LAND DEDICATION FOR ECODYNAMIC DESIGN AND ECOLOGICAL CONSERVATION, A CASE STUDY

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ABSTRACT

Protected area and reserve system provide the core areas for biodiversity conservation. Establishment of protected areas is necessary for promoting sustainable management and biodiversity conservation. Protected area effectiveness, however, depends on management, monitoring, and improving protected area system design, as well as increasing local and national support. This research was conducted in the Hamadan province from 2006 to 2009. The aim of this research is to study and identify the sites in the province with appropriate capabilities for conservation under environmental management. Makhdoum's model was used for evaluation and identification of the land's potential for ecological conservation. This model was presented for the ecological conditions of Iran by Majid F. Makhdoum, an Iranian Environmentalist, in 2002. In this model, 12 parameters related to different factors are used, and each informational layer consists of several classes. The model defines the capabilities of ecological conservations of the studied area. Based on the literature review and field patrolling, only eight GIS data layers were obtained related to the studied area. The title of these layers are Habitat Trends (H_a), Biodiversity of Mammal Species (B_a), The Value of the Mammal Species (B_s), Protected Areas (P_r), Sensitive Habitats (S_i), Overall Slope (S_o), The Value of the Protective Plant Species (C_{vt}), and Hydrologic Soil Groups (P_{hg}). The software Arc View (version 3.2a) was used with the UTM projection to analyze the data. Based on our evaluation of the results, areas that may be suitable for ecological conservation were included on a map of the studied area. The total area that was suitable for ecological conservation based on these data was 189,000 hectares, which is 9.7 percent of the province area. According to these evaluations, the Hamadan province has a moderate potential for environmental conservation.
Keywords: biodiversity, conservation, ecology, environmental evaluation and planning, GIS, methodology.

1 INTRODUCTION

People are dependent on nature in many ways; it is necessary for the provision of food, water, and shelter, as well as for recreational and commercial purposes. Furthermore, nature is necessary for the preservation of species and biodiversity richness, and, as a result, it has been protected for thousands of years. However, the reasons for the protection have changed over time. Approximately 10,500 years ago, prior to the first farm settlement in the rich agricultural breeding grounds in Mesopotamia in the Middle East, people used to hunt and gather food from their territory [1]. Today, a new approach to land-use planning that focuses on the long-term health of the forest and habitats is necessary. This approach is called ecological conservation-based land-use planning. The Forest Reserves, Natural Forest Parks, Artificial Forest Parks, Natural Parks, National Parks, Wildlife refuges, National Natural Monuments, Protected Areas, Biosphere Reserves, World Heritages, Ancient Monuments, Historic Monuments, and all the habitats therein are important parts of environment, and they should be preserved and protected [2]. The lack of knowledge about the ecological potential of the land may damage the environment severely. Thus, various procedures, including frequent evaluation of the land, have been proposed to determine these ecological potentials [3]. The protected area and reserve system provide the core areas for biodiversity conservation. This reserve system is not sufficient in itself for long-term conservation, however, and it must be harmonized with conservation efforts in other areas as well as in the area of land use.

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Iran is located in the palaearctic realm and is considered the center of origin for many of the world's genetic resources. Iran is a land of diversity; the temperature ranges from −35°C during the winter in the northwest to 50°C in the summer on the Persian Gulf shoreline [4]. In Iran, habitats and areas protected by the Department of Environment (DoE) cover 8.5 million hectares [5]. Currently, the size of the DoE-supervised areas reaches over 12 million hectares (about 7.3% of the land area). The goal of the DoE is to increase this proportion to 10% of the national land area.

The Hamadan province covers an area of approximately 19,493 km^2 and is located in the west of Iran, 320 km from Tehran. The province lies at a longitude of 47°34′ to 49°36′ East and a latitude 33°59′ to 35°48′ North (Fig. 1). This province has a population of 1.7 million; the average precipitation reaches 320 mm per year and the average annual temperature is 11°C [6, 7]. The Hamadan province has six protected areas: Lashkardar, Khangarmz, Golparabad, Malosan, Almoblagh, and Nashr covering an area of 54,000 hectare which is approximately 2.7% of the total area of the province. As a result of the high population density and rapid development in the Hamadan province, separation and dedication of sites for ecological conservation is somewhat difficult.

The aim of this research is to study and identify the sites appropriate for ecological conservation and development. Makhdoum's model is used in this research. It is a linear, multi-unknown quantity model, and it is used to evaluate and identify the possibilities of land protection and conservation. This model was first presented for the ecological conditions of Iran by Majid F. Makhdoum, an Iranian Environmentalist, in 2002. The model consists of parameters relating to 12 informational layers, and each layer consists of several classes.

The model can be specified by the following structural equations [2]:

$$Ce = S_0(9,10) \tag{1}$$

Or

$$Ce = E_s(3,4,5,6,7) \tag{2}$$

Or

$$Ce = E_1(4,5) \tag{3}$$

Or

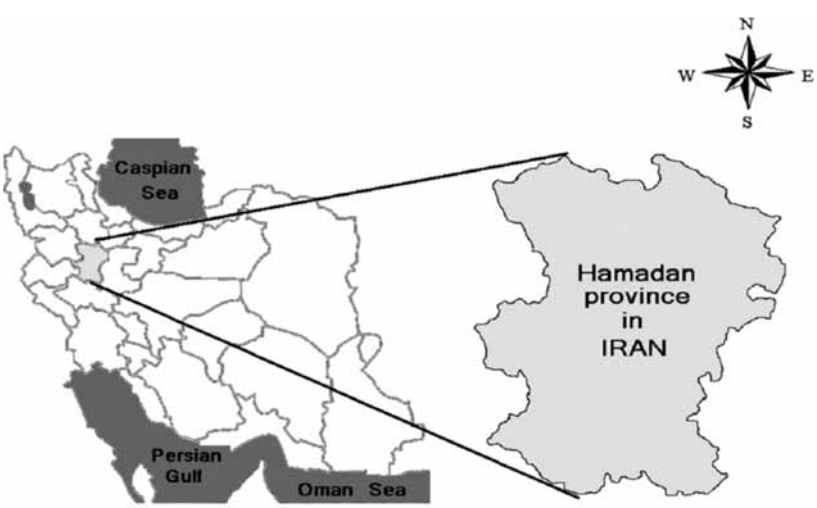

Figure 1: Geographical position of the studied area.

$$Ce = B_a(1,2) + B_s(1,2) \tag{4}$$

Or

$$Ce = P_{hg}(4) \tag{5}$$

Or

$$Ce = S_i(1,2,3,4,5,6,7) \tag{6}$$

Or

$$Ce = C_{vt}(1,2) \tag{7}$$

Or

$$Ce = H_a(1,2,5) \tag{8}$$

Or

$$Ce = H(1,2,3,4,5,6,7,8,9,11,12) + H_1(3) \tag{9}$$

Or

$$Ce = P_r(1,2,3,4,5,6,7,8,9,10,11,12) \tag{10}$$

where
Ce : Appropriate areas for ecological conservation
S_o : Overall slope as percent (in 10 classes)
E_s : Soil Erosion by water (in 7 classes)
E_1 : Stone resistance toward erosion (in 3 classes)
P_{hg}: Hydrologic Soil Group (in 4 classes)
B_a : Biodiversity of Animal Species (in 3 classes)
B_s : The Value of the Mammal Species (in 5 classes)
S_i : The Sensitive Plant Areas (in 8 classes)
C_{vt} : The Value of the Protective Plant Species (in 3 classes)
H_a : Habitat Trends (in 5 classes)
P_r : Protected Areas (in 13 classes)
H : Geohydrology (in 12 classes)
H_1 : Geohydrology related to water supply (in 3 classes)
The capabilities of ecological conservation of the land are defined in this model [5].

2 METHODS

This research was carried out in the Hamadan province from 2006 to 2009 and is still underway. Several methods have been presented for the study and evaluation of the ecological capacity of the land. In order to study and identify the land that would be suitable for ecological and environmental preservation and management in the Hamadan province, Makhdoum's model was used. In this research, the process of evaluation and identification of the land's ecological capability for conservation is presented in the following three sections [8].

2.1 Resources recognition and gathering information

First, library studies were conducted in which libraries, companies, research institutes, and ministries were used as resources in an attempt to gather all required digital maps and other information. In this

process, valid academic resources were used for the identification of mammals and tree species [9]. Following the library study, it was necessary to update the collected information by comparing field data from all of the essential areas with analyses and comparisons of the natural conditions of the lands.

2.2 Information analyses

Each area has several environmental characteristics and these characteristics may define and determine an ecological system. Therefore, an important aspect of the survey was the evaluation of the land, which included studying and analyzing the environmental characteristics [10]. Since the applied model in this evaluation is Makhdoum's model, the information obtained was analyzed and classified based on the format of the model.

2.3 Evaluation

Evaluation of the ecological capability is the determination of the potential of land with respect to ecological conservation. Due to lack of available information, only eight environmental parameters were used in this model. To study and identify the lands with appropriate ecological capability for conservation in the studied area, a Geographical Information System (GIS) was used as the main tool [11]. The software used was Arc View (version 3.2a) with a Universal Transfer Mercator (UTM) projection system. WGS84 was used as a datum and ellipsoid plan for the Global Positioning System (GPS) and the scale was 1/250,000.

In this research, the overlay method was used to implement the model [12]. After collecting and classifying information, digital information layers were harmonized. Following the preparation of digital information, Arc View was used to classify the layers accompanied with the base layer of the province itself according to the applied model. The layers were then changed from their vector data to raster data with the "convert to gird" command in Arc View. Furthermore, the cell size was set to 100 m, causing the operation to be highly accurate. The Map Query command was then used for each parameter and the extent of interfering overlapping between the cases was later analyzed using the multiple map query commend (Fig. 2).

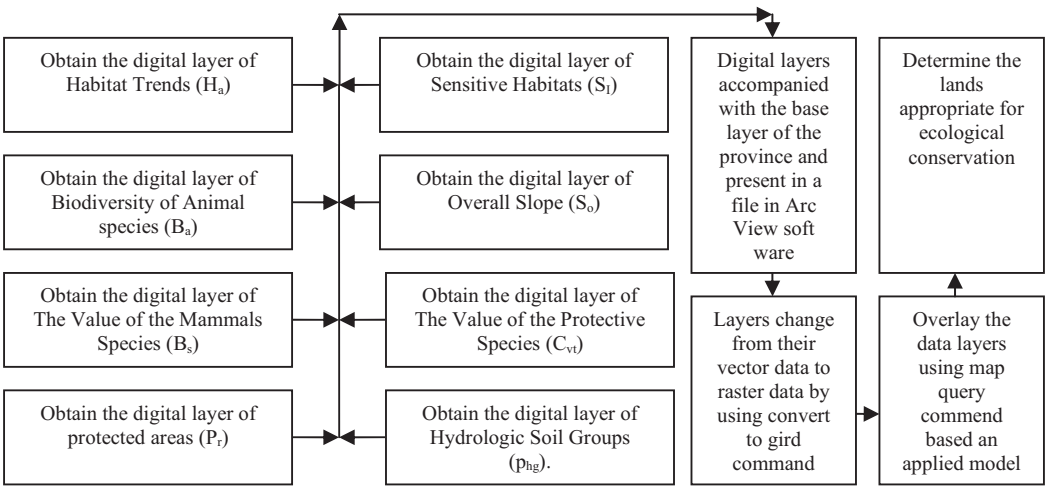

Figure 2: Simplified procedure of the research method used in this study.

3 RESULTS

Eight digital information layers (digital maps) were used based on the classifications and groups predicted by Makhdoum's model. The particulars of these layers are shown in Figs 3–10. The prepared information includes the following items.

3.1 Habitat trends (H_a)

A habitat is the aquatic and terrestrial environment required for a plant or an animal to complete its life cycle. It includes air, food, shelter, water, and several other requirements. Habitat trend is the expected status of the habitat in the future. It indicates the effectiveness of preservation and maintenance of habitat and how much amendment is needed. Table 1 shows the classification of habitat trends based on Makhdoum's model. Habitats can be aquatic, earth, underground, or aerial. Underground habitats include caves, artificial cavities, and the roots of plants. These habitats are full of water and sometimes animals seek out the favorable living conditions that they offer. Habitat trends are a management indicator that determines the direction of change in the habitat over time. The habitat trends of the Hamadan province have been studied and classified based on Makhdoum's model (Fig. 3), which uses a classification system with five classes.

Table 1: Classification of H_a [2].

Characteristics	Class	Area of province in %
Excellent	1	1.8
Ordinary	2	39.6
Poor	3	53.2
Degraded	4	2.8
Vulnerable	5	2.6

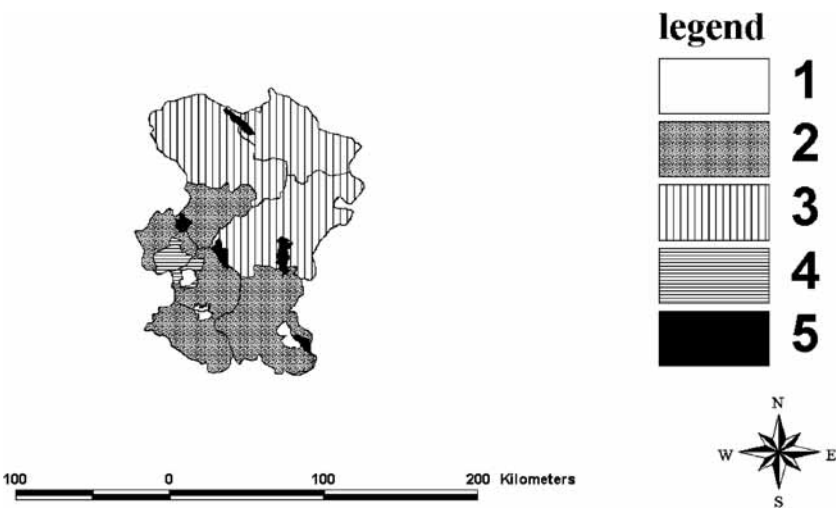

Figure 3: Characteristics of H_a in the studied area.

Table 2: Classification of B_a [2].

Number of animal species per hectare	Class	Area of province %
10–14	1	3.8
6–9	2	4.8
2–5	3	91.4

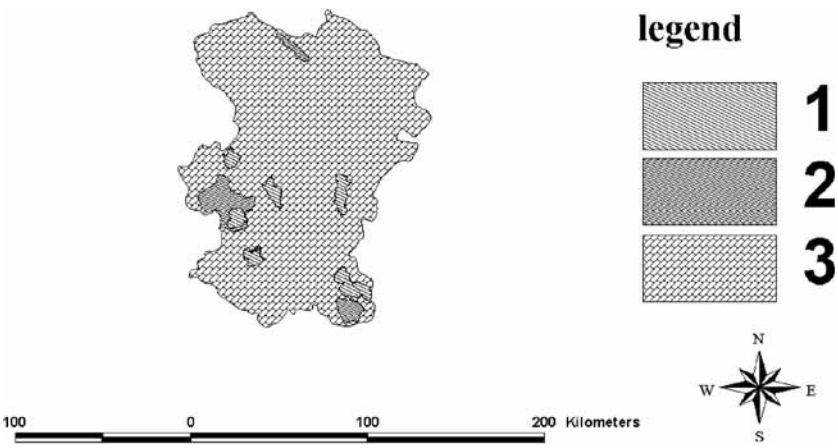

Figure 4: Characteristics of B_a in the studied area.

3.2 Biodiversity of animals (B_a)

Biodiversity is vital for human survival and livelihoods, and it is necessary to conserve it for future generations. The climatic diversity of Iran has resulted in 7576 plant species, 517 bird species, 208 reptile species, 170 fish species, and 22 amphibians [7].

Table 2 shows the classification of Biodiversity of Animals (B_a) based on Makhdoum's model. Biodiversity of animals is very useful to us, and in the model used for this research, this feature is divided into three partitions. The province has been studied and classified into three categories based on the results of this research (Fig. 4).

3.3 The value of the nammal species (B_s)

All mammals are at risk of habitat loss. However, the nature and degree of the threat vary regionally, and threatened land mammals are concentrated in South and Southeast Asia. Table 3 shows the classification of the Value of the Mammal Species (B_s) based on Makhdoum's model, which places the mammal species of Iran in five different classes. Based on this research, the status of animal species of the province, particularly in protected areas, has been identified and the information has been compiled as digital maps (Fig. 5).

Table 3: Classification of B_s [2].

Mammals	Class	Area of province %
Cheetah (*Acinonyx jubatus*), Persian wild ass (*Equus hemionus*), Persian fallow deer (*Dama mesopotamica*), red deer (*Cervus elaphus maral*), roe deer (*Capreolus capreolus*), North Persian leopard (*Panthera pardus saxicolor*), goitered gazelle (*Gazella subgutturosa*), jebeer gazelle (*Gazella bennettii*)	1	1.9
Wild goat (*Capra aegagrus*), wild sheep (*Ovis orientalis*), gray wolf (*Canis lupus*), stone marten (*Martes foina*), wild cat (*Felis silvestris*), brown bear (*Ursus arctos*)	2	8.2
Common fox (*Vulpes vulpes*), badger (*Meles meles*), striped hyaena (*Hyaena hyaena*), least weasel (*Mustela nivalis*)	3	6.9
Wild boar (*Sus scrofa*), Indian crested porcupine (*Hystrix indica*), Persian squirrel (*Sciurus anomalus*), golden jackal (*Canis aureus*), Afghan pika (*Ochotona rufescens*)	4	54.9
Hedgehog (*Paraechinus hypomelas*), Eurasian pygmy shrew (*Sorex minutus*), Kuhl's pipistrelle (*Pipistrellus kuhlii*), hare (*Lepus europaeus*) and other rodents	5	28.1

3.4 Protected areas (P_r)

Protected areas are important to the conservation of Biodiversity [13]. A protected area is an area of public land that the government has declared as a preserved area under the legal provisions. These areas contain ecological, historical, and cultural attractions that make protection necessary. Table 4 shows the classification of protected areas based on Makhdoum's model, which uses 13 classes of protected areas. The protected areas of the province were studied and classified based on Makhdoum's model (Fig. 6).

3.5 Sensitive habitats (S_i)

Sensitive habitats, or endangered ecosystems, are designed to minimize adverse impacts on the resource. Table 5 shows the classification of Sensitive Habitats based on Makhdoum's model, which

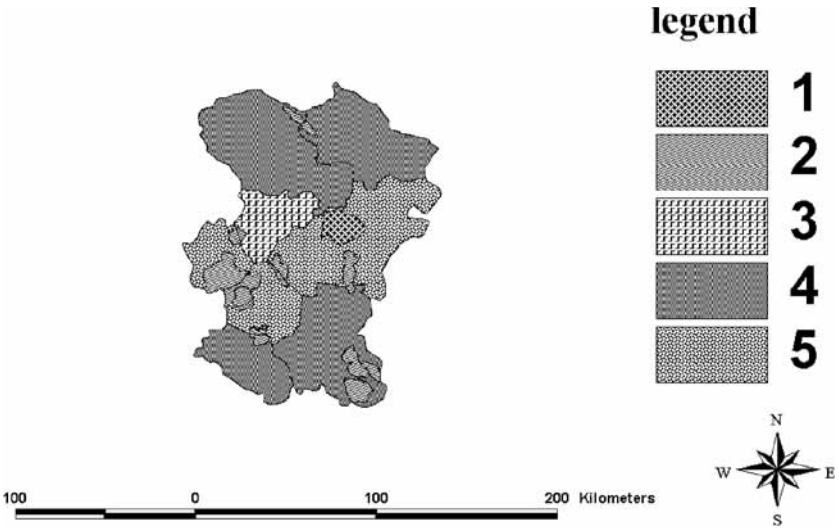

Figure 5: Characteristics related B_s in the studied area.

Table 4: Classification of P_r [2].

Characteristics	Class	Area of province %
Forest Reserves	1	0.01
Natural Forest Parks	2	0.01
Artificial Forest Parks	3	0.0
Natural Parks	4	0.0
National Parks	5	0.0
Wildlife refuges	6	0.0
National natural monuments	7	0.0
Protected landscape	8	8.5
Biosphere Reserves	9	0.0
World Heritages	10	0.0
Ancient Monuments	11	0.7
Historic Monuments	12	0.8
Others	13	89.98

uses the following eight classifications: wetlands, river bank, mangrove, savanna, coastal hills, forest, firth, and others. The Hamadan province has no river banks and there are no mangroves, coastal hills, or savanna in the province. The studied area has forest regions covering approximately 35,000 hectares and a few small wetlands, some of which are dry in the summer. In this research, the cases related to forests and wetlands have been studied despite the small area. The status and area of the sensitive habitats are shown in Fig. 7.

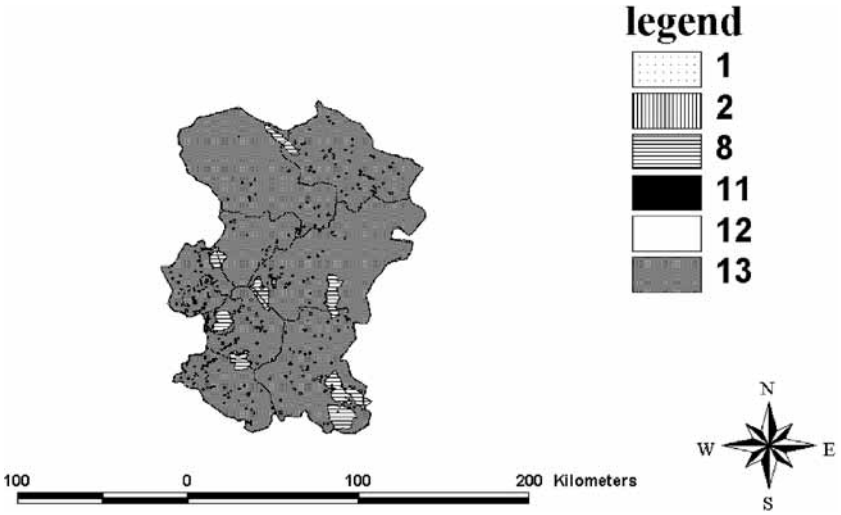

Figure 6: Characteristics of P_r in the studied area.

Table 5: Classification of S_i [2].

Characteristics	Class	Area of province %
Mangrove	1	0.0
Firth	2	0.0
Wetland	3	0.2
Savanna	4	0.0
River bank	5	0.0
Coastal hill	6	0.0
Forest	7	1.2
Others	8	98.6

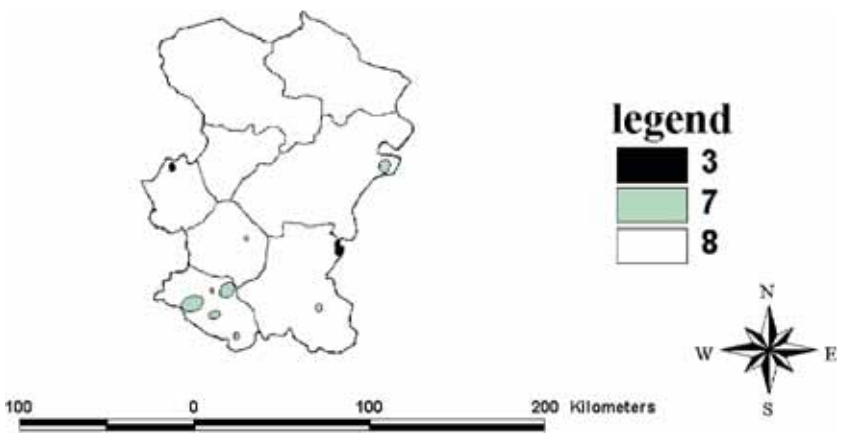

Figure 7: Characteristics of S_i in the studied area.

3.6 Overall slope (S_o)

Topography status is an effective measure of soil quality, water resources, plant growth, communication network, and many environmental parameters, and, as a result, Makhdoum's model pays special attention to this parameter. The model uses 10 classifications for the overall slope (Table 6). The status of the overall slope of the province has been studied, and the related information has been prepared with the contour information and is presented in Fig. 8.

3.7 Value of the protective plant species (C_{vt})

Table 7 shows the classification of the Value of the Protective Plant Species based on Makhdoum's model. In this model, the Value of the Protective Plant Species has been classified into three groups.

Table 6: Classification of S_o [2].

Slope (%)	Class	Area of province %
0–2	1	47
2.1–5	2	18
5.1–8	3	8
8.1–12	4	6
12.1–15	5	1
15.1–20	6	6
20.1–25	7	3
25.1–40	8	7
40.1–65	9	3
65+	10	1

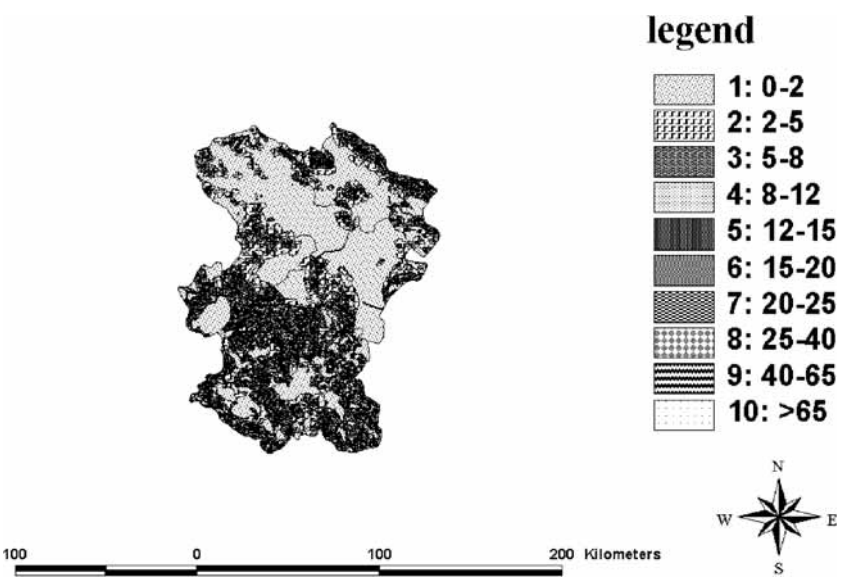

Figure 8: Characteristics of S_o in the studied area.

Table 7: Classification of C_{vt} [2].

Name of plants	Class	Area of province %
Common yew (*Taxus baccata*), box tree (*Buxus hyrcana*), poplar (*Populus caspica*), cypress (*Cupressus sempervirens*), mountain ash (*Sorbus torminalis*)	1	0.0
Greek uniper (*Juniperus excelsa*), arbor vitae (*Thuja orientalis*), common juniper (*Juniperus communis*), black mangrove (*Rhizophora mucronata*), montpelier maple (*Acer monspessulanum*), mazzard cherry (*Cerasus avium*), Persian oak (*Quercus brantii*), pear tree (*Pyrus communis*)	2	0.1
Other species	3	99.9

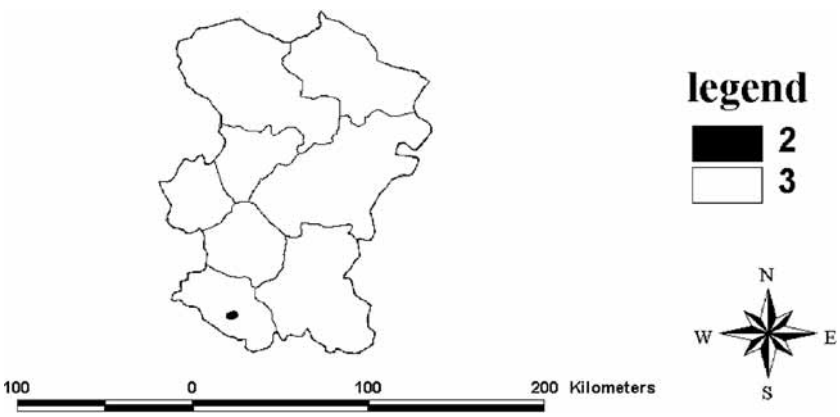

Figure 9: Characteristics of C_{vt} in the studied area.

Based on the results of this research, the species of the first group of this layer is not present in the Hamadan province and the species of the second group are only present in limited numbers in forest regions of Nahavand woodlands (Fig. 9). This parameter is mainly important in forest areas. Due to the limited forest regions in the Hamadan province, less attention is focused on this parameter than on others.

3.8 Hydrologic Soil Groups (P_{hg})

In the United States, the Soil Conservation Service (SCS) classifies the soil into four Hydrologic Soil Groups based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C, and D. Group A generally has the smallest runoff potential and group D has the greatest. The definitions of the four classes are the following.

3.8.1 Soils with low runoff potential (A)
Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep well-drained to excessively well-drained sands or gravels.

3.8.2 Soils having moderate infiltration rates (B)
Even when thoroughly wetted, and consisting chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures.

3.8.3 Soils having slow infiltration rates (C)
Even when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures.

3.8.4 Soils with high runoff potential (D)
Soils having very slow infiltration rates, even when thoroughly wetted, and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay layer at or near the surface, and shallow soils over nearly impervious material [14].

Hydrologic groups are used in equations that estimate runoff from rainfall. In Makhdoum's model, the Hydrologic Soil Group classification is presented as many important factors. Soils related to the mentioned area have been studied and classified based on this model (*Table 8*). The status of Hydrologic Soil Groups of the province is presented in Fig. 10.

Table 8: Classification of P_{hg} [2].

Soil class	Class	Area of province %
A	1	0.3
B	2	6
C	3	44.4
D	4	44.3

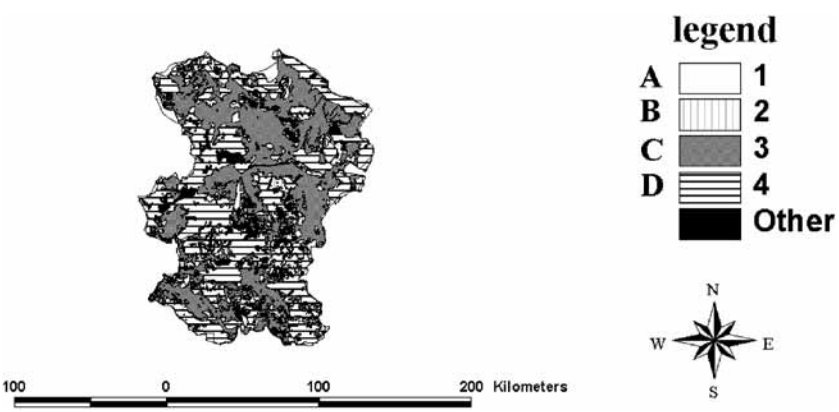

Figure 10: Characteristics of P_{hg} in the studied area.

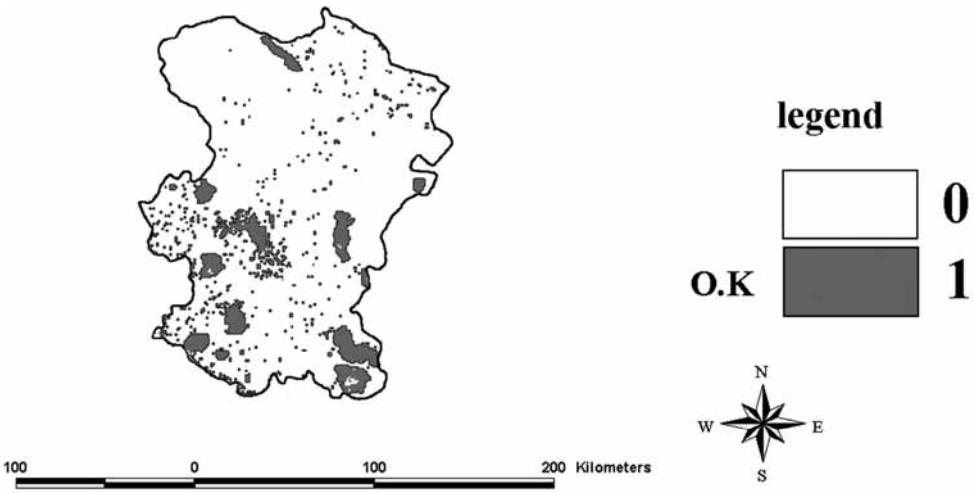

Figure 11: Appropriate areas for ecological conservation in Hamadan province.

4 EVALUATION RESULTS

The basis of Makhdoum's model is a systemic analysis. Therefore, the studied area is divided into several micro-ecosystems, each with its own special ecological capability. Based on the results of this evaluation, the areas appropriate for conservation activities in the province are equal to 189,000 hectares (9.7 percent of the province area) and these areas are shown in Fig. 11.

5 DISCUSSIONS

Land conservation programs vary according to their purpose and size as well as the organization running them. Some organizations aim to preserve ecological resources while others provide recreation [15]. This research has led to a new framework for land dedication for ecological conservation. This case study showed that spatial data and temporal data are actually important in environmental management. Makhdoum's model was used to analyze the data. The results demonstrated that land-use planning and ecological capability evaluation can be used to determine many of the management issues related to protected areas. The results recommend areas for protected area status in the Hamadan province. The validity of obtained results was evaluated and validated by filed patrolling. The results represented high accuracy in estimating the land dedication for ecodynamic design and ecological conservation in the studied area. Indeed, six protected areas in Hamadan province were situated within the borders of the results of this evaluation.

Geneletti and Iris reported that the protected area zoning is a decision-making issue that requires the evaluation of multiple objectives [16]. To promote transparency and to facilitate communication with stakeholders, a clear step-by-step methodology needs to be adopted. Natalie and Ban applied a decision support tool for marine protected area design in two regions of British Columbia and Canada, and sequentially excluded the datasets with the most limited geographic distribution [17]. It was determined that the reserve selection method was accurate, in spite of some missing datasets. The removal of upper layer significantly changes the geographic patterns of the importance of areas for conservation. Indeed, including abiotic datasets plus at least 12 biotic datasets resulted in a spatial pattern similar to the special pattern obtained when including all available biotic datasets. The most accurate representation of both habitats and species was

obtained when abiotic and biotic datasets were combined. The clustering patterns differed when one set was used alone compared with those when both sets were used in combination. Biotic datasets served as better surrogates for abiotic datasets than vice versa, and both represented more biodiversity features than randomly selected reserves.

GIS and digital data were used for this research, making analysis of information precise and quick. The use of a GIS played a major role in this evaluation and site selection. The methodology of this study can be compared with a similar study done in the Golbasi Specially Protected Area, which is located 20 km from the center of Ankara in Turkey. This study used GIS for analysis of the hydrologic landscape structure, permeability of the soil structure, permeability of the geological structure, and finally determining the conservation zones of the Golbasi district [18].

According to the evaluations, the Hamadan province has moderate potential for environmental conservation. The authors believe that this model would be applicable for other provinces in Iran, as well.

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