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Full Length Research Paper

Application of geographic information systems in land-use suitability evaluation for beekeeping: A case study of Vahregan watershed (Iran)

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Decisions on land use have become progressively more difficult in the last decade. The main reasons for this development lie in the increasing population combined with an increasing demand for new land and resources and in the growing consciousness for sustainable land and resource use. The objective of this paper is to incorporate the concept of multiple land use into geographic information systems (GIS)-based land suitability analysis using the Food and Agricultural Organization (FAO) approach. The effective environmental factors and vegetation parameters on apiculture were described as map layers within GIS so that each map layer represented one alternative. Three alternative land suitability patterns for beekeeping are presented. The study indicated that decreasing nectar or pollen species and shortening of the flowering period were the most limiting factors in land suitability for beekeeping. In contrast suitable distribution of water resources, the good climate condition and dominant unpalatable species by over grazing with extended flowering period increased the land suitability for beekeeping. Generally, 54% of the area had an acceptable score of excellent suitability for beekeeping. Therefore, apiculture may have an important role in increasing and promoting better land use.

Key words: geographic information systems (GIS), Food and Agricultural Organization (FAO), land-use suitability analysis, landscape pattern, apiculture.

INTRODUCTION

Land should be used based on its capacity to meet human needs and ensure the sustainability of ecosystems. Improper land use due to changing needs and pressures leads to the destruction of land resources and an increase in poverty and other social problems (FAO, 1976, 1977, 1995a, b; Duc, 2006; Cengiza and Cengiz, 2009). Improper land-use problems are observed to be widespread. These problems can be resolved by realizing the sustainable use of natural and human resources with a rational land-use plan (Hopkins, 1977; Collins et al., 2001; Malczewski, 2004; El-Nahry and Khashaba, 2006). The fundamental principle of sustainability is to ensure the most suitable land use considering the properties of the land and the needs of users (Prakash, 2003; Abdul Mohit and Mahmud Ali, 2006). The suitability of land for specific purposes is assessed by suitability analysis (FAO, 1985; Rossiter, 1996; Aly et al., 2005). Land suitability analysis aims at identifying the most appropriate future land uses in a region according to specific sets of requirements and preferences (Collins et al., 2001; Dai et al., 2001; Malczewski, 2004; Geneletti et al., 2010).

Geographic information systems (GIS) has long been used as a tool for developing alternative uses of agricultural land, precision farming, crop yield or land suitability mapping (Noor Maris et al., 2008). Suitability analysis is one of the most useful applications of GIS for spatial planning and management (Collins et al., 2001; Malczewski, 2004). The analysis aims at identifying the most appropriate spatial pattern for present and future land uses according to environmental factors, specify

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requirements, preferences, or predictors of some activities (Hopkins, 1977; Collins et al., 2001). In general, the GIS-based land suitability analysis assumes that a given study area is subdivided into a set of the basic units of observations such as polygons or rasters. Then, the land-use suitability problem involves evaluation and classification of the areal units according to their suitability for a particular activity (Amiri, 2009, 2010a; Amiri and Arzani, 2010b). Over the last 100 years or so, Iranian rangelands were used only as a source for livestock grazing. Amiri (2011a) employed the FAO (1991) method to evaluate the suitability of rangelands for livestock grazing. The results of this study showed that, due to uncontrolled exploitation over the years, the majority of severely degraded rangelands, and income from rangelands to provide livelihood for villagers and nomads whose lives depended on these resources, was not enough.

The overall goal of integrated catchment management is to sustain a healthy ecosystem for the enrichment, health and well being of future generations (Itami et al., 2000). Planning of protected areas requires the evaluation of multiple land attributes according to multiple objectives. In the present research, land-use suitability analysis for beekeeping was carried out as a one of the aspects of rangeland use, which not only contributes to sustainability of the system, but also helps the community in social and economic development, using the GIS Module. This case study was conducted at the Vahregan watershed area in Iran. GIS was employed using the Food and Agricultural Organization (FAO) approach and suitable land-use types were mapped. The approach demonstrates the use of GIS-based land suitability assessment for potential beekeeping.

MATERIALS AND METHODS

Study area

The experiment was conducted in 2009 and 2010 at Vahregan village of Zagros rangeland in the upland area of central Iran (56´-33°, 48´N, 50°, 00´-50°, 12´E; altitude 2200 to 3135 m). The local climate is semi-arid, with a mean annual temperature of 10°C ranging from 3.1°C in winter to 16.7°C in summer and with a mean annual rainfall of 542 mm over the study period (Figure 1). The catchment covers an area of 25,012.4 ha. It is characterised by extremely diverse soil types and topography, making it suitable for a wide variety of land-use. Currently, about 73.34% of the village area is devoted to rangeland and perennial horticulture, as well as pastures (Amiri 2011b).

Primarily, the beekeeping land use alternatives are environment factors, vegetation cover and water resources. The criteria for these alternatives were based on expert knowledge (from environmentalists, agricultural engineers, forestry engineers, range managers, agricultural organizations, universities, and natural resource and environmental organizations) and a questionnaire was developed from which a model structure was established for the study (Figure 2). Criteria were determined for apicultural land-use and their suitability values were assigned by the FAO (1991) method in order to identify the spatial data. FAO (1993) had also suggested three methods to define different degrees of land-use suitability for special utilizations. In the present study, the "limited available conditions in land quality assessment" method was used to define different suitability levels. Based on the least limiting degree for each determining factor in land-use suitability, a separate suitability map was created.

For understanding land potentials for beekeeping activity, primary maps including vegetation map, topography, geology, soil, water resources, roads and access paths need to be provided (Amiri et al., 2011c). The vegetation was determined randomly within 30 quadrates (2 × 1 m). Attractive indices of each plant were determined by direct observation and calculating the average of the number of bees and the length of time that each bee spent on the flowers (Faghih et al., 2005; Rastgar et al., 2007; Amiri et al., 2011c). The diversity of attractive index of nectar and pollen species was determined by Shannon and Weaver (1963) index. Environmental parameters were obtained from synoptic weather Fridenshahr stations and then isotherm precipitation and temperature maps were created. The MICROSTATION software was used to separate the road data layer from digital topographic map scales of 1:25000. Employing the MICROSTATION software and Arc-GIS 9.2, available water distribution maps were extracted (Amiri, 2009). An erosion criterion was determined based on the EPM model:

$$Z = Y.\ Xa\ (\psi + I^{0.5}) \quad (1)$$

Where Z is the erosion severity index, Y is the sensitivity of soil and bedrock to erosion, Xa is the land use index, Ψ is the erosion index of the watershed, and I is the average gradient of the slope (Ahmadi, 2006).

The suitability values obtained were incorporated into the GIS to calculate suitability classes of the land mapping units for apicultural land-use. The scores obtained from this calculation were classified and designated as highly, moderately and marginally suitable or as unsuitable. Suitability maps were produced based on this classification for the three alternatives and were then overlaid into a GIS to produce the synthesized suitability map.

RESULTS AND DISCUSSION

The study area contained 10 vegetation types: three shrub communities, one grass community, one forbs community and five botanical compositions of shrubs, forbs and grass communities (Figure 3). *Astragalus adscendens* and *Ferula ovina* are the two largest vegetation types in the study area (covering 36.39 and 16% of the area, respectively), which are located in the eastern and southern parts of the region (Table 1). According to models determined by the FAO method, the alternative for beekeeping development in Vahregan village locality was supported by vegetation parameters (composition and attraction for a honey bee and flowering period), environmental factors (temperature, precipitation and road availability rating) and water resource's availability. Suitability maps were produced for each criterion (Figures 4 to 6). The ratios of land highly suitable in terms of water resource's availability, environmental and vegetation criteria were 72.9, 33.12 and 50.2%, respectively (Table 2). Thus, the environmental criteria, vegetation cover and water resources criteria are important factors in the development of beekeepers in the

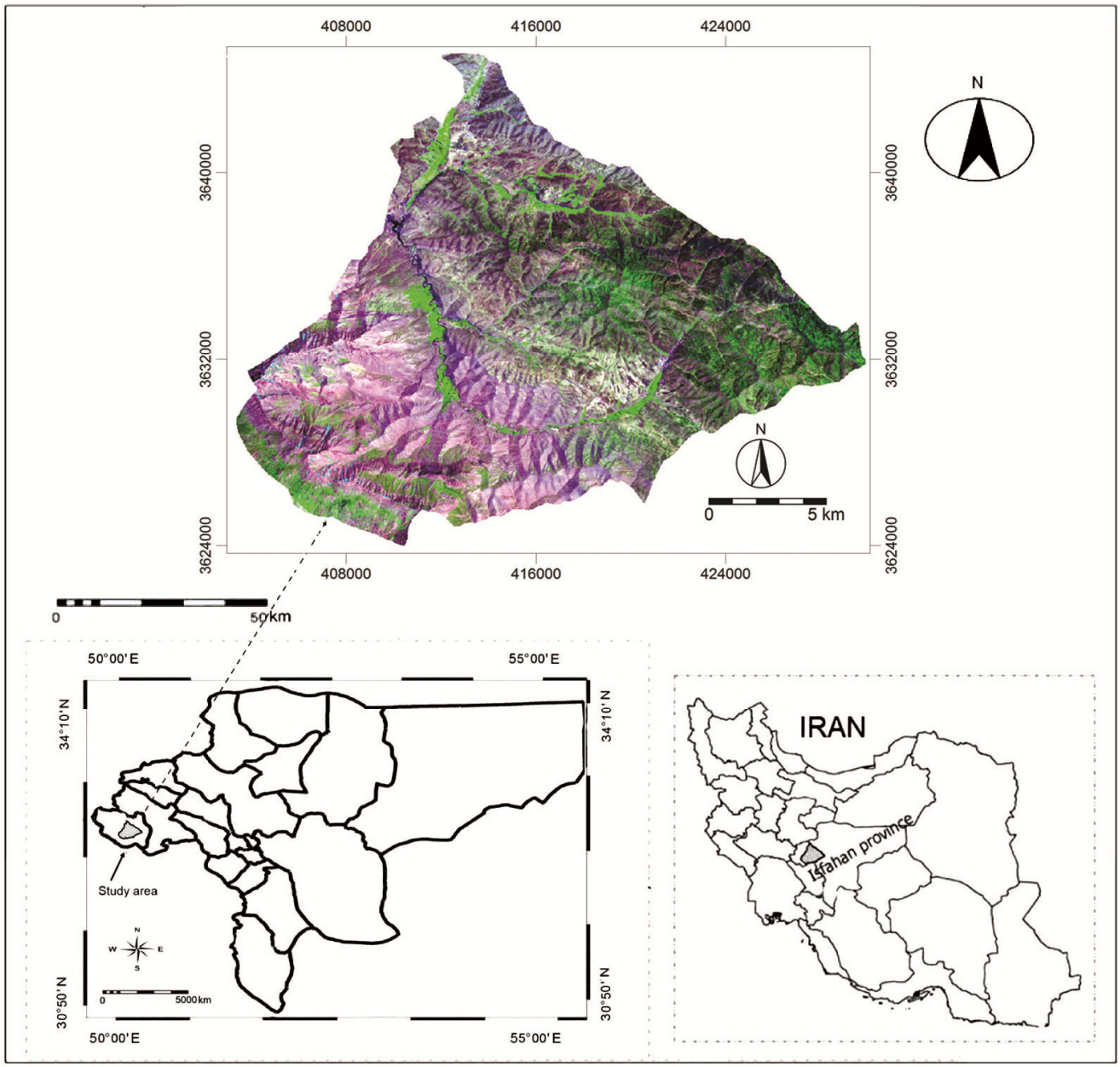

Figure 1. Location map of the study area (the image is a colour composite of IRS p6-listri bands 1,2,3 as red, green, and blue).

area. Eastern parts of the study area are more suitable for apiculture activities (Figure 7), and these lands correspond to the plains with abundant pollen and nectar plants (vegetation density with more than 40 percent cover).

Furthermore, in this part of watershed, water resources distribution was more favorable. However, there are significant differences between the present and proposed apicultural land use (Table 3). The land used for apicultural purposes in the study area covers 408 ha even though not all of the area is suitable for beekeepers. Although beekeeping is the most important economic activity, this area is insufficient to enable local people to make a living since the land potential has not been taken into account and advanced apicultural methods are not applied. According to the analyses, the most suitable areas for apicultural use are located in the western and southern parts of the plain (Figure 7b). However, there is no apiculture in the present land use pattern (Figure 7a), and almost all suitable land for apiculture has been allocated for livestock grazing. Thus, all parts of the range area function as pasture and the favorable vegetation are destroyed by livestock grazing. Conversely, dominant unpalatable species as a consequence of over

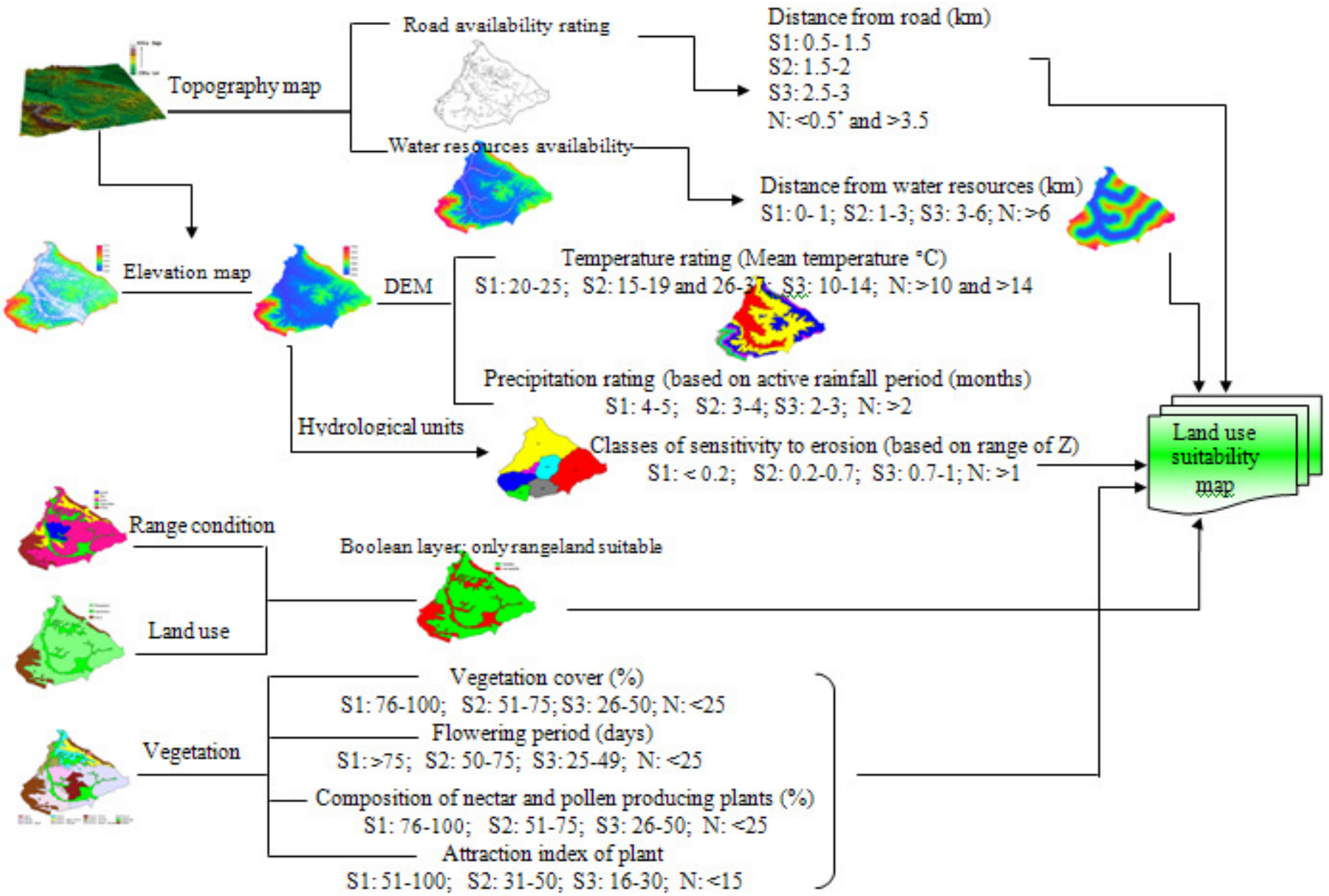

Figure 2. Hierarchical model for selection of beekeeping as a sustainable land-use. S1: Highly suitable; S2: moderately suitable; S3: marginally suitable ; N; not suitable.

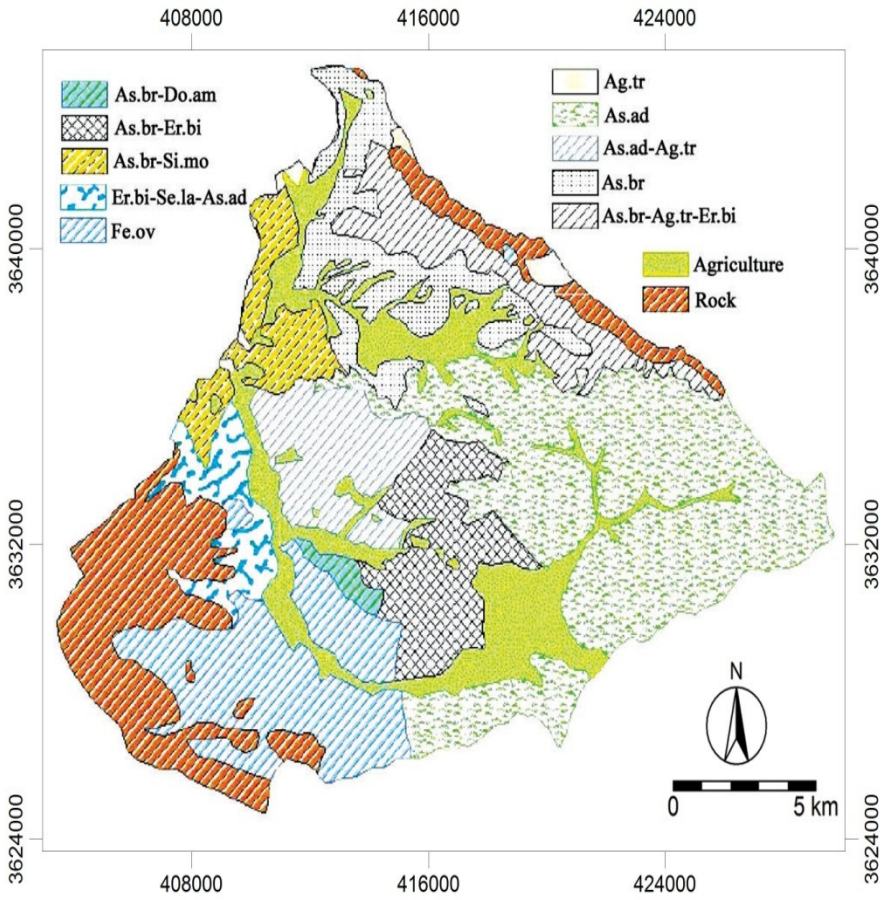

Figure 3. Vegetation map of the study area.

Table 1. Vegetation types in the study area.

Number	Vegetation type	Area (ha)
1	*Agropyron trichophoum*	206.46
2	*Astragalus brachycalyx*	1,857.68
3	*Astragalus brachycalyx- Agropyron trichophorum-Erngium billardierii*	1,293.84
4	*Astragalus adscendens*	6,676.61
5	*Astragalus brachycalyx - Eryngium billardierii*	1,759.61
6	*Astragalus adscendes - Agropyron trichophorum*	1,533.35
7	*Astragalus brachycalyx - Dorema ammoniacum*	183.74
8	*Eryngium billardierii - Serratula latifolia - Astragalus adscendens*	850.97
9	*Ferula ovina*	2,931.52
10	*Astragalus brachycalyx - Silene conoidea*	1,052.42
Total rangeland area		18346.2

grazing had increased the land suitability for beekeeping. According to the proposed land use (Figure 7b), 5804.5 ha was suitable for beekeeping, and 11863.63 ha of the rangeland generally utilized for livestock grazing could be turned into beekeeping, therefore removing pressure on the rangeland.

Land assessment requires consideration of a comprehensive set of factors and a balance of multiple objectives in determining the suitability of a particular area for a defined land use. Unsuitable land use leads to the destruction of natural resources and causes many problems. In order to prevent emergence of such

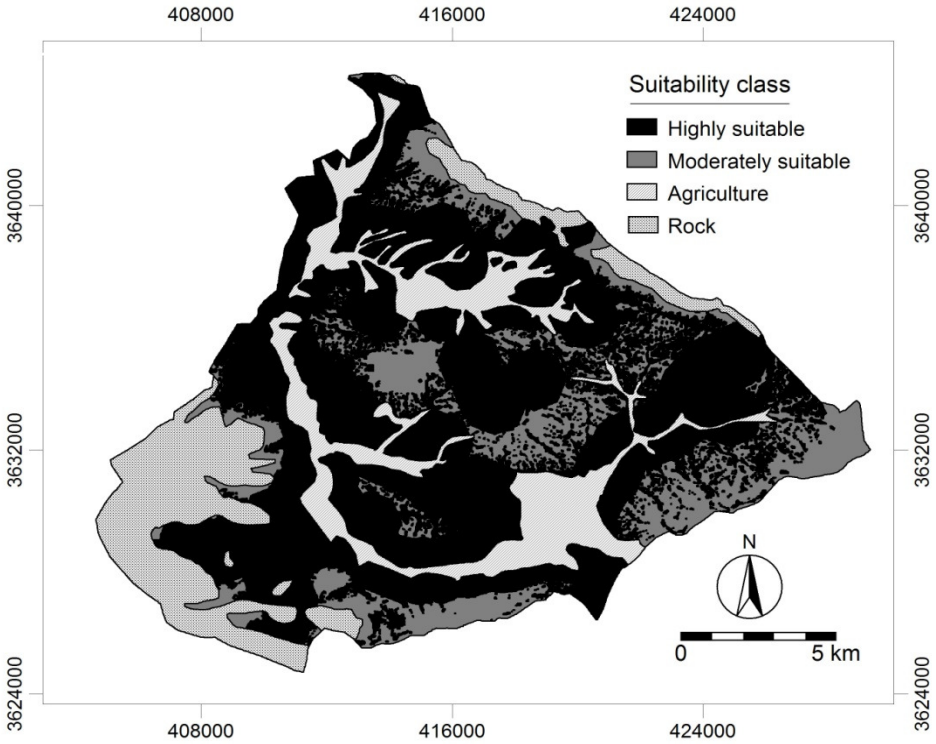

Figure 4. Water resources suitability map for beekeeping.

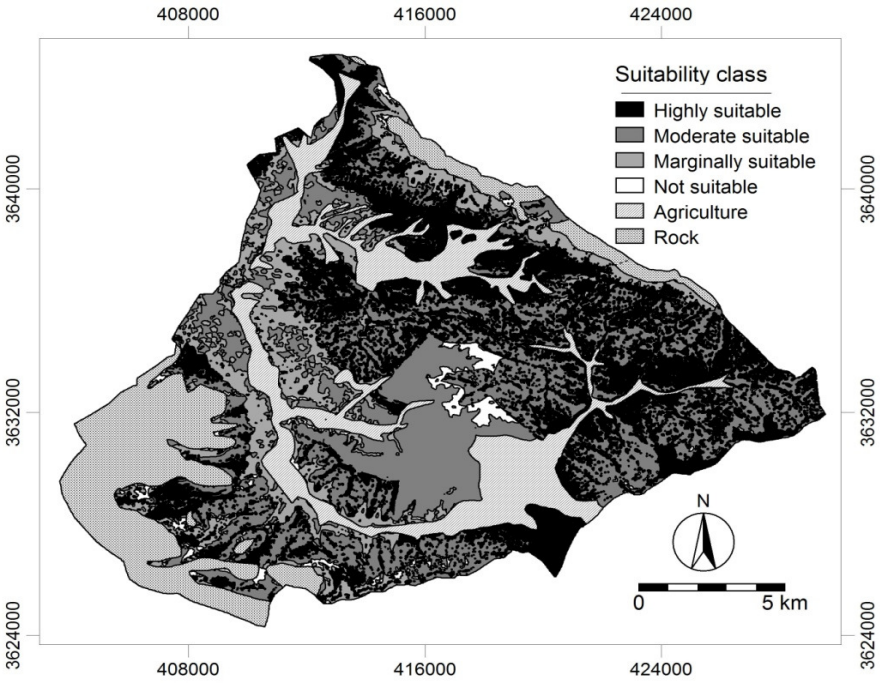

Figure 5. Environmental factors suitability map for beekeeping.

problems land suitability evaluation studies should be conducted based on the land potential and local needs. In land suitability evaluation for beekeeping, it was necessary to consider a complex array of critical factors drawn from technical and environmental disciplines. Noor Maris et al. (2008) discusses the application of GIS and

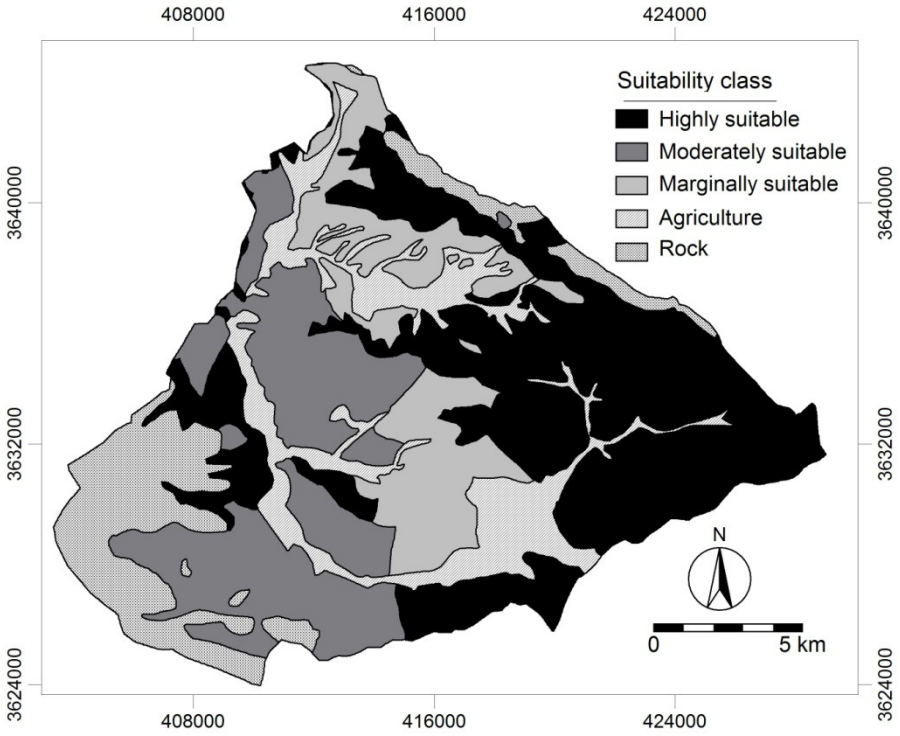

Figure 6. Vegetation suitability map for beekeeping.

Table 2. Area of rangeland under different suitability levels with respect to water resources, environmental factors, and vegetation composition criteria.

Suitability class	Water resources		Environmental factors		Vegetation	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Highly suitable	13377.91	72.9	6077.61	33.12	9211.62	50.2
Moderately suitable	4968.29	27.1	8547.05	46.58	5517.29	30.07
Marginally suitable	-	-	3043.54	16.58	3617.29	19.17
Not suitable	-	-	678	3.7	-	-
Total rangeland area	18346.2	100	18346.2	100	18346.2	100

MCDA technology as a tool to aid decision-making in a case study to locate beekeeping zones in the state of Selangor. Land suitability analysis and zoning was carried out with respect to the bee's need and some other important factors (e.g. water availability, road access, topography, nectar and pollen species class). The results of the analysis indicated that 34.73% of study area was classified as unsuitable area, leaving the remainder as potential areas.

The conceptual framework of this study was to increase income of local users and decrease the pressure on the rangeland, while considering the physical suitability conditions. The contribution of GIS was considered not only as a method for data gathering but also as a tool for visualizing a composite overlay map. The results of the study showed that water resources distribution and temperature were not limiting factors for beekeeping land use suitability. The roads and path ways were a limiting factor in some parts of the area. Over grazing was the most important limiting factor in beekeeping, as the density and composition of the nectar and pollen species were decreased. Land used for apicultural purposes in the study area covers 408 ha even though not all are suitable for beekeeping. In a similar study, vegetation cover (flowering period and attraction for honey bee), soil (by indirect effect on the vegetation cover), roads and paths (access to different vegetation types), and altitude and temperature were equally effective in the apicultural model (Amiri et al., 2011c). All vegetation types were mostly located around the villages at lower altitudes and were heavily damaged due to over grazing by livestock. The sparse vegetation cover of these sites was mostly

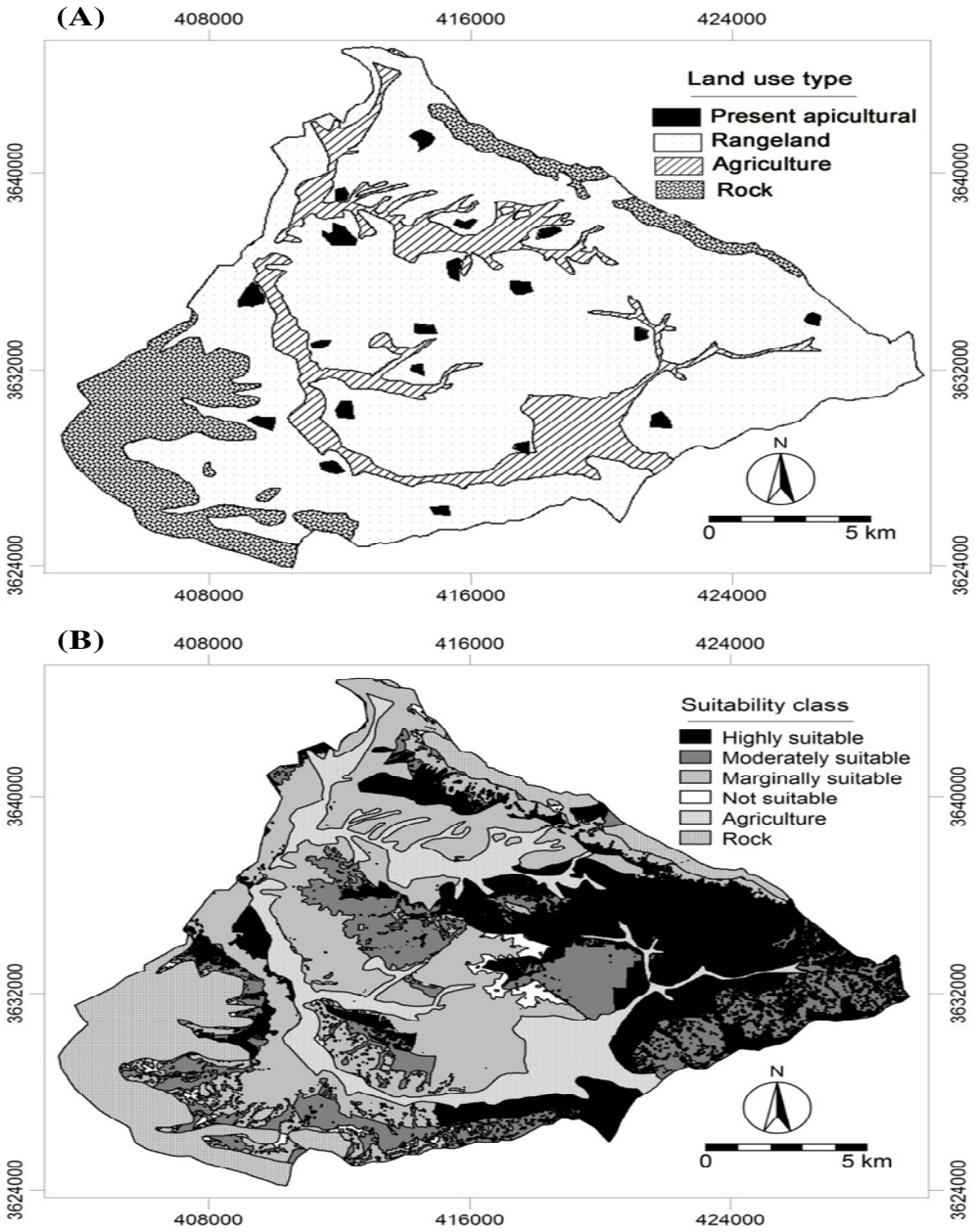

Figure 7. Present apicultural land use (A) compared with proposed apicultural land-use suitability (B).

comprised of annual, poisonous and roughage plants with low palatability and quality. However, a few of the species are useful to honey bees among which, *Thymus kotschyanus*, *Salvia limbata* and *Astragalus* species arenoticeable.

Conclusion

The presence or absence of nectar and pollen producing plants was considered as an important suitability factor in a research by Safaeian (2005). However, in the present study, the presence of nectar and pollen producing plants was considered only as a pre-requisite for further studies on them. In addition to the vegetation cover, composition of vegetation, attraction class, flowering period and the amount of nectar produced should also be measured for an accurate assessment of suitability of the vegetation community. Early and over grazing by livestock in the western parts of this study area were the most important factors resulting in a significant reduction in forage production and soil erosion, and also had caused

Table 3. Present and proposed apicultural land-use.

Suitability class	Present		Proposed	
	Area (ha)	%	Area (ha)	%
Highly suitable	73.84	0.4	5804.57	31.64
Moderately suitable	96.18	0.52	4164.98	22.70
Marginally suitable	207.14	1.13	7698.65	41.96
Not suitable	30.64	0.17	678	3.70
Total rangeland area	18346.2	100	18346.2	100

destruction in flowering plants which adversely affected apiculture activities.

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