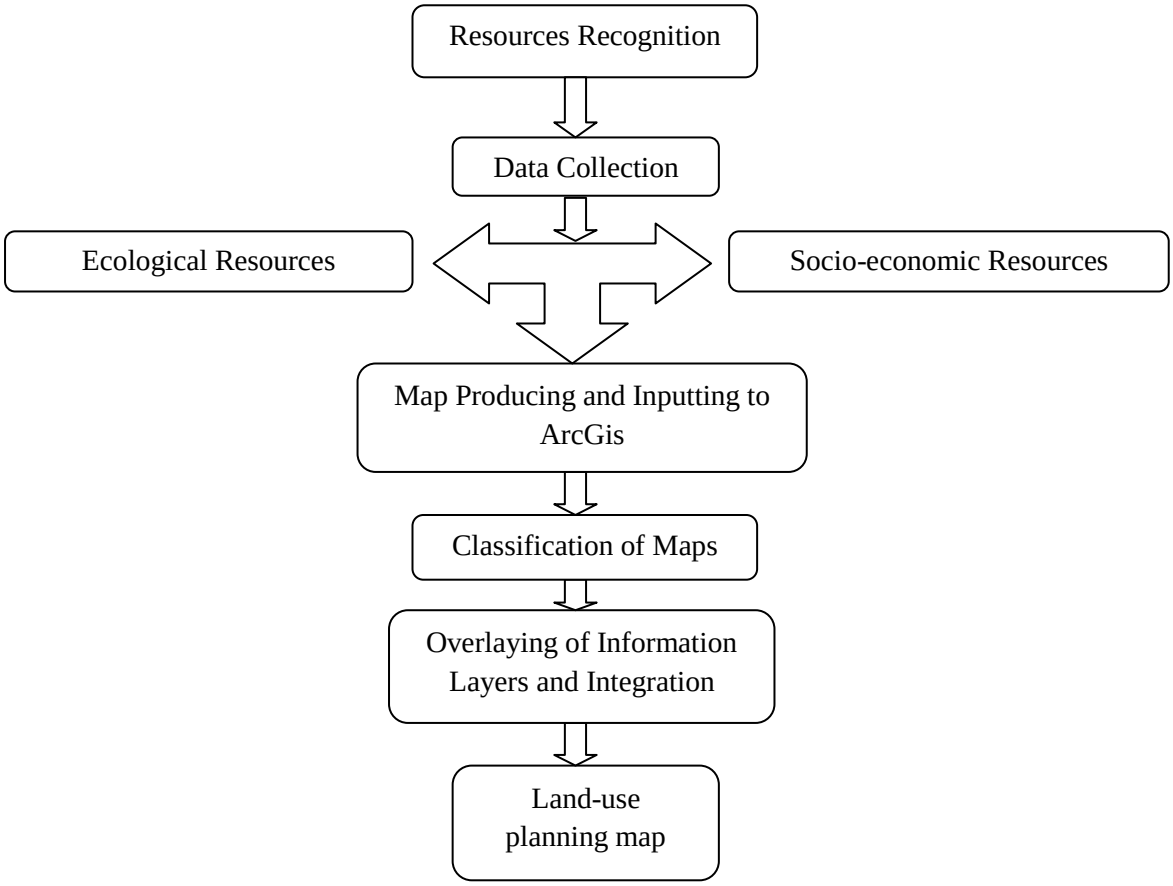

Figure 2 Flowchart showing the methodology for land-use planning adopted in the study

3 RESULTS

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 8 and percent of area for different ecological capabilities of land-uses is observed in Table 1.

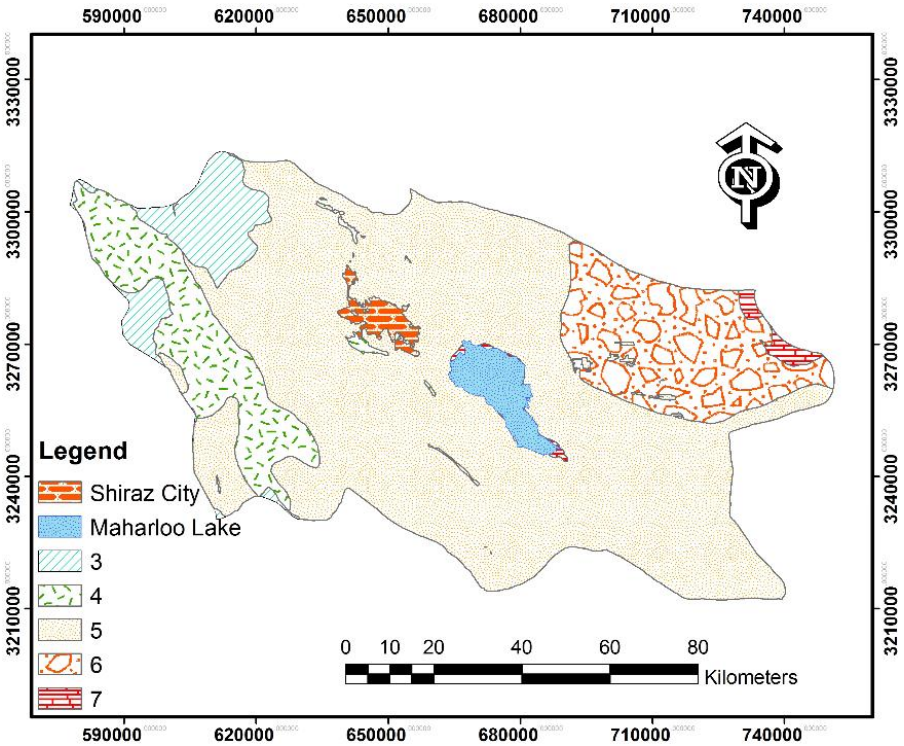

Figure 3 Land capability map for irrigation agriculture in Shiraz Township

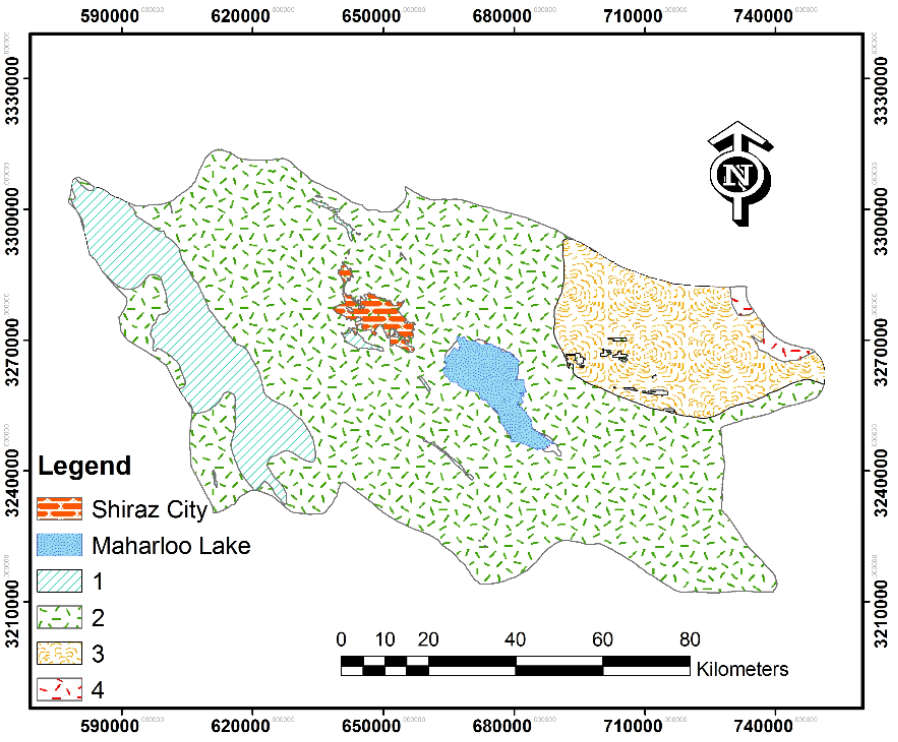

Figure 4 Land capability map for range and dry farming in Shiraz Township

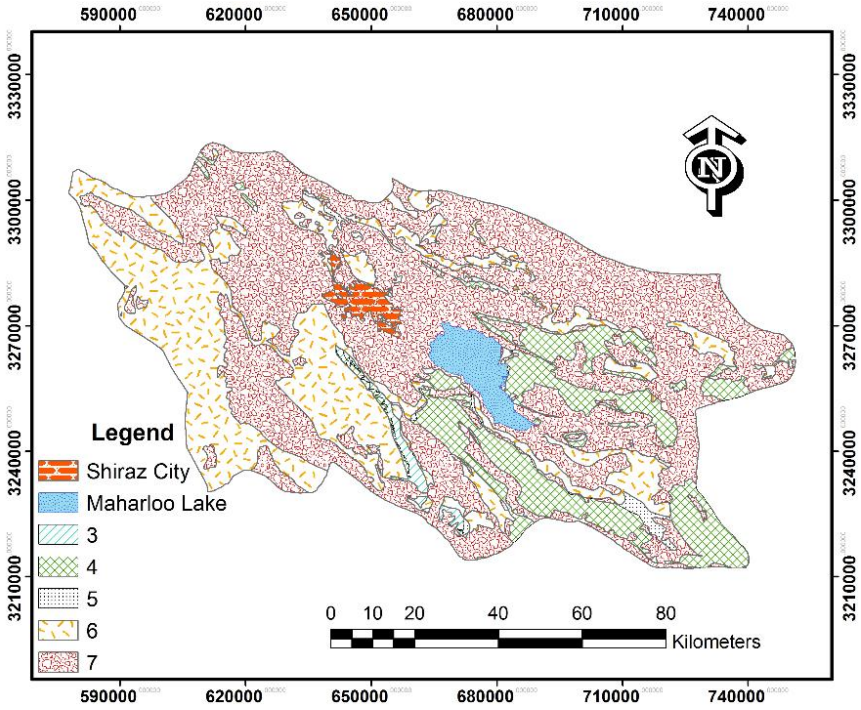

Figure 5 Land capability map for forest in Shiraz Township

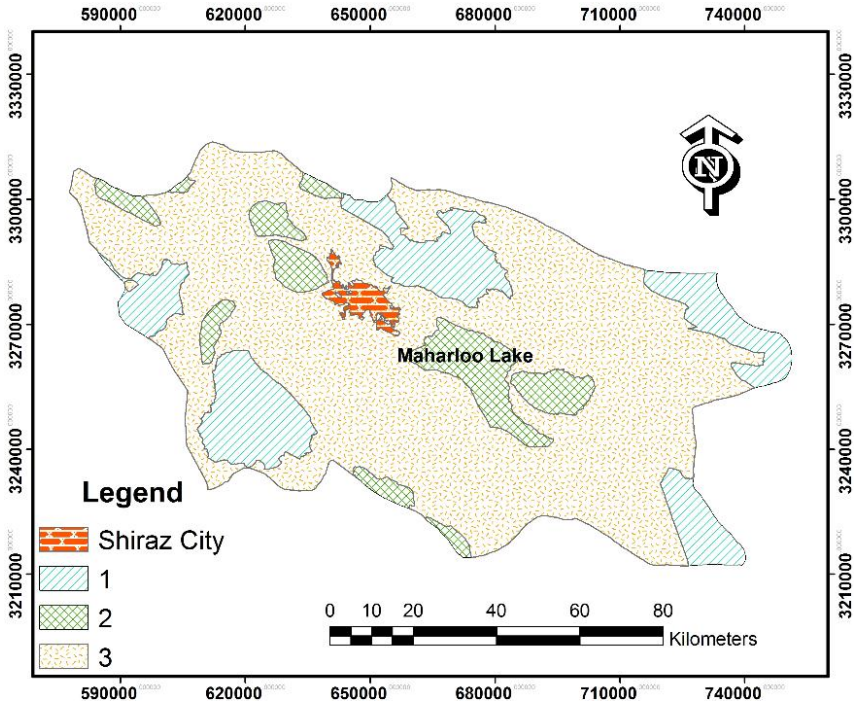

Figure 6 Land capability map for environmental conservation in Shiraz Township

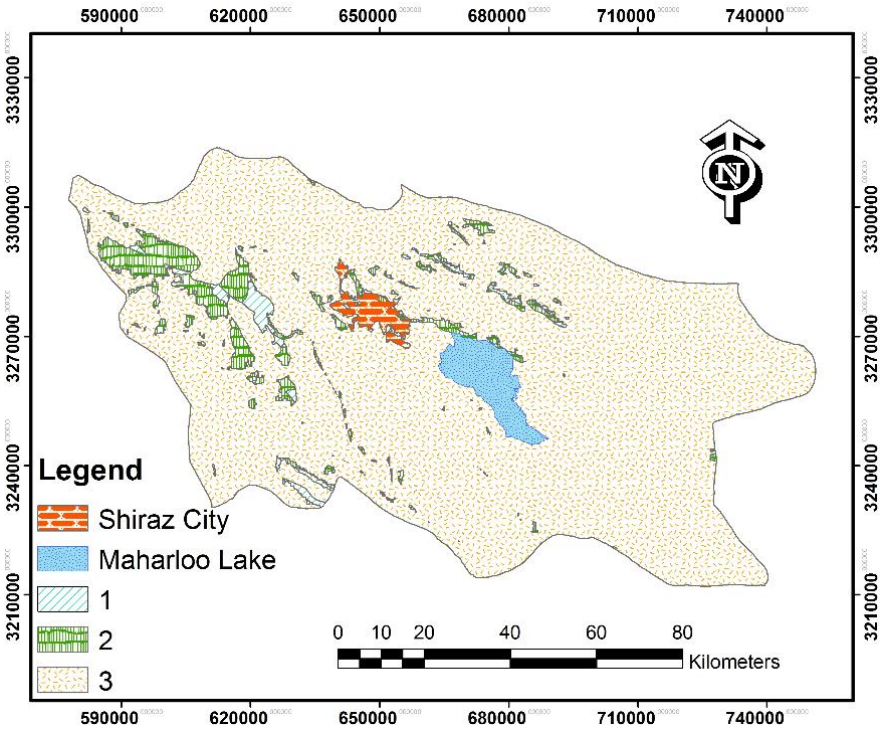

Figure 7 Land capability map for ecotourism in Shiraz Township

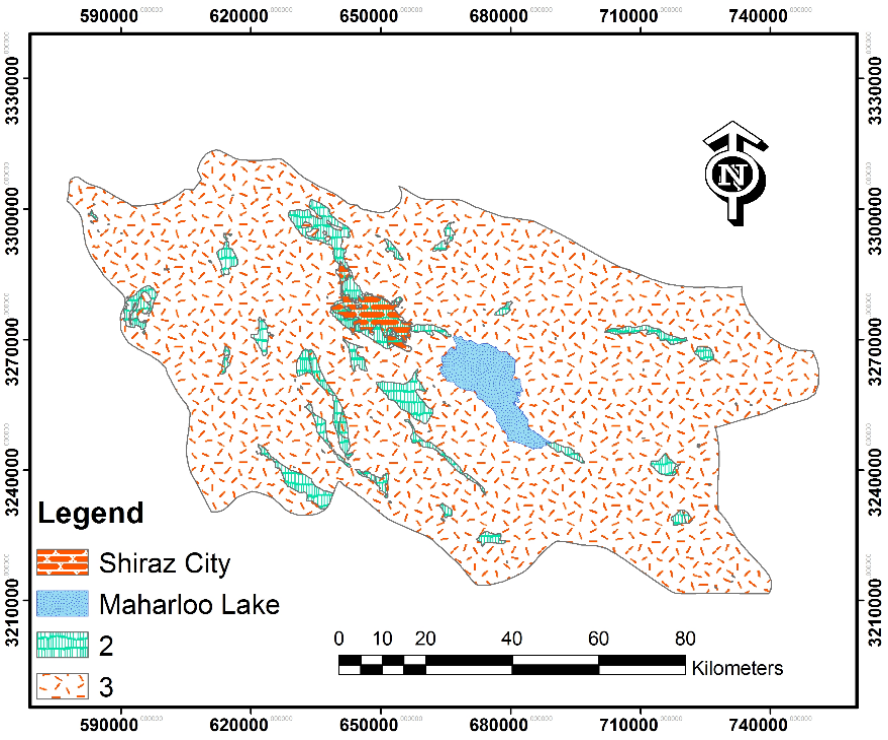

Figure 8 Land capability map for urban, rural and industrial development in Shiraz Township

Table 1 Percent of area for different ecological capabilities of land-uses

Land Type	Class	Percent
Agriculture	3	5.8
	4	10.4
	5	67.6
	6	13.4
	7	2.8
Range land and dry farming	1	10.4
	2	73.5
	3	13.3
	4	2.8
Forest	3	0.9
	4	12.7
	5	0.8
	6	26.5
	7	59.1
Conservation	1	17.4
	2	9.5
	3	73.1
Ecotourism	1	1.1
	2	4.6
	3	94.3
Development of urban, rural and industry	2	6.8
	3	93.2

Then land capability maps were overlaid and land-use planning map (Figure 9) by quantitative approach was assessed. A comparison of land percent in current land-use and proposed land-use maps is observed in Table 2. The main results from this comparison indicate that current area is more than proposed area for forest and irrigation agriculture 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, range land (and dry farming) and environmental conservation showing these land-uses are located less than their capabilities in the study area. Also Figure 9 and Table 2 show the maximum area of proposed uses is 39.3 % that is related to range and dry farming. Dry farming and range were considered together. While minimum area of proposed uses is 3.3 % that is related to irrigation agriculture with range.

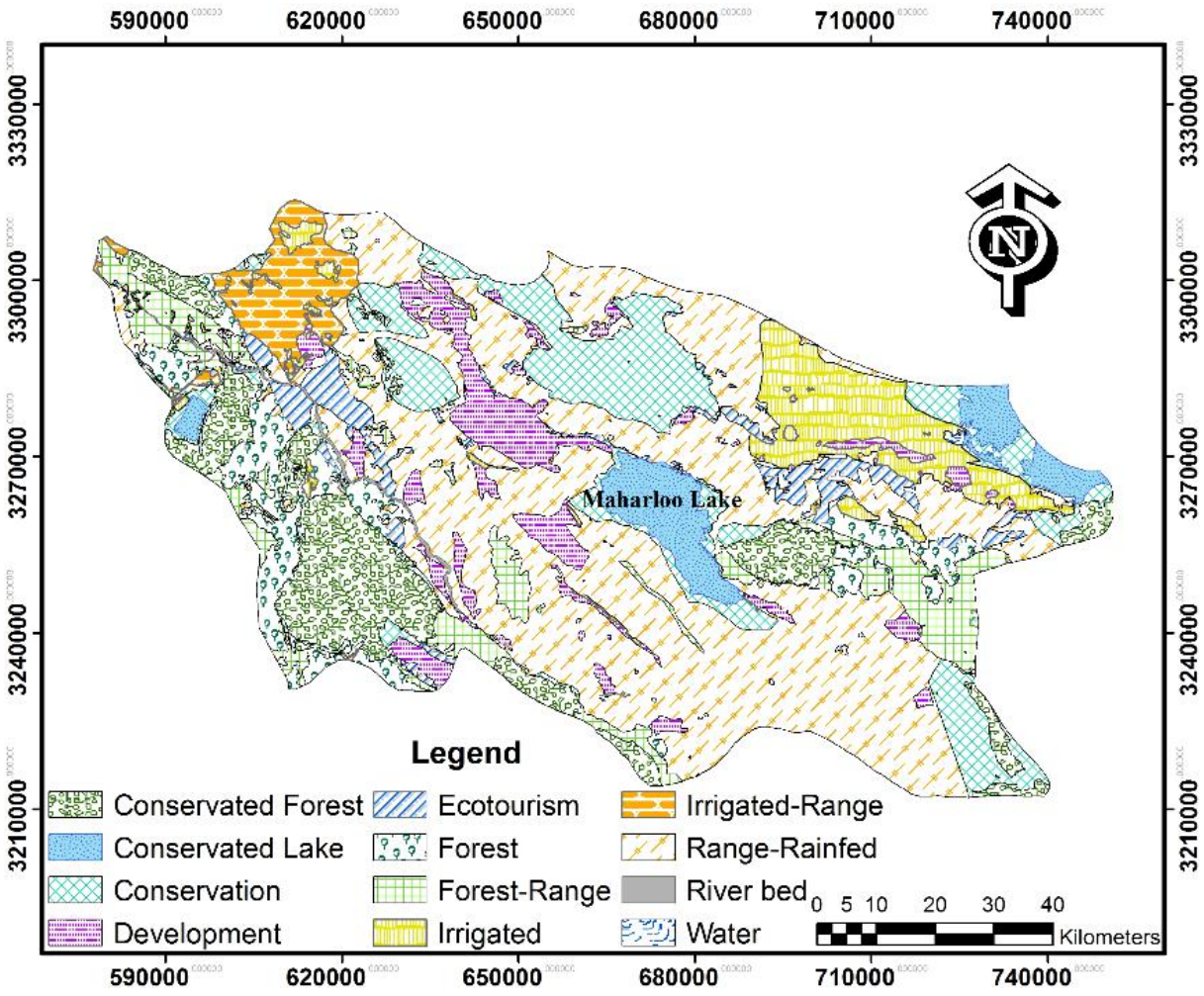

Figure 9 Land-use planning map by the proposed quantitative model in Shiraz Township

Table 2 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
Forest	24.36	5.95
Ecotourism (by natural resources)	-	3.85
Urban, rural and industrial development	1.66	6.54
Irrigation agriculture	27	6.66
Range and dry farming	40.79	39.30
Environmental conservation	17.4	12.03
Lake (Conserved lake)	4.37	4.37
Saline land	0.24	0
River bed	0.34	0.34
Conserved forest	-	10.44
Irrigation Agriculture - Range	-	3.3
Forest- Range	-	7.22
Bare land	1.24	-
Sum	100 (with conservation lands)	100

4 DISCUSSION AND CONCLUSION

Arid and semi-arid regions of Iran are undergoing rapid desertification in response to climatic variations and anthropogenic disturbances. Hence, it should be noted that establishment the best land-use in land causes land improvement. Thus there is need to improve land-use planning strategies. Causes of land degradation can be divided into natural hazards, direct causes, and underlying (indirect) causes. Direct causes are unsuitable land-use and inappropriate land management practices, for example cultivation in steep slopes (Masoudi, 2010). Some anthropogenic activities like deforestation, encroachment to rangelands for cultivation, mining and urbanization harm the natural vegetation cover and degrade land. All these activity has to be controlled by local natural resources offices based on the capacity of natural vegetation cover and land-use planning (Masoudi, 2010). In regions such as the eastern part of the Mediterranean region factors affecting land-use changes (e.g. Population and urban expansion) causes land degradation (Abu Hammad and Tumeizi, 2010). In Iran and study area are seen such status, too. Determination of the appropriate land-use for the purpose of best 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 (Bocco *et al.*, 2001; Prato, 2007).

Through employing GIS and combining the various vector layers of the area, which in reality represent its ecological resources, one can obtain a map for appropriate land utilization of the area. However, determination of priorities for appropriate land-use from obtained maps can't be adequately precise without considering the socio-economic condition of the area or the tendency of area residents to utilize the land for certain specific uses.

The capabilities maps of different uses, which represent the natural features of the land, the class can be reduced by increasing the ecological capability (Figures 3 to 8). This is displayed in agricultural and forest maps with 7 classes, urban development and ecotourism maps with 3 classes. Use of ecotourism has been investigated based on intensive ecotourism, because of the importance of it in

the study area. Based on the results obtained from this paper, the minimum and maximum percentages of the final maps of land-use planning are to forest and range Land and dry farming.

Lack of elementary classes in each model (e.g., class 1 in the model of urban development) is resulting from the approach is evaluated with Boolean logic (Table 1). 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 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 land evaluation (FAO, 1976) using maximum limitation, make 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.

Amiri *et al.* (2010) utilized two methods for assessing the ecological capability of forest 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 agreement with them, from the perspective of Boolean.

Babaie-Kafaky *et al.* (2009) showed 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.
Through examining the prepared land planning maps, we determine that we cannot only use environmental units for just a single purpose; the potential exists for multiple uses. However, in any one unit, no more than a single type of utilization can, ultimately, be implemented (Makhdoom, 2001). Hence, under special circumstances and only through considering the socio-economic conditions of the area and its resident's way of life as well as their tendency and desire to use the land for specific utilization, must the best use for each unit be determined and prioritized. 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 (Espejel *et al.,* 1999). 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 (Pierce *et al.,* 2005). In some units where one use has no advantage over another and from the priority point of view are close, multiple uses may be proposed (Makhdoom, 2001).

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

The results of this study are suggested to managers according to this land management study.

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

مسعود مسعودی[۱] و پرویز جوکار[۲]

۱- دانشیار گروه مهندسی منابع طبیعی و محیط زیست، دانشکده کشاورزی، دانشگاه شیراز، ایران
۲- دانش‌آموخته کارشناسی ارشد گروه مهندسی منابع طبیعی و محیط زیست، دانشکده کشاورزی، دانشگاه شیراز، ایران

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چکیده آمایش سرزمین علمی است که با توجه به ویژگی‌های اکولوژیکی و اقتصادی اجتماعی سرزمین نوع بهینه کاربری اراضی را تعیین می‌کند. هدف اصلی این تحقیق، ارزیابی کاربری‌های اراضی و منابع طبیعی به منظور برنامه‌ریزی و استفاده پایدار از سرزمین در آینده و با کمک سامانه اطلاعات جغرافیایی (GIS) بوده است. از این‌رو در این تحقیق از مدل رایج آمایش سرزمین دکتر مخدوم برای تجزیه و تحلیل نقشه‌های پایه و اکولوژیک منطقه مورد مطالعه استفاده شد. 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 شهرستان تهیه شد. گام نهایی تحقیق، اولویت-بندی کاربری‌ها با در نظرگیری خصوصیات اکولوژیکی و اقتصادی اجتماعی منطقه توسط یک مدل کمی بود. نتایج نشان داد که بیش‌ترین مساحت کاربری پیشنهادی (بهینه) با ۳۹/۳ درصد متعلق به کاربری مرتع و دیم بود. هم‌چنین کم‌ترین مساحت کاربری بهینه پیشنهادی با ۳/۳ درصد متعلق به کاربری کشاورزی- مرتع بود.

کلمات کلیدی: تعیین کاربری بهینه، تئوری بولین، مدل اصلاح شده مخدوم، مدیریت زمین