| Cuadernos de Investigación Geográfica *Geographical Research Letters* | 2021 | Nº 47 (2) | pp. 545-556 | EISSN 1697-9540 |
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http://doi.org/10.18172/cig.4291

# AN MCE-BASED INNOVATIVE APPROACH TO EVALUATING ECOTOURISM SUITABILITY USING GIS

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**ABSTRACT.** Geographic Information System (GIS) can be used in ecotourism as a decision support tool for sustainable tourism planning, impact assessment, visitor flow management, and tourism site selection. Therefore, this system has the potential to be widely applied in tourism. The purpose of the study was to explore the potential for ecotourism development using GIS in Sepidan region, placed in the southwestern part of Iran. An innovative method was proposed for adjusting effective parameters in evaluation of ecotourism. The methods used for evaluation comprised Boolean, current multi-criteria evaluation methods (weighted linear combination), and the proposed methods of geometric mean and its calibration. Results showed that an improved method using geometric mean (kappa= 0.72) was better than Boolean (kappa= 0.56) and multi-criteria evaluation (kappa= 0.59) models. The calibrated geometric mean was also the best among the different models used. It should be noted that the geometric mean method was simpler than multi-criteria evaluation and did not require the weighting process.

## *Una aproximación innovadora basada en MCE y SIG para evaluar la idoneidad del ecoturismo*

**RESUMEN.** Para el estudio del ecoturismo los Sistema de Información Geográfica (SIG) pueden ser utilizados como una herramienta de apoyo para tomar decisiones en la planificación del turismo sostenible, la evaluación del impacto, la gestión del flujo de visitantes y la selección de áreas turísticas. En consecuencia, este método tiene potencial para ser ampliamente aplicado a la actividad turística. El objetivo del estudio es explorar el potencial para el desarrollo del ecoturismo en la región de Sepidan, localizada en el suroeste de Irán, utilizando SIG. Un método innovador se aplicó para ajustar los parámetros útiles en la evaluación del ecoturismo. La metodología utilizada para la valoración incluyó métodos Booleanos, de evaluación multi-criterio (combinación lineal ponderada), y métodos de media geométrica y su calibración. Los resultados mostraron que un método mejorado usando la media geométrica (kappa= 0,72) fue más apropiado que los modelos Booleanos (kappa= 0,56) y de evaluación de criterios múltiples (kappa= 0,59). La media geométrica calibrada también fue la más idónea entre los diferentes modelos utilizados. Cabe señalar que el método de la media geométrica fue más simple que la evaluación de criterios múltiples y no requirió el proceso de ponderación.

**Keyword:** Ecotourism, MCE, Geometric Mean, Evaluation, Boolean.

**Palabras claves:** Ecoturismo, MCE, Media Geométrica, Evaluación, Booleano.

Received: 13 June 2019

Accepted: 5 June 2020

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## 1. Introduction

For a sustainable development of a region, it is important to consider the interest of its local population. Ecotourism involves visiting the nature without damaging it and disturbing habitats. In terms of ecotourism development, researchers have recently begun to examine the role of local residents in ecotourism activities. Due to the development of alternative forms of ecotourism, these activities have attracted the interest of governments, communities, and researchers. However, environmental conservation plays an important role in ecotourism development. Many scholars now agree that ecotourism requires a two-way link between tourism and environmental conservation (Ryngnga, 2008). Therefore, ecotourism has to be developed in a planned approach where Geographical Information System (GIS) and spatial decision-making tools can act as decision support systems. Spatial decision-making tools can be considered as a good framework for land suitability across a landscape via the actual data, criterion outcomes, and preferences and decisions of various stakeholders and. As a result, multi-criteria evaluation (MCE) methods can assess decision-making alternatives for future land-use planning (Malczewski and Rinner, 2015).

MCE is a well-known method for spatial decision making in the field of geography (Voogd, 1983; Carver, 1991; Jankowski, 1995; Thill, 1999). This method is comprised of a multitude of evaluation criteria and a preference weighting scheme to evaluate decision-making alternatives. There are various MCE methods for assessing land use suitability, including simple additive scoring (SAS) (Massam, 1988; Heywood *et al*., 1995), multiattribute value technique (MAVT) (Pereira and Duckstein, 1993; Keeney, 1996), multiattribute utility technique (MAUT) (Janssen and Rietveld, 1990; Keeney and Raiffa, 1993), analytic hierarchy process (AHP) (Banai, 1993; Jankowski, 1995; Najafinezhad *et al*., 2013; Pourkhabbaz *et al.,* 2014), ordered weighted average (OWA) (Yager, 1988; Jiang and Eastman, 2000; Malczewski *et al*., 2003; Malczewski, 2006), and outranking methods (Kangas *et al*., 2001; Joerin *et al*., 2001). MCE methods determine realistic results through their spatial variations in aggregation structures and weighting schemes.

Multi-criteria decision making (MCDM) methods have significantly advanced the conventional map overlay approaches to land-use suitability analysis (Zarei and Alsheikh, 2012; Oyinloye and Kufoniyi, 2013). Generally, a problem associated with land use suitability analysis methods is they do not assure a spatial pattern with contiguity or compactness in land allocations for different land use types. Furthermore, these methods are difficult to use while land suitability maps must be consistent with ground truth, and evaluation methods should be simple.

The main objective of this paper was to implement a simple innovative and quantitative model and its comparison to the current MCE approaches for ecotourism planning.

## 2. Materials and Methods

### *2.1. Study area*

With an area of 286,000 hectares, Sepidan is situated northwest of Fars province, Iran. It is located between 51° 59' east longitude and 30° 15' north latitude (Fig.1). Its ten-year average rainfall is 758 mm, with approximately 35% and 65% of evenly distributed snow and rain, respectively. It is very cold in the winter and cool and mild in the summer. “From the contemporary technicalities of climatic classification and general populace, this city is considered cool and moist to semi-dry” (Goudarzian and Yazdani, 2015). Of note, Sepidan is one of the most well-known ecotourism locations in Iran. Figure 1 represents a sketch of the area.

The present study aimed to provide a planning method for evaluating ecotourism suitability. Hence, GIS was employed to analyze the obtained data, which were of two types, namely numerical and thematic, mainly in map format. All the relevant data were obtained from the local and main offices and institutes of the Ministries of Agriculture and Energy and thoroughly processed using GIS techniques.

The boundaries of maps were modified by Google Earth images and Global Positioning System (GPS) tools along with field work. The criteria evaluated based on expert opinion and primary model (Makhdoum, 2006), included topography, climate, soil and geology, vegetation, water, and conservation of environment.

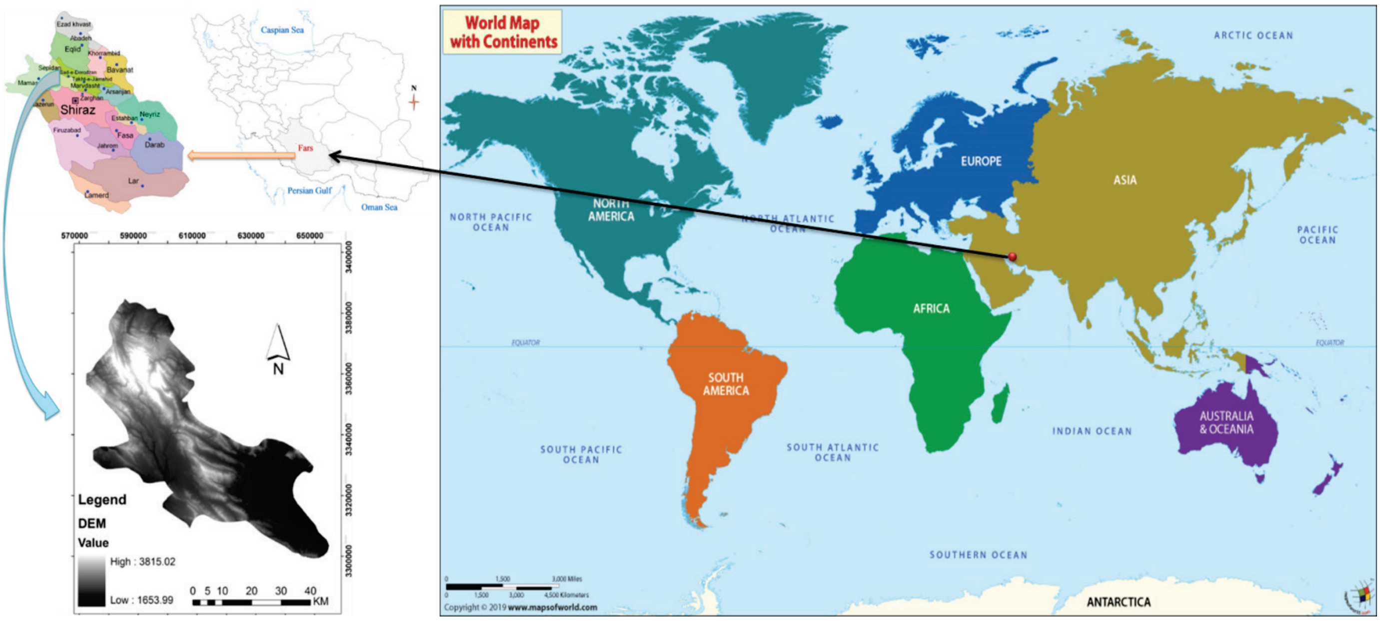


*Figure 1. Location of the study area (Sepidan) in Fars Province and Iran.*

## *2.2. Model framework and data classification*

Model Framework involves the following steps (Fig. 2):

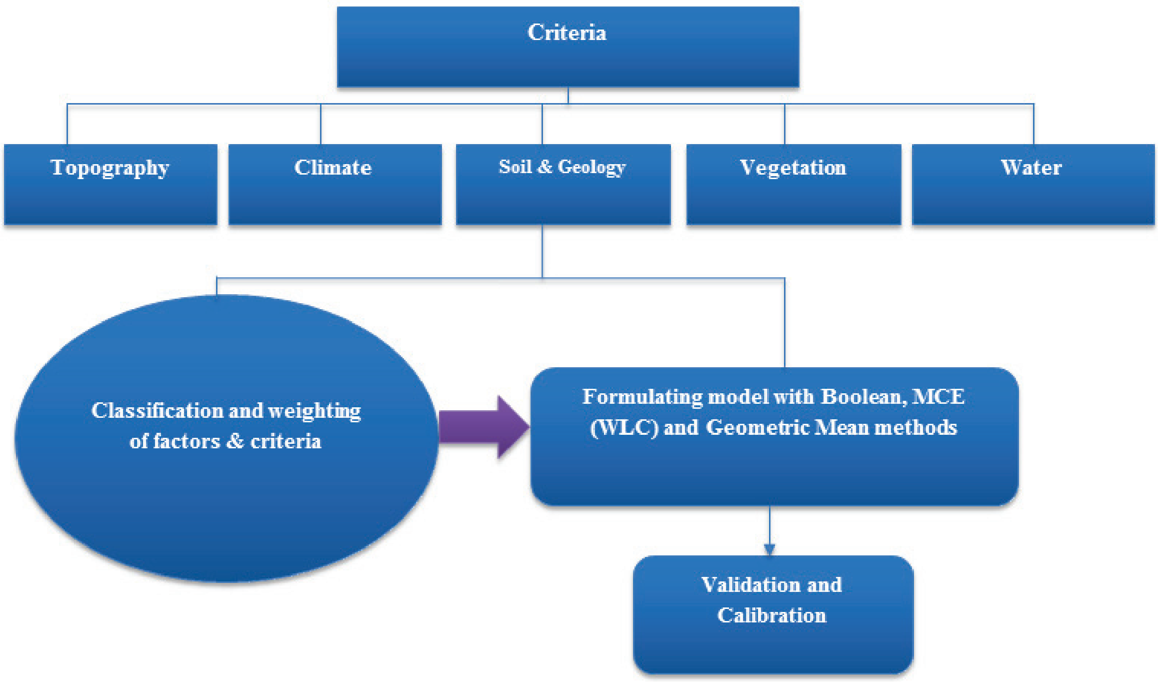


*Figure 2. Platform structure of designed mode.*

i. Sampling of ecotourism regions: In this research, the data concerning the ecotourism regions of Sepidan were collected using Google Earth. These regions were modified with GPS tools during field work. In the next step, these regions were entered into ArcGIS software for analysis. In total, 187 points of ecotourism regions were systematically sampled in ArcGIS environment in order to improve and test the model.

ii. Primary model: The Iranian ecological model (Makhdoum, 2006) was run for the study area. It is composed of three classes pertaining to the ecological potentials of ecotourism and their associated capability class numbers. Class 1 is considered as suitable, class 2 is moderate, and class 3 is poor and non-suitable.

iii. Improved model: The Iranian ecological model and its indicators were improved based on the existing models (Makhdoum, 2006; Makhdoum *et al*., 2009; Mahdavi *et al*., 2015; Bunruamkaew and Murayama, 2011; Anane *et al*., 2012; Chakrabarty, 2011). Certain parameters such as soil depth were further ignored to increase the model efficiency (Jokar and Masoudi, 2016). As a result, effective parameters in the improved model are shown with an asterisk in Table 1. It should be noted that the next stages of evaluation were based on this model.

*Table1. The indicators used in the model of land evaluation for Ecotourism (3classes)*

| CRITERIA | INDICATOR | Highly Suitable (2) | Moderately Suitable (1) | Poor & Not Suitable (0) |
|---|---|---|---|---|
| **TOPOGRAPHY** | *Slope (%) | 0-15 | 15-30 | >30 |
| **CLIMATE** | *Number of sunny days (in spring & summer months) | >15 | 7-15 | <7 |
| | *Average of temperature (°C) (in spring & summer seasons) | 21-24 | 18-21, 24-30 | >30, <18 |
| **SOIL** | *Texture | Usually moderate | Coarse, light, heavy | Very heavy |
| | Depth(cm) | Deep | Semi deep | Shallow |
| | *Drainage (cm/hr) | Good (2-6) | Moderate to poor (0.1-2, 6-25) | Incomplete (<0.1, >25) |
| | Evolution (Structure) | Perfect (granular) | Moderate | Low |
| | Fertility (organic matter %) | Good, Moderate (>1) | Low (1) | Very Low (<1) |
| **GEOLOGY** | *Lithology | pyroclastic rocks, Granite Ophiolite of melange color, sand dunes, continental shelf sediments | Limestone and Dolomite, sandstone, loess, schist and gneiss and amphibolite, quartzite, alluvial fans, flood plain | marl, Shale, Clay Stone, Conglomerate, Salt domes, gypsum dome, calcite and dolomite marble |
| **VEGETATION** | *Vegetation type | Forest lands with canopy cover of 50-80 % | Forest lands with canopy cover of 5-50% | Poor Rangelands, Forest lands with canopy cover >80%, Desert |
| **WATER** | *Quantity of water For everyone (Lit/day) | >40 | 12-39.9 | <12 |
| **CONSERVATION** | *Protected area | Forest park of Natural and planted, Nature Park, National Park, Protected Area, Biosphere Reserve, World Heritage, Historical artefacts and national and pilgrimage | - | Reserve forest, Wildlife Sanctuary, National natural monuments |

iv. Evaluation of the final model with mathematic methods: To evaluate the model, two basic methods (Boolean and MCE) and one proposed method (Geometric Mean) were used:

– Boolean: Boolean algebra is a mathematical system for the manipulation of variables that can have one of two values represented by: True or False, Yes or No, On or Off, 1 or 0. Boolean logic has three basic operators: Intersection (the logical term AND), Union (the logical term OR) and Inverse (the logical term NOT). These Boolean operators use integers or terms such as “True” and “False” as an input raster on a cell-by-cell basis. Output values of True are (1) and those of False are (0) (Froja, 2013). In this paper, the primary and final models were evaluated based on the Boolean method.

– MCE (WLC) method: In the present research, MCE was used to assess the ecotourism. Accordingly, 35 questionnaires were given to experts in the field of ecotourism for weighting different criteria and factors, which was done via Expert Choice software. Table 2 shows the weight of criteria and factors with consistency ratio (CR)<0.1. Afterwards, WLC (weighted linear combination) method was used for the weighted overlay of the input data layers. With the weighted linear combination, the factors were primarily combined through applying a weight to each factor and criteria, followed by a summation of the results to yield a suitability map (Equations 1 and 2). Finally, the constraint factors ($C_i$) were multiplied in the map (Fallahshamsi, 2004; Ghadimi *et al.,* 2011):

$$\text{Equation 1} = [(W_1 \times \text{factor1}) + (W_2 \times \text{factor 2}) \ldots + (W_n \times \text{factor})] \times C_i \quad (1)$$

$$\text{Equation 2} = [(W_1 \times \text{Criteria1}) + (W_2 \times \text{Criteria2}) \ldots + (W_n \times \text{Criteria})] \times C_i \quad (2)$$

*Table 2. Weight of criteria and indicators by AHP.*

| **Criteria** | **Criteria Weight** | **factor** | **factor Weight** |
|---|---|---|---|
| Topography | 0.16 | Slope (%) | 1 |
| Climate | 0.13 | Number of sunny days (in spring & summer months) | 0.5 |
| | | Average of temperature (°c) (in spring & summer seasons) | 0.5 |
| Soil and Geology | 0.16 | Texture | 0.33 |
| | | Drainage (cm/hr) | 0.37 |
| | | Lithology | 0.3 |
| Vegetation | 0.18 | Vegetation type | 1 |
| Water | 0.19 | Quantity of water For everyone (Lit/day) | 1 |
| Conservation | 0.18 | Protected area | 1 |
| **CR (Consistency Ratio) < 0.1** | | | |

– Geometric mean method (proposed): In the geometric mean method (such as MEDALUS model (Kosmas *et al.*, 1999)), every index (Table 1) was given a weight from 0 (non-suitability of ecological conditions for ecotourism use such as deserts) to 2 (the most suitable ecological condition for ecotourism). Next, every criterion was calculated based on the geometric mean of indicators according to Equation 3:

$$\text{Equation 3: Criterion\_X} = [(\text{Layer-1}) \times (\text{layer-2}) \times \ldots \times (\text{Layer-n})]^{1/n} \quad (3)$$

where Criterion _ X is a defined criterion, Layer is an indicator map of the criterion, and n is the number of used indicators. The criteria were then multiplied through geometric mean (Equation 4):

$$\text{Equation 4: Final Criterion} = [(\text{Layer-1}) \times (\text{layer-2}) \times \ldots \times (\text{Layer-n})]^{1/n} \quad (4)$$

where Final Criterion is the final layer of ecological capability, and n is the number of used criteria. For ecotourism planning, qualitative and suitability classes of ecological capability were identified by use of GIS (Jokar *et al.,* 2015) (Table 3).

*Table 3. Suitability classes in the Capability Maps and models for 3 classes uses regarding the scores of polygons.*

| | **Suitability classes** | | |
|---|---|---|---|
| | Good (1) | Moderate (2) | Poor & Not suitable (3) |
| **Their score** | 1.5-2 | 0.5-1.5 | < 0.5 |

v. Validation and Calibration: The accuracy of the identified classes was assessed by detailed ground reality (Makhdoum *et al.,* 2009). For this purpose, ecotourism regions (as suitable classes of ground reality) were primarily created by use of Google Earth, GPS, and field work. After that, the samples of these areas were systematically gathered by “Create Fishnet” algorithm in ArcGIS 9.3 environment (Fallahshamsi, 1997). Of note, sampling of suitable classes (ecological and socioeconomical) of ground reality were more than others (such as moderate and non-suitable classes), as shown in Figure 3 (Fallahshamsi, 1997). This means the current ecotourism areas were sampled more than those with less suitability for ecotourism. In fact, these regions were selected as ground reality and had to be compared with potential conditions. Afterwards, these points (ground reality) were overlaid to the land capability maps. The obtained results are shown in Table 4 (error matrix or agreement matrix), and quantitative indices such as overall accuracy, kappa coefficient, and in class coefficient were calculated.

vi.

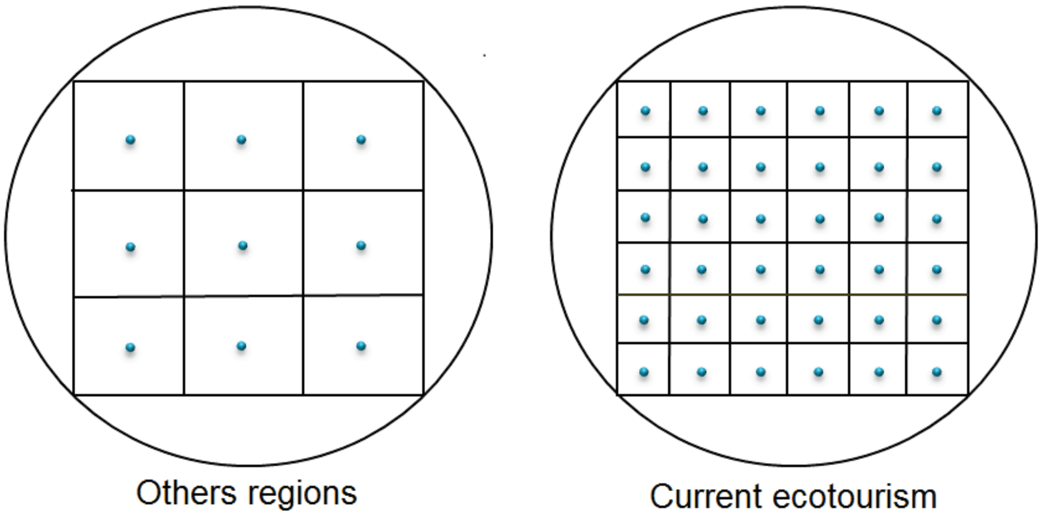


*Figure 3. Sampling of suitable classes of ground reality comparing to other.*

*Table 4. Error Matrix for ecotourism use in study area.*

| **Model** | **Ground Reality** | | | |
|---|---|---|---|---|
| | Class | Current ecotourism | Forest lands with canopy cover 5-50% (exception current ecotourism and Non-suitable) | Poor Rangelands, Desert |
| **Classify** | Suitable | * | | |
| | Moderate | | * | |
| | Non-suitable | | | * |
| | Point number | 187 | 440 | 469 |

A particular aspect of the proposed accuracy assessment is that capability classes indicate the relative rather than the absolute values of capability for a particular area (Sepehr *et al.,* 2007). Omission and commission errors were used to increase the accuracy and calibrate the model. Hence, according to these errors in the geometric mean method, the quantitative ranges of suitability classes (Table 3) were slightly changed. This kind of calibration has been performed in other classifications such as MEDALUS method (Kosmas *et al.*, 1999). In the present research, class 1 ranged from 1-1.47 to 2.

## 3. Results and Discussion

Using ArcGIS software, the geospatial data were processed and the Boolean, MCE, and the proposed methods were implemented. The output maps obtained for ecotourism land capability are presented in Figure 4. The maps include primary and improved models by Boolean algebra, MCE, geometric mean, and calibration of geometric mean. Figure 5 also presents land percentage under different capability classes in different maps and the flexibility of each model. For instance, in Boolean methods, most regions tended towards the weaker classes while in MCE methods, the opposite was the case. However, the proposed methods (geometric mean and calibration of geometric mean) showed a balanced state between the foregoing models. They showed all three classes in the maps and had more agreement with the ground reality of the region. According to Figures 4 and 5, the primary model (Iranian ecological model) with Boolean has the least suitable class (0.018%). In this method, the most widespread area was in poor and none-suitable class (79.63%), showing the highest percentage for this class among all methods. Its improved method (with Boolean view) showed a slight increase in good class (0.08% of region). The moderate class increased (56.05%) and the none-suitable class (43.87%) decreased compared to the primary model. Results showed that among the evaluation methods, the averaging methods (MCE, geometric mean, and calibration) had a better classification compared with Boolean methods. It should be noted that geometric mean and its calibration were the most optimal methods, hence useful and flexible for ecotourism purposes. The suitability of each class has to be accurately determined. Table 5 shows the results related to the number of accuracy indices for all methods used. As observed, the method improved using geometric mean was better than Boolean and MCE models, calibrated geometric mean was the best, and primary model (Iranian ecological model) had the least accuracy.

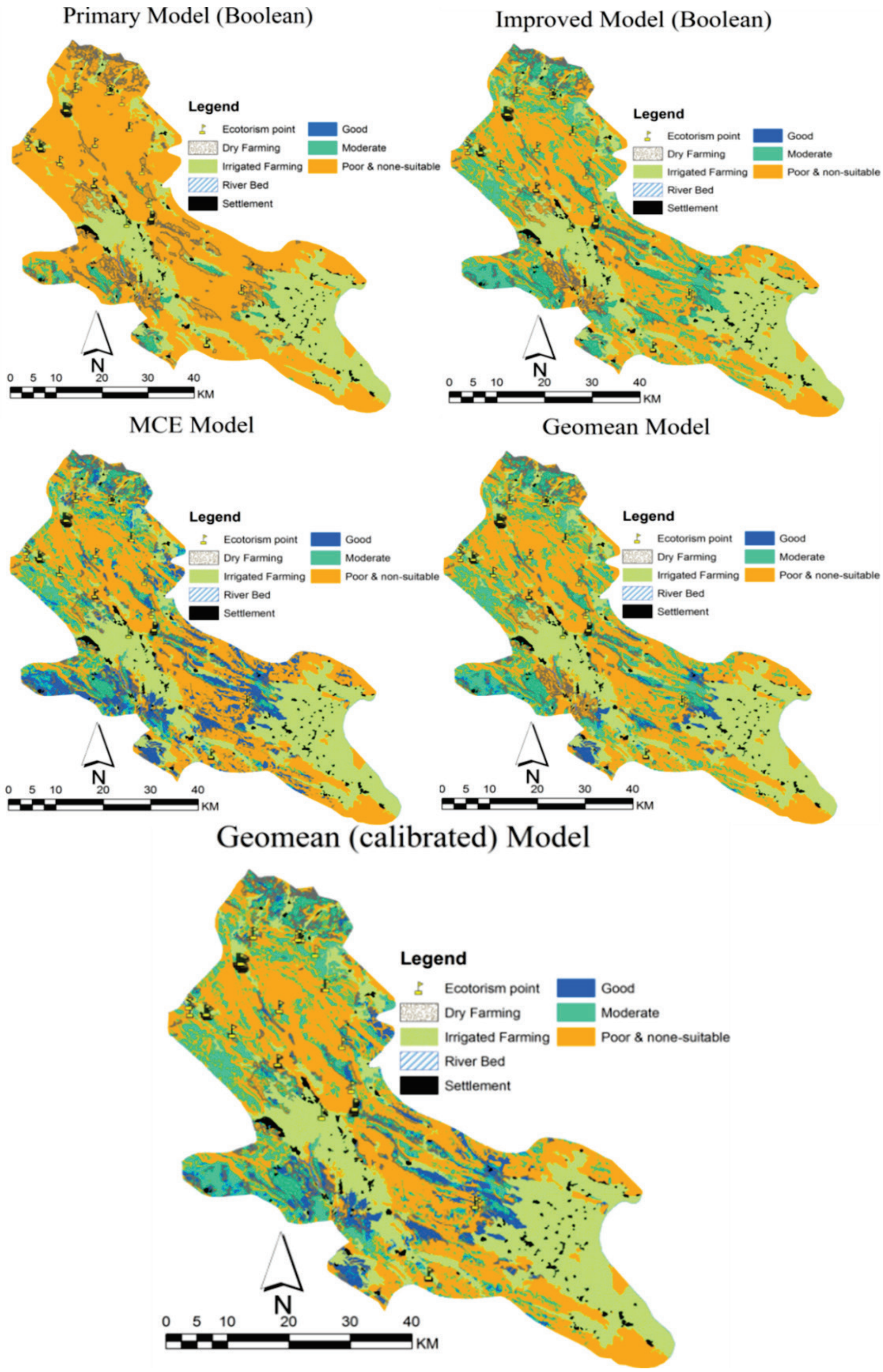


*Figure 4. Ecological capability maps prepared for used models.*

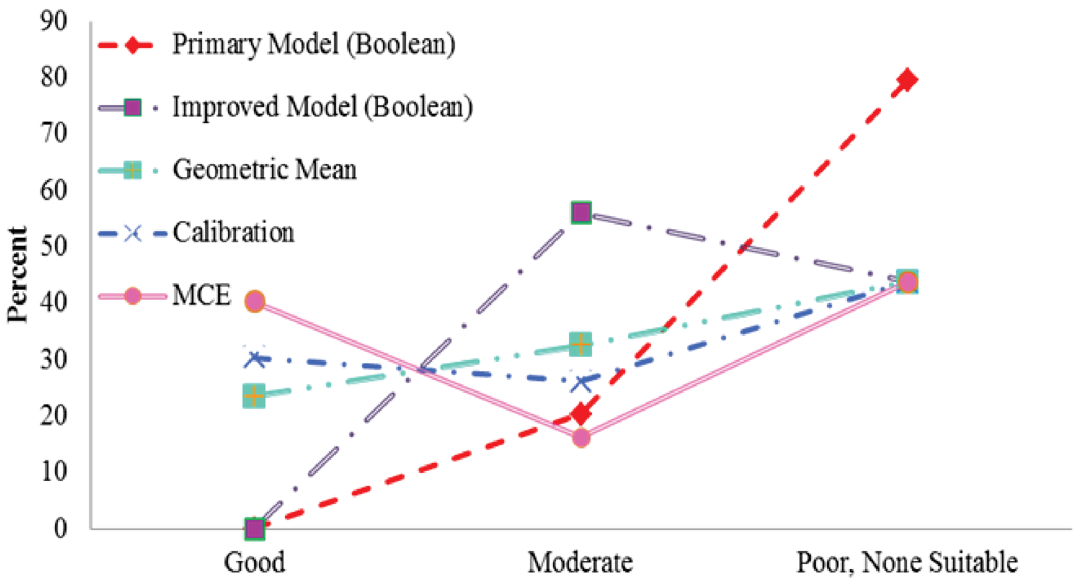


*Figure 5. Percent of land under different capability classes for different methods of ecotourism use.*

*Table 5. Overall Accuracy, Inclass and Kappa Coefficients in the used models.*

| Land Use | Model / Index | Primary | Improved | | | |
|---|---|---|---|---|---|---|
| | | Boolean | Boolean | MCE | Geometric | Calibration |
| Ecotourism | Overall Accuracy | 54 | 74 | 73 | 81 | 82 |
| | Kappa Coefficient | 0.2 | 0.56 | 0.59 | 0.7 | 0.72 |
| | Inclass Coefficient | 0 | 0 | 0.76 | 1.14 | 1.35 |

## 4. Conclusion

This study successfully implemented a GIS-based method as an advanced and more precise MCE approach to evaluating the capability and suitability of ecotourism area. The proposed model can be applied to all types of study areas. The geometric mean method is simpler than MCE and does not require weighting process whereas most studies (Kangas *et al*., 2001; Joerin *et al*., 2001; Najafinezhad *et al*., 2013; Pourkhabbaz *et al*.,2014) have assessed land capability based on subjective opinions. Also, among the models generated by Boolean, MCE (WLC), and geometric mean methods, the results showed that the primary model (Iranian ecological model) by Boolean had the lowest accuracy, which is line with Najafinezhad *et al*. (2013) and Fallahshamsi (2004). However, after modifying the model (by the same Boolean method), the results and accuracy were further improved (Table 5). Next, the evaluation methods of the improved model were changed by averaging methods (MCE, geomean and calibration, Table 5). Results (Table 5) showed that these methods had a higher accuracy compared with Boolean methods (in accordance with Fallahshamsi, 2004; Ghadimi *et al*., 2011; Najafinezhad *et al*., 2013; Elaalem *et al*., 2010). Geometric mean method had a higher accuracy than MCE method, and its calibration was the most optimal method for ecotourism planning as man-made use. Additionally, compared to Boolean model, geometric mean reduced the dependency on indicator numbers (like soil with higher indicators compared to those criteria that include fewer indicators such as topography). Hence, this point can be considered by geometric mean and its type of evaluation. Therefore, for example, climate and topography with only two indicators had the same weight as soil factor with more indicators, which is in good agreement with other studies (Jokar *et al.,* 2015; Jokar and Masoudi, 2016).

Due to the importance of natural hazards, parameters such as drought and climate change should be considered in future research. It is recommended that the results of this study be considered by managers and other stakeholders in management planning processes.

## Acknowledgement

Especial thanks to the official organizations of Iran (especially Shiraz University) for providing the data, maps and reports for this project.

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