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A GIS-based fuzzy-analytic hierarchy process (F-AHP) for ecotourism suitability decision making: A case study of Babol in Iran

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ABSTRACT

Managing ecotourism through appropriate zoning is critical for land use planning. This study is the first to integrate a geographic information system (GIS) with a Fuzzy-Analytic Hierarchy Process (F-AHP) to evaluate the relative importance of physical, natural, environmental, and socio-economic factors for determining the suitability of ecotourism sites. Eleven factors were selected through questionnaire-based surveying of 35 ecotourism and land management experts. F-AHP was applied to weight these factors in order to index and map the suitability of an Iranian case study area for ecotourism using GIS data. A reliable model for the identification of zone suitability was developed which revealed that landform and distance to stream, followed by temperature and elevation were the most important factors for calculating the suitability index. This paper provides useful insights into this novel application of a GIS-based F-AHP for ecotourism planning relevant for policy-makers, planners and practitioners.

1. Introduction

Ecotourism is a rapidly growing industry that plays an important role in the economy of many countries worldwide (Hunt, Durham, Driscoll, & Honey, 2015; Lenao & Basupi, 2016; Loperz & Monteros, 2002; Nyaupane, Morais, & Dowler, 2006; Xiang & Gretzel, 2010). Typically ecotourism is staged in 'natural' areas (Brown, Strickland-Munro, Kobryn, & Moore, 2016; Dhami, Deng, Burns, & Pierskalla, 2014; Higham & Lück, 2007) holding the sustainability of the resource as a core value (Fung & Wong, 2007). Diamantis (1999) applied the term ecotourism in the late 1980s acknowledging global developments in sustainable ecological practices. Since then one of the most influential definitions has been offered by Ceballos-Lascuráin (1996) who described ecotourism as “*travelling to relatively undisturbed or uncontaminated natural areas with the specific objectives of studying, admiring, and enjoying the scenery and its wild plants and animals, as well as any existing cultural manifestations (both past and present) found in these areas.*” Other definitions have incorporated ideas about ecotourism responsibility, environmentally friendly destination management, and sustainable development of host communities (Jeong, García-Moruno, Hernández-Blanco, & Jaraíz-Cabanillas, 2014; Ocampo, Ebisa, Ombe, & Escoto, 2018; Torquebiau & Taylor, 2009).

Ecotourism has been growing extensively at rates of 10%–12% per year over the past decade that is three times faster than the global tourism industry (IES, 2008). Additionally, many developing countries that are home to the majority of the world's rare and threatened species have embraced ecotourism. Rapid and uncontrolled ecotourism development in sensitive natural areas is known to have significant detrimental effects on the environment (Begley, 1996; Cater, 1993; Chaminuka, Groeneveld, Selomane, & van Ierland, 2012; Fiorello & Bo, 2012; Helena Chiu, Lee, & Chen, 2014; Rhormens, de Pedrini, & Ghilardi-Lopes, 2017; Song & Kuwahara, 2016). Thus, ecotourism as a progressive form of educational travel to conserve the environment and benefit local communities requires rigorous management to adhere to its idealistic agenda (Adhami, Sadeghi, & Sheikhmohammady, 2018; Akhtar, Lodhi, ShahKhan, & Sarwar, 2016; Ars & Bohanec, 2010; Ramosa & Prideauxa, 2014; Wishitemi, Momanyi, Ombati, & Okello, 2015; Xu, Mingzhu, Bu, & Pan, 2017).

Strategies to develop land for ecotourism require careful planning and incremental inclusion of land with a focus on environmental sustainability. In order to reduce negative impacts, ecotourism development must be controlled and adapted to the natural values and

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ecological sensitivity of a specific area (Li et al., 2012). Therefore, many authors admonish that the development of ecotourism can only be achieved through the involvement of local experts and the community in the management process (Ramosa & Prideauxa, 2014; Wishitemi et al., 2015).

Spatial zoning is one critical management tool for planning whether a site is suitable for ecotourism (Brown, Sanders, & Reed, 2018; Feng, Chen, Li, Zhou, & Yu, 2016; Vaudour, Carey, & Gilliot, 2010; Walsh, Cóstola, & Labaki, 2017; Yates, Schoeman, & Klein, 2015; Zhang et al., 2013). Zoning involves the division of space into parcels of land serving different purposes (Drumm, Moore, Sales, Patterson, & Terborgh, 2004). Best-practice zoning approaches entail the creation of spatial models (Gigović, Pamučar, Lukić, & Marković, 2016) incorporating social and environmental factors relevant for ecotourism development and the establishment of strategic spatial plans. Accordingly, the suitability and therefore potential of each zone for ecotourism development is evaluated based on the specific conditions of natural resources and other land parameters.

In this research, we focus on ecotourism planning in Iran. Thus far, researchers have investigated different areas of the tourism industry in Iran such as market positioning and image of domestic tourism destinations (Pezeshki, Saeida Ardekani, Khodadadi, Almodarresi, & Hosseini, 2019), tourism economic growth (De Vos, Cumming, Moore, Maciejewski, & Duckworth, 2016; Habibi, Rahmati, & Karimi, 2018), urban and rural tourism development (Ghanian, Ghoochani, & Crotts, 2014; Khodadadi, 2016a; Masih, Jozi, Lahijanian, Danehkar, & Vafaeinejad, 2018), tourism and nature conservation (Ghoddousi, Pintassilgo, Mendes, Ghoddousi, & Sequeira, 2018), tourism sustainability (Reihanian, Binti Mahmood, Kahrom, & Hin, 2012; Hashemi & Ghaffary, 2017), and medical tourism (Moghimehfar & Nasr-Esfahani, 2011; Momeni, Janati, Imani, & Khodayari-Zarnaq, 2018). However, compared to the international field of tourism research that has flourished over the past three decades and addressed many critical aspects of tourism planning (e.g., Jiang & Ritchie, 2017; Marais, Du Plessis, & Saayman, 2017; McCabe & Johnson, 2013; Nilashi et al., 2019; Park, Hahn, Lee, & Jun, 2018; Solnet, Ford, Robinson, Ritchie, & Olsen, 2014; Tang, Zhong, & Ng, 2017), there is a general dearth of corresponding studies in Iran. In fact, even in international studies, developing a theoretical model and investigating the relative importance of different critical factors (CFs) for ecotourism development has largely been overlooked.

Our research fills these gaps using Babol, Iran, as a case study area. We present a new approach to identifying suitable ecotourism sites by integrating a geographic information system (GIS) with a Fuzzy-Analytic Hierarchy Process (F-AHP). AHP on its own is ineffective when applied to ambiguous problems and it has therefore been highly recommended by researchers to apply F-AHP. As an extension of conventional AHP, the F-AHP based on fuzzy set theory handles uncertainty and overcomes the limitation of a standalone AHP by addressing the fuzziness integral to decision makers' opinions (Nilashi, Ahmadi, Ahani, Ravangard, & Bin Ibrahim, 2016). Coupling GIS with an F-AHP model helps with evaluating critical factors for decision making identified by a large number of decision-makers (Liu et al., 2017). The effectiveness of this methodology was demonstrated by Bali, Monavari, Riazi, Khorasani, and Kheirkhah Zarkesh (2015) who applied F-AHP to develop a model for optimized ecotourism site selection in the Caspian Hyrcanian Mixed Forests ecoregion. Thus, in comparison with research efforts found in the literature, our work has the following differences.

To our knowledge, no research has been conducted on the critical factors for ecotourism development. In the current study, we focussed on the critical factors in a case study area capitalising on experts' opinion. Moreover, we presented a new approach for identifying suitable ecotourism sites by integrating a geographic information system (GIS) with a Fuzzy-Analytic Hierarchy Process (F-AHP). This enabled us to assess the importance of 11 physical, natural, environmental, and socio-economic factors for determining the suitability of sites for ecotourism development. Therefore, this study contributes to the understanding of ecotourism planning by integrating a GIS-linked F-AHP as a decision making tool while harnessing the knowledge of tourism experts.

Factors for input into our modelling approach were selected by interviewing tourism experts and through an in-depth literature review. While the development of ecotourism experiences is gaining popularity, there has been insufficient research soliciting tourism experts' opinions, and then integrating this knowledge into a GIS-based F-AHP model to facilitate decisions on where to develop ecotourism sites. To our knowledge, this study is the first to do so, and thereby identified and evaluated 11 key factors for determining the suitability of sites for ecotourism development.

In conclusion, our study will showcase the use of a unique and highly effective decision support methodology that fills a niche at the intersection of multi-criteria analysis, spatial analysis and ecotourism management. From a case study perspective, this study will lead to a better understanding of the ecotourism potential in Babol, a region whose potential for the development of ecotourism has not been sufficiently explored yet.

Although decision-making methods are starting to be implemented and achieve good performance in the study area, there is still no uniform framework for ecotourism assessments. To solve this problem, we introduce a framework as a guide for others who will apply this methodology in the future.

This remaining paper is organized as follows: Section 2 briefly describes related works and introduces the basic concepts of fuzzy set theory, and the applied AHP and GIS approach. In Section 3, an assessment hierarchy framework and F-AHP model are developed around the concept of sustainable ecotourism development considering a case study of Babol, Iran. Section 4 presents the Results and Discussion followed by our Conclusion and future research suggestions in Section 5.

2. The Analytic Hierarchy Process (AHP) and fuzzy set techniques

In this Section, we give a brief overview of fuzzy set theory and the Analytic Hierarchy Process (AHP) as adopted in tourism planning studies. An appropriate combination of GIS and fuzzy set techniques will help select the most relevant of multiple criteria for identifying ecotourism sites.

The Analytic Hierarchy Process (AHP) is an eigenvalue approach that measures intangible factors by using pairwise comparisons of judgements that represent the dominance of one factor over another with respect to a property they share. AHP is now one of the most widely used multiple criteria decision-making tools (Saaty, 1980, 1990) because its flexibility allows it to be integrated with multiple techniques such as Linear Programming, Quality Function Deployment, and Fuzzy Logic. Advocating the effectiveness of relative judgements, Saaty (2008) describes the four steps of the AHP as follows:

i. Defining the problem.
ii. Creating a decision hierarchy.
iii. Constructing a set of pairwise comparisons related to the research problem.
iv. Weighting the criteria under comparison using the priorities derived from the previous steps.

A fundamental scale from 1 to 9 is used in the AHP with 1 representing two criteria of equal importance and 9 indicating the strongest order of difference between two criteria under assessment.

In spite of the popularity of the AHP, two types of limitations have been perceived: limitations associated with the AHP as a methodology, and limitations due to the uncertainty associated with the parameters.

Limitations regarding the validity of the AHP as a methodology include the following:

Table 1
Main methods and objectives of key eco (tourism) study adopting fuzzy sets, Analytic Hierarchy Processes (AHP), geographic information systems and closely related methods.

S. No	Authors	Main method	Objectives	Study subject
1	Sarkar et al., 2016	Fuzzy Inference System; Remote sensing and GIS	Highlight a Fuzzy-based Risk Assessment Model (FRAM)	Wetland risk zone
2	Khazaee Fadafan et al., 2018	Fuzzy AHP	Identify suitable zones for intensive tourism	Tourism development
3	Chan et al., 2014	Fuzzy AHP	Life-Cycle Assessment (LCA); environmental management accounting (EMA)	Environmental management
4	García-Melón et al., 2012	ANP-Delphi	Evaluate sustainable tourism strategies	Sustainable tourism
5	Valjarević et al., 2017	GIS; geospatial analysis and geosite assessment model	Evaluate tourist potential and natural attraction	Tourist development plan
6	Nino et al., 2017	GIS; landsat images	Identify ecotourism potential	Sustainable management
7	Leman et al., 2016	AHP; GIS	Evaluate environmentally sensitive areas	Tropical tourism islands; conservation
8	Arsić et al., 2017	SWOT; ANP; FANP	Prioritise strategies of sustainable development of ecotourism	Ecotourism development
9	Dhami et al., 2014	AHP; GIS	Map forest-based ecotourism areas	Suitability index
10	Agyeiwaah et al., 2017	Meta-analysis	Identify key indicators	Sustainable tourism
11	Lee and Hsieh, 2016	The fuzzy Delphi method; AHP	Identify critical indicators	Sustainable wetland tourism
12	Zhang et al., 2013	GIS; fuzzy set	Generate maps of conservation, eco-tourism, and community development sites	Protected area zoning
13	Zhou et al., 2015	AHP	Investigate the utility of AHP in destination competitiveness	Tourism destination
14	Doroles Sarrión-Gavilán et al., 2015	GIS; Spatial analysis	Analyze tourism flows and spatial distribution of tourism demand	Tourism development
15	Ocampo et al., 2018	Fuzzy set theory; Delphi method	Develop sustainable tourism indicator sets	Sustainable ecotourism
16	Reihanian et al., 2012	SWOT	Explore the applicability of transforming the current state of tourism	Tourism development strategy
17	Castellanos-Verdugo et al., 2016	Structural equation models	Assess the relevance of psychological factors in the ecotourism experience	Attitudes towards ecotourism
18	Albuquerque et al., 2018	GIS	Develop a better decision making process, accessing politicians and managers in tourism development	Tourism marketing
19	Zhang et al., 2015	Neural network	Employ a nonlinear dynamic evaluation method	Tourism sustainability
20	Mohammadian Mosammam et al., 2016	Questionnaires	Identify the best ecotourism development approach	Tourism sustainability
21	Mikulić et al., 2015	Weighting indicators	Highlight weighting procedures	Tourism sustainability
22		Fuzzy; AHP	Explore tourist preferences	Development of smart tourist attractions
23	Lin and Chuang., 2012	Fuzzy-ANP; Fuzzy Delphi	Evaluate the sustainability of an ecotourism site	Ecotourism sustainability
24	González-Ramiro et al., 2016	VGI; GIS; AHP	Assess the spatial distribution of rural tourism potential	Rural tourism
25	Zarei et al., 2016	Fuzzy TOPSIS; ANP	Determine optimal tourism sites	Tourism industry
26	Xu et al., 2016	Fuzzy modelling	To exhibit high forecasting method	Tourism demand forecasting
27	Kim et al., 2017	AHP	To investigate the perceptual differences in core competencies of tourism	Tourism industry
28	Nahuelhual et al., 2013	GIS; AHP	Map recreation areas	Ecotourism management
29	Aliani et al., 2017	Fuzzy, WLC, ANP	Evaluate of the development of ecotourism	Ecotourism development
30	Du and Wang., 2018	GIS, Fuzzy-AHP	Monitoring sites	World Natural Heritagesites (WNHs)
31	Gao et al., 2018	Fuzzy	To construct of tourism agglomeration areas	Tourism management
32	Lu and Stepchenkova, 2012	A quantitative method	To classify of satisfaction attributes	ecotourism experiences

- The aggregation method of Saaty's AHP suffers rank reversal (that is, the best alternative out of a set fails to be chosen when another, even unimportant, alternative is excluded from the set) (Watson & Freeling, 1982, 1983; Dyer, 1990a, 1990b).
- Similarly, the addition of indifferent criteria (for which all alternatives perform equally) causes a significant alteration of the aggregated priorities of alternatives (Pérez, Jimeno, & Mokotoil, 2006).
- In practice, pairwise comparison data do not provide consistent matrices (Dubois, 2011).

As for the uncertainty associated with the parameters, we relied on tourism experts' opinion which introduces some uncertainty for the following reasons.

- Experts' competence which plays a crucial role in the final decision making varies. However, we took steps to ensure that uncertainty in regards to this was minimised. We applied strict selection criteria as defined in 3.2 when inviting experts.
- The number of experts to be considered depends on their availability and accessibility. Given the lack of research that specifies the number of experts needed to apply group decision techniques like AHP (Nixon, Dey, & Davies, 2010), we have followed recommendations by Saldaña (2014) and even exceeded their recommended number of 20–30 interviews.

A questionnaire was administered to experts to determine the importance of different factors for ecotourism development. Academic staffs of the Department of Geography, Geology and Urban Planning of three major universities (Babol University; Sari University and Gorgan University) were chosen as experts for this study. The experts were asked to rank the importance and relevance of identified ecotourism indicators associated with ecotourism suitability in Babol City from the most to least important (Kurttila, Pesonen, Kangas, & Kajanus, 2000). In total, 35 experts were interviewed to solicit their opinions regarding critical factors that influence tourism development in Babol, Iran. Interviews were conducted face-to-face, via questionnaire, using online video tools (e.g. Skype), or by telephone.

The questionnaire was based on Saaty's model (1996) and encompassed 37 questions. A pair-wise comparison was employed because it provides more meaningful information for the assignment of weights to the various elements. These pairwise elements are then utilized to make comparative judgments in order to ensure accuracy. In this sense, measurements derived from many pairwise comparisons are more scientific than by assigning numbers more or less arbitrarily through guessing (Saaty, 2005). The data retrieved from the completed questionnaires were loaded into the Super Decision Software version 2.2 in order to calculate the relative weights of the various elements of the matrices.

More generally, fuzzy logic enables one to handle vagueness of human judgment. A so-called fuzzy set was originally developed to represent vagueness and imprecision and to reduce uncertainty in statistical modelling (Zadeh, 1965). The use of fuzzy set theory (Zadeh, 1965) allows decision makers to incorporate unquantifiable information, incomplete information, non-obtainable information and partially obscured facts into decision-making models (Kulak, Durmusoglu, & Kahraman, 2005). The notion of a fuzzy set was introduced into mathematics by Zadeh (1965) as an extension of the concept of a classic set. The fuzzy set improves the classic set by granting that there are varying degrees of belonging to a set of elements rather than just two possible states of belonging or not belonging. Thereby, F-AHP assigns a fuzzy number instead of a precise numerical value of importance, which is sometimes impossible to obtain. The fuzzy approach was applied here because AHP on its own has numerous limitations (Prakash & Barua, 2015).

AHP in combination with GIS is the most commonly used method for evaluating ecotourism land use suitability/potential (e.g., Bunruamkaew and Murayam, 2012; Nino et al., 2017; Petz et al., 2014; Prueksakorn et al., 2018; Santarém et al., 2018). Table 1 presents a number of key studies in this field and their specific focus. Nahuelhual et al. (2013) for example combined GIS and participatory methods including Delphi and AHP to map recreation for ecotourism development at the municipality level. This methodology showcased the potential for informing local decision making for recreation site planning. Dhami et al. (2014) applied AHP to identify and map ecotourism sites in forested areas in West Virginia in the United States by incorporating visitors' preferences. The results of this study revealed significant variations in visitors' preferences for land use. Aliani et al. (2017) reported a study on the evaluation of ecotourism development in Taleghan, Iran based on a multi-criteria evaluation method utilizing fuzzy logic and weight linear combination (WLC) operators. Their study teased out the potential of potential ecotourism development sites and highlighted that combining fuzzy set logic and an AHP provides more logical and flexible conditions compared to other methods.

Similarly, Arsić et al.'s (2018) study about prioritization strategies of sustainable development of ecotourism in a Serbian national park showed a better readability/interpretability of the results when fuzzy logic was applied. Finally, Du and Wang (2018) used GIS and F-AHP in a study about World Natural Heritage protection by determining appropriate impact monitoring locations which demonstrate multi-factor decision making. Gao et al. (2018) proposed a fuzzy adaptive minimum spanning tree model which assisted in government decision making on tourism resource planning and contributed to regional tourism competitiveness. Accordingly, Multi Criteria Decision Making (MCDM) methods are regarded as the best tool for solving environmental problems in the mentioned studies. In recent years, a wide range of techniques and methods in combination with GIS and the applications of decision-making methods have been applied when evaluating and zoning land for ecotourism potential (see Table 1).

Most of these studies adopt a tourism management strategy of analysis, and have examined district in terms of a specific province or region.

This study proposes a novel approach by integrating GIS with F-AHP for modelling and mapping of ecotourism land use. Although this mixed methodology has proved more effective and flexible than other methods in numerous contexts (e.g., Alaqeel and Suryanarayanan, 2018; Prakash and Barua, 2016; Tian et al., 2017; Vishwakarma et al., 2016), we are the first to adopt it to solve a complex ecotourism planning problem. We staged our case study in Babol, Iran, where we selected a comprehensive set of 11 factors describing physical, natural, environmental, and socio-economic characteristics to develop a model for choosing suitable ecotourism regions.

3. Methods

3.1. Study area

This study was carried out in the Babol district, 200 km north of the capital of Iran between the Alborz Mountains and the Caspian Sea (Fig. 1), with a 2016 population of 250,000 inhabitants (Statistical Center of Iran, 2016). Babol with its 32 km^2 is rich in resources that are attractive to ecotourists and features great environmental diversity and awe-inspiring landscapes (Statistical center of Iran, 2016). Its altitude ranges from sea level to 4000 m above. Close to the Caspian Sea, the climate is Mediterranean with warm and dry summers, while the conditions further inland are continental with a temperate and humid character. The annual mean temperature reaches 16.5°C; monthly mean temperatures of January and July are 7.6°C and 26.1°C, respectively (Babolsar Meteorological Administration, Archives Bureau, 2016).

Ecotourism is an increasingly important industry in Babol especially due to its positive effect on land value and local income. Babol's ecotourism agenda is embedded in the policies of the 2013 Tourism

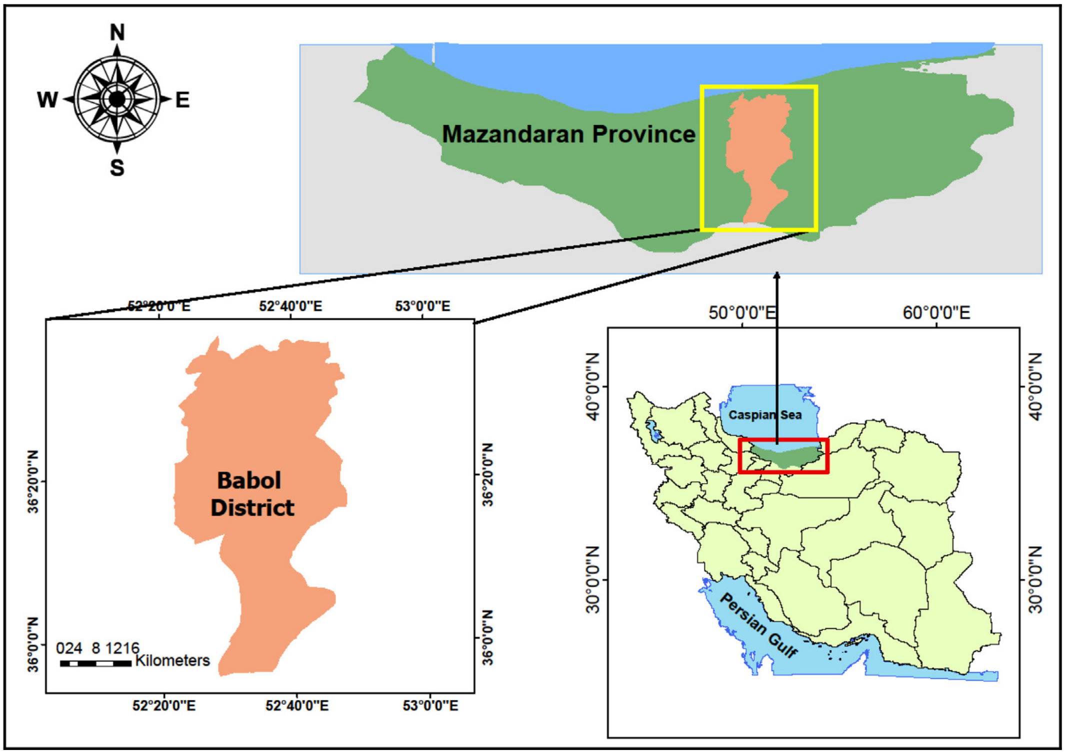

Fig. 1. The case study area's geographical location (Babol, Iran).

Promotion Plan for Babol's Northern Cities. Strongly supported by the government, an ecotourism action plan was implemented which realised regional development projects scoping for potential ecotourism sites in 2017.

3.2. Methodological overview

This paper proposes the use of a GIS-coupled fuzzy-AHP (F-AHP) to determine the ecotourism suitability/potential of the case study area, Babol, on a granular scale. Figure 2 illustrates the specific steps involved in this methodology which involved four steps: (1) finding suitable factors to use in the analysis, (2) assigning factor priority (weight), (3) determining the suitability index of each 'land area' (GIS raster cell) in Babol, and (4) generating an ecotourism suitability map (Kiker et al., 2005). Firstly, 'suitability factors' relevant for calculating an ecotourism suitability index were identified from informal interviews with 35 local experts in the field of tourism, land use and environmental management between March and July 2017.

The interview guideline addressed topics such as prerequisites of ecotourism planning, land characteristics and other environmental factors with high planning relevance, along with expected outcomes. This was complemented by an in-depth literature review as pertinent to the Iranian context (agricultural organization of Babol for the year 2016; Geological Survey of Iran, 2016; Iran meteorological organization, 2016; Iran National Cartographic Center (INCC), 2018; Mazandaran administration of roads and urban development for the year 2016; Mazandaran regional water resources authority for the year 2016). Generally, spatial MCDM entails a combination of several structural processes including identification of factors affecting the purpose (evaluation factor maps), their integration and finally, contribution to land use managers and planners by providing them with proper response/decision making variables (Malczewski, 2006).

Identification and selection of effective factors can be taken as the first step and backbone of land evaluation for tourism development. Despite the mentioned importance, there has not been any coherent framework to identify and select the effective factors. According to biophysical and socio-economic characteristics of a given region, different types of factors should be selected and specifically analyzed (Barzekar et al., 2011; Castellani and Sala, 2010; Cottrell et al., 2013; Kim et al., 2013; Liu et al., 2012; Logar, 2010; Xin and Chan, 2014).

In this study, we chose the following factors that have demonstrated relevance for ecotourism land use planning: elevation; slope; temperature, precipitation, geology; land type, distance to rivers; distance to streams; distance to roads; distance to a fault, and the proximity to the 'hotspots' (most inhabited parts) of nearby villages.

In the selection process of interviewees we have adopted Bogner, Littig, and Menz's (2009) definition of an expert being a person with technical, process and interpretative knowledge in relation to their areas of expertise; along with Meuser and Nagel (1991) who view an expert as being responsible for a concept, an implementation or ability to solve a problem, and as someone who has relevant factual knowledge, aggregated or specific knowledge about processes, group behaviors, and strategic decisions but also someone who has knowledge, (general) information or privileged access to information. In addition, Saldaña (2014) recommends conducting 20–30 interviews to gain a deep understanding of the phenomenon. Accordingly, interviews were conducted with 35 experts who fulfilled these criteria for ecotourism land use planning with particular knowledge of planning in the Babol district. Interviews were conducted face-to-face, using online video tools (e.g., Skype), or by telephone. How land use planning intersects with ecotourism development is of political significance across all scales of governance. Consequently our experts included public managers from the national, regional, and municipal government. All interviewees were directly involved in ecotourism planning and possessed a broad understanding of government decision making as well as deep insights into implementing corresponding actions.

Table 2 provides an overview of the academic background and scientific expertise of our interviewees.

Secondly, F-AHP was used to assign weights to each suitability factor. This was achieved by developing an F-AHP model (see Section 3.2.1) in which data was input from the questionnaire about the relative importance of these factors for determining ecotourism

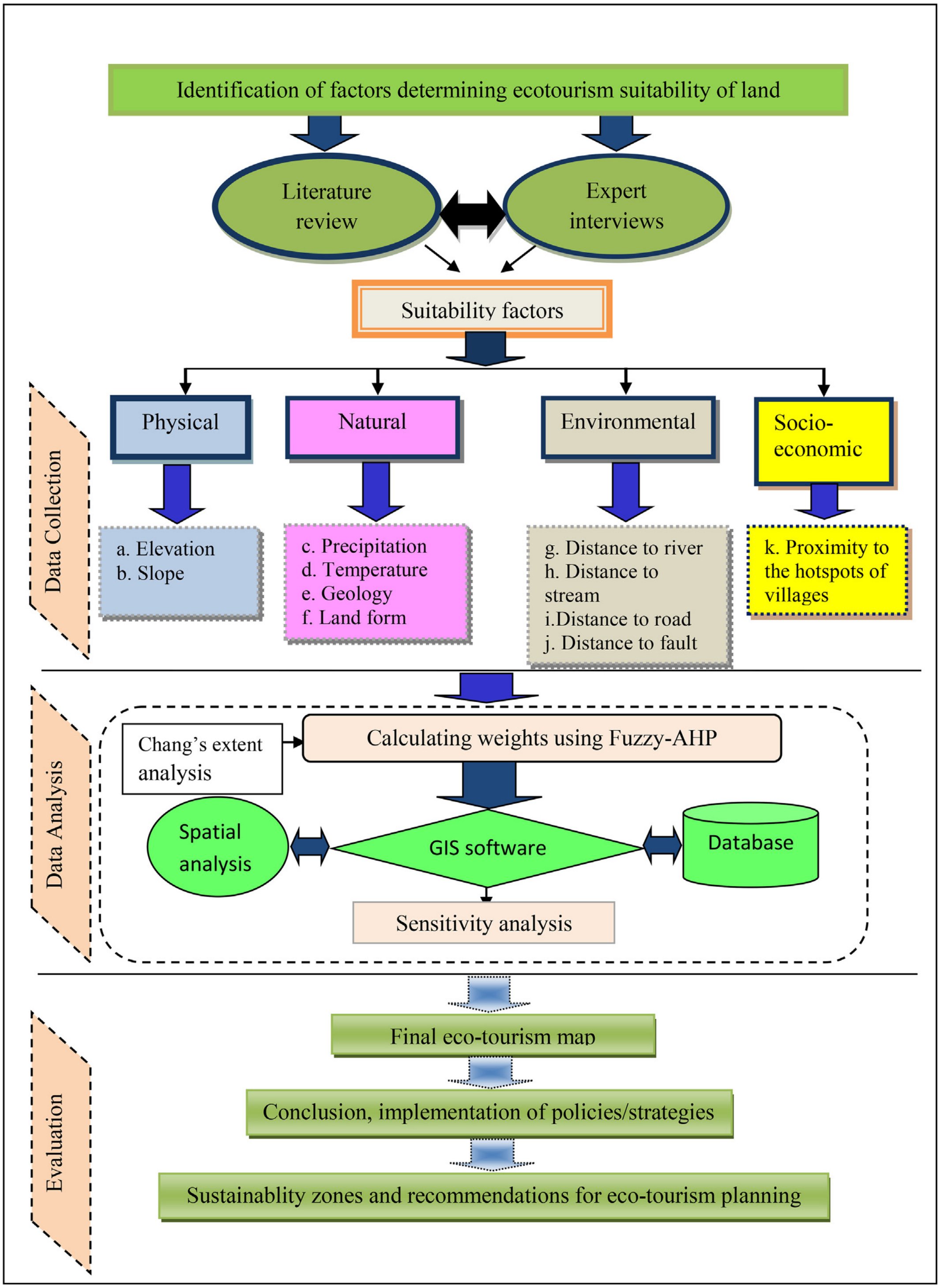

Fig. 2. Assessment hierarchy framework of ecotourism suitability of land integrating GIS with a fuzzy-Analytic Hierarchy Process (F-AHP) model. The data collection phase involved the rating of the relative importance of the suitability factors in a survey with 35 experts to determine the suitability of land for ecotourism, along with the GIS data collection to capture factor values for each raster cell in the Babol region of Iran.

Table 2
Profiles of the experts interviewed.

Gender		Academic level		Scientific expertise	
Male 45%	Femal 55%	Bachelor	5%	Environmental Engineering	15%
		Master	5%	Economics	10%
		Ph.D.	90%	Environment (Tourism, Urban and regional planning)	70%
				Others	5%

suitability. For this purpose, a questionnaire-based survey was conducted with the 35 experts who rated the relative importance of the suitability factors in pairwise comparisons to determine the ecotourism suitability of land in Babol. Integrating AHP with fuzzy set logic had the significant advantage of achieving precision when calculating the relative weights of the suitability factors based on participants' judgement, and was necessary to develop a hierarchical structure in the model.

Working with experts in environmental decision making, is critical to harness the wealth of knowledge that is required to solve complex problems. Many fields have benefited from such an approach (Senante et al., 2015) sourcing expert opinion from a variety of places (Kozierkiewicz-Hetmańska, 2017). Decisions here are made based on the knowledge of a collective.

The experts who participated in this study were carefully chosen in order to obtain in-depth information on how ecotourism suitability could have an impact on the tourism industry. For this matter, we adopted the guidelines by Ackermann and Eden (2001), which foresees the aggregation of opinions from different experts, thereby generating holistic insights. Three criteria were applied for selecting experts to join the panel. Firstly, some experts (5%) were chosen if they had worked as environmental engineers in the field of tourism or within the cultural government departments of Iran. Second, other experts (5%) worked on projects relating to tourism economics. As such, they had direct contact with tourists and tourism agents representing an important sector of the tourism industry and were well aware of their needs and preferences (Kozak and Rimmington, 1999). Finally, most of the experts (90%) who participated were academic staff from three public universities (see Table 2). Although their highest level of academic degree varied, these experts all had more than 12 years of industry experience in projects related to tourism management (90%). Their number of years of experience was an important criterion for considering them as subject-matter experts as it was thought to enhance the reliability of their answers. Another purpose was to obtain genuinely practical information from a variety of experts (Taylor & Wallace, 2007).

The weighting of factors was the prerequisite for a GIS raster analysis where the 'weighted sum overlay' analysis was applied to calculate an ecotourism suitability index for each raster cell in the Babol region. This analysis used the weights assigned to the 11 GIS data layers of the suitability factors as estimated through F-AHP performed on the survey data. GIS data layers had been sourced for each of these factors from multiple sources as described further below. Raster maps were overlaid and an overall ecotourism suitability index was calculated and visualised in a map.

In addition, a sensitivity analysis was used for model validation. To ascertain which of the 11 factors was the most influential in driving the calculation of the suitability index and thus for deciding which part of Babol was more or less suitable for ecotourism development.

3.2.1. F-AHP model development

The development of the model to guide decision making on ecotourism site selection involved AHP computations, the evaluation of alternatives with F-AHP and the determination of the final weights, The overall goal of developing the F-AHP model was to obtain the importance of weightings for the suitability factors by calculating the importance ratings of each individual factor while accounting for the relationships between them. F-AHP handles the hierarchical process of interrelationships between factors by performing a series of pairwise comparisons. The architecture of the statistical model incorporating F-AHP theory is described as a full model of integration. Its basic organization is constituted through three core modules: The Fuzzy AHP weights used for this work were calculated based on Chang's extent analysis method (Chang, 1996). The following section outlines the extent analysis method:

Definition 1. A fuzzy number M on R is to be a Triangular Fuzzy Number (TFN) if its membership function μM (x): R → [0, 1] is equal to the following Eq. (1) (Chang, 1996).

$\chi \in [l, m]$

otherwise

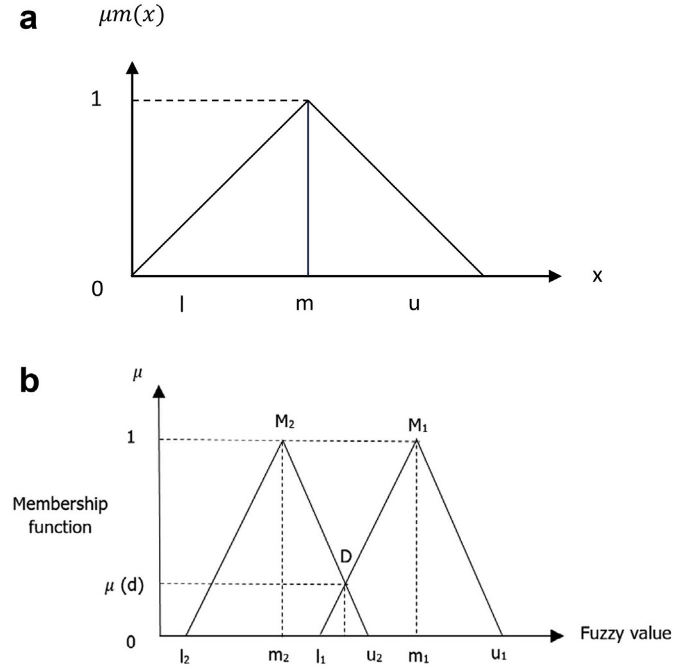

Fig. 3a. The membership functions of Triangular Fuzzy Number (TFN).
Fig. 3b The intersection between two fuzzy numbers.

$$\mu_M(\chi) = \begin{cases} \dfrac{(\chi - 1)}{(m - 1)} \\ \dfrac{(\chi - u)}{(m - u)} \\ 0 \end{cases} \chi \in [m, u] \tag{1}$$

From Eq. (1), $l \leqslant m \leqslant u$, where l and u mean the lower and upper value of the fuzzy number M, and m is the model value (see Figs. 3a; 3b). TFN can be denoted by $M = (l,m,u)$.

According to the method of extent analysis of Chang (1996).

$M_{gi}^1, M_{gi}^2, ...M_{gi}^m \; i = 1, 2, 3. ., n.$

where all the M_{gi}^j $(j = 1, 2, 3, .., m)$ are triangular fuzzy numbers given in Table 3.

The steps of Chang's analysis can be presented as follows:

Step 1. The fuzzy judgement matrix i.e., $\widetilde{A} = (a_{ij})$ can be expressed mathematically as in Eq. (2) (Efendigil, Önüt, & Kongar, 2008).

$$\check{A} = \begin{matrix} 1 & \widetilde{a}_{12} & \widetilde{a}_{13} & .... & \widetilde{a}_{1\,(n-1)} & \widetilde{a}_{1n} \\ \widetilde{a}_{21} & 1 & \widetilde{a}_{23} & .... & \widetilde{a}_{2\,(n-1)} & \widetilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \widetilde{a}_{(n-1)1} & \widetilde{a}_{(n-1)2} & \widetilde{a}_{(n-1)3} & ... & 1 & \widetilde{a}_{(n-1)n} \\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & \widetilde{a}_{n3} & ... & \widetilde{a}_{n(n-1)} & 1 \end{matrix}$$

$$DisplayedEquation - Numbered - (2) \tag{2}$$

Table 3
Fuzzy comparison measures (Chang, 1996; Ertay et al., 2005; Lee, 2010; Lin and Yeh, 2012).

Linguistic scale of importance	Assigned triangular fuzzy numbers (TFNs)
Just equal (JE)	(1, 1, 1)
Equally important (EI)	(1/2, 1, 3/2)
Weakly more important (WMI)	(1, 3/2, 2)
Strongly more important (SMI)	(3/2, 2, 5/2)
Very strongly more important (VSMI)	(2, 5/2, 3)
Absolutely more important (AMI)	(5/2, 3, 7/2)

Equation (7) should be changed to (2).

The judgment matrix $\widetilde{A}$ is an n × n fuzzy matrix containing fuzzy numbers $\widetilde{a}_{ij}$. Where, *aij* can be interpreted as the degree of preference of ith attribute over jth attribute; and vice versa (Nazari et al., 2012; Nefeslioglu et al., 2013).

Each column of the pairwise comparison matrix is divided by sum of entries of the corresponding column to obtain the normalized comparison matrix. The eigenvalues of this matrix would give the relative weight of attribute *i*. The result of the pairwise comparison on *n* criteria can be summarized in a *(n × n)* evaluation matrix *A* in which every element *aij* is the quotient of weights of the criteria, as shown in Eq. (3) (Wang and Yang, 2007).

$$A = (a_{ij})\ (i,j,=1,\dots\dots\dots,n)$$

DisplayedEquation − Numbered − (3) (3)

Step 2. The values of the fuzzy synthetic extent with respect to the i-th criterion are defined as:

$$s_i = \sum_{j=1}^{m} M_{gi}^{i} \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]$$

DisplayedEquation − Numbered − (4) (4)

$$\sum_{j=1}^{m} M_{gi}^{j} = \sum_{j=1}^{m} l_{ij}, \sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{m} u_{ij}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} uij}, \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} mij}, \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} lij}$$

where l is the lower limit value, m is the most promising value and u is the upper limit value.

Step 3. The degree of possibility of $M_2 = (l_2,m_2,u_2) \geq M_1 = (l_1,m_1,u_1)$ can be defined as:

$$V\,(M_2 \geq M_1) = \text{hgt}\,(M_2 \cap M_1) = \mu\,(d)$$

$$= \frac{l_1 \_ u_2}{(m_2 - u_{2)}(m_1 \_ l_1)} \text{ otherwise}$$

DisplayedEquation − Numbered − (5) (5)

where μd is the highest intersection between two fuzzy numbers (see Fig. 3b). To compare between M_1 and M_2 it is necessary to compute both $V\ (M2 \geqslant M1)$ and $V\ (M1 \geqslant M2)$. The degree of possibility for convex fuzzy numbers to be greater than k convex fuzzy numbers *Mi* ($i = 1,2,3,\dots,k$) can be defined as:

$$V(M \geq M_1, M_2, M_3, \dots M_k) = V[(M \geq M_1), (M \geq M_1), \dots, M_k)] = \min V(M \geq M_1),\ i = 1, 2, 3, \dots k \quad (6)$$

By assuming that $d'(A_i) = \min V\ (Si \geq Sk)$

For $k = 1,2,3,4,5,\dots, n\ (k \neq i)$, the weight vector is given by

$$W' = (d'(A1), d'(A2), \dots, d'(An))^T \quad (7)$$

where Ai ($i = 1,2,3,4,5,\dots,n$) are n elements.

Step 4. Via normalization, the normalized weight vectors are given by

$$W = (d(A_1), d(A_2), \dots, d(An))^T \quad (8)$$

where W is a non-fuzzy number.

Finally, adding the weights per option multiplied by the weights of the corresponding criteria gives the final score for each option (Chang, 1996).

3.2.1.1. Efficiency of using F-AHP

Due to the vagueness and uncertainty attached to judgements by decision-makers, crisp pairwise comparisons in the conventional AHP seem insufficient and too imprecise to capture these judgements adequately (Taha and Rostam, 2011, 2012). These issues are addressed in the F-AHP (Saaty, 1977; Torfi et al., 2010) which makes it a highly popular MCDM choice in that it is a robust and flexible decision-making tool. It is used to find solutions even in the most complex multi-criteria problems such as soil erosion risk assessments (Jaiswal et al., 2014). Recently, a comprehensive analysis has been carried out by Chan et al. (2019) to provide insights on the conditions relating to differences between the triangular fuzzy AHP and classical AHP from both a quantitative and qualitative perspective. The closed forms of the difference between the fuzzy AHP and classical AHP have been demonstrated and presented for small matrix scales. Chan et al. (2019) further verified the conditions when it is necessary to apply the fuzzy AHP. The authors concluded that the triangular F-AHP becomes useful when the pairwise comparison matrix is highly consistent. It provides different criteria rankings for references to avoid the subjectivity of using a relatively small group of experts forjudgment on the model criteria. This study provides insights on the usefulness of F-AHP from an analytical perspective, and describes the conditions when F-AHP can introduce differences over classical AHP (refer to Chan et al., 2019).

Although AHP has been used to capture experts' knowledge, the traditional AHP still cannot adequately reflect the human way of thinking (Kahraman et al., 2003). The traditional AHP method is problematic in that it uses an exact value to express a decision maker's opinion compared to alternatives (Wang and Chen, 2007). Thereby, the traditional AHP method is often criticized due to its use of unbalanced scales of judgments and its inability to adequately handle the inherent uncertainty and imprecision that imbues the pair-wise comparison process (Deng, 1999). To overcome these shortcomings, F-AHP was developed for solving the hierarchical problems. Decision makers usually exhibit greater confidence at making interval judgments than fixed value judgments. This is because usually they are unable to state an exact preference to a fuzzy problem (Kahraman et al., 2003). Therefore, this paper advocates the use of F-AHP for determining the weights of the main criteria.

In summary, the benefits of an F-AHP model consist of its flexibility, and its comparability and combination of factors in the GIS, adding new value to the evaluation of ecotourism land use planning problems (Büyüközkan and Çifçi, 2011). Moreover, F-AHP models are more powerful to handle real-world problems whereas traditional AHP does not handle such problems (Moktadir et al., 2018). To the best of authors' knowledge, this is the first time that F-AHP was applied in relation to ecotourism site selection; in this case study area in Babol, Iran.

3.3. Determining the fuzzy linguistic degree

To determine the relative weight of each suitability factor the expert ratings measured in qualitative scales ("linguistic scales of importance') were transformed into a fuzzy membership score (= triangular fuzzy number) according to Table 3. In doing so, a questionnaire was first developed to perform a pairwise comparison between evaluation factors by 35 experts. Afterwards, the qualitative scales used in the completion of questionnaires were transformed to a fuzzy membership score based on Table 3 and the fuzzy linguistic scales are illustrated in Fig. 4.

Weight vector of suitability factors can be obtained by either directly assigning or indirectly using pair-wise comparisons. Here, it is suggested that the decision makers use the linguistic variables (an example of fuzzy comparison measures is presented in Table 3) to evaluate the weight vector suitability factors.

This linguistic scale was taken from the previous study with the help

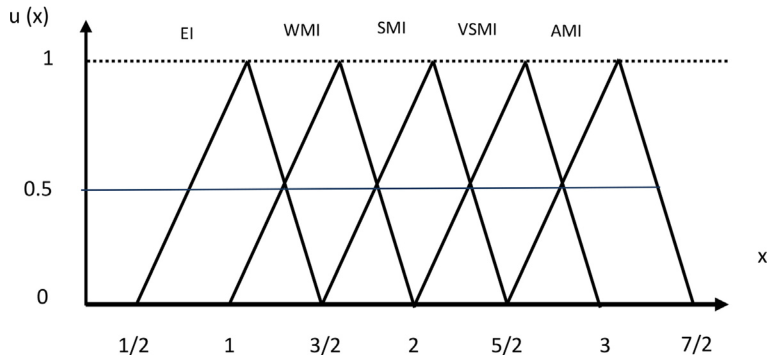

Fig. 4. Fuzzy set scale used in this study (adapted from Kahraman et al., 2003; Lin and Yeh, 2012).

of Kahraman et al., 2003; Lin and Yeh, 2012 (Fig. 4) that were assigned to the sustainability factors which were collated as GIS data layers as described in the following.

3.4. GIS data layers of the suitability factors

Identifying critical success factors for tourism development is indeed a popular field of study and the literature has showcased the importance of such studies and that critical success factors can differ between individual tourism sectors (Choon-Chiang, 1998; Manners, 2011; Marais et al., 2017). They also differ by tourism activities and location-specific characteristics such as topography. Furthermore, critical success factors can be related to tangible physical elements such as the distance/presence to water sources or intangible service elements captured in the distance to nearby settlements (Wang & Hung, 2015). Geography and positioning towards attractions play a critical role, and so do topography, related geographical aspects, and weather and climatic factors (Li et al., 2018; Mahdavi and Niknejad, 2014, Samanta and Baitalik, 2015, Jeong et al., 2014, Delavar et al., 2010). Ultimately no single set of critical success factors will apply everywhere (Getz and Brown, 2006), and thus soliciting expert opinion in conjunction with a literature review is important.

Land and topographic data were sourced from the Iranian topographic map at a scale of 1:25,000, produced by Iran National Cartographic Center (INCC), 2018. Tourism activity is highly affected by meteorological parameters such as ambient temperature and related parameters (Gössling and Hall, 2006; Falk and Lin, 2018). Hence, climatic data were analyzed from four meteorological stations of the Meteorological Bureau of the Mazandaran Province close to the study area. Data were averaged from 1985 to 2015. The distribution of the meteorological stations used was determined in ArcGIS 10.1 (ESRI, 2009). Meteorological data layers included mean temperature (temperature isolines map), precipitation, and water availability (distance to rivers and streams). A digital elevation model (DEM) dataset was derived from a 1:25,000-scale topographic map at a resolution of 80 m.

Data were sourced from various government departments such as the Babol agricultural organization, the Statistical Center of Iran, the Iranian Meteorological Organization and various meteorological stations. The proximity to the 'hotspots' (most inhabited parts) of the village was collected from the Iran National Cartographic Center (INCC), Archives Bureau, 2018. Distance data to rivers and streams were collected from the Mazandaran Regional Water Resources Authority for 2016. This factor was deemed important as ecotourism staged around river-based activities and settings play a key role in engaging communities residing in ecologically sensitive areas in offering ecotourism experiences (Shie, 2020; Tseng et al., 2019; Woodman et al., 2019); ecotourism experiences; classification of satisfaction attributes (Lu and Stepchenkova, 2012).

DEM and geological map of the study area were collected from the Iranian Geological Survey 2015. Since the 1980s, geological sites have rapidly been made accessible to the ecotourism industry worldwide so geology was an important factor to determine ecotourism site suitability (Dashti et al., 2013; Durant et al., 2012; Li et al., 2009; Nino et al., 2017). Our goal was to assess the kinds of factor potentially influencing ecotourists in Babol. In reality, a variety of complex factors influence ecotourism decisions vary by different geographic regions (Nerg et al., 2012; Neuvonen et al. 2010). Roads network data were sourced from the Mazandaran administration of roads and urban development for 2016. Accordingly, a GIS raster analysis using 'weighted sum overlays' was applied to calculate an ecotourism suitability index for each raster cell to produce raster maps for the Babol region.

4. Results and discussion

The aim of this paper was to develop and showcase the process of evaluating the suitability of land for ecotourism through F-AHP modelling in conjunction with GIS analysis to produce the zonation maps. As the following results will show, this was achieved and some land in Babol, Iran, was successfully mapped as being moderate to highly suitable for ecotourism while another land was deemed unsuitable.

In order to identify the weights accurately, 35 experts were invited to participate in the decision-making process. Their role was to examine the sensibility of criteria and determine the relative importance of each criterion. Once the sensibility of the criteria was established, the experts were asked to adopt linguistic terms as provided in Section 4.1.

4.1. Weights calculated in the F-AHP model and fuzzy thresholds

Summary of fuzzy standardization of the criteria is presented in Table 4. These were assigned as weights to the corresponding GIS data layers. The consistency threshold is the evaluation index to judge whether the preference relation satisfies the consistency or not. Fuzzy threshold schemes of dataset are given in Table 5. The optimum threshold will take into account the membership in each of the classes, which implicitly makes the threshold variant. Each sustainability factor (referred to as "criterion" in this modelling context) was divided into sub-criteria. For instance, elevation was divided into five classes ranging from low levels of elevation to high levels; each assigned a different class weight based on their importance as per the experts' opinion. F-AHP then allowed for the calculation of one final weight for each sustainability factor.

For all criteria whose element values gradually change from one location to another, a fuzzy membership function was applied through a linear transformation as a means to classify. These values were defined by the user between the minimum value as a membership of 0 and maximum value as a membership of 1. Selecting point markers properly requires a definition of the degree of membership. There are often four point markers noted in the fuzzification and membership function: the first point mark (a) is located where the membership function starts to rise above 0. The second point mark (b) demonstrates the place where it

Table 4
Summary of fuzzy standardization of the criteria.

Indices	Fuzzy function modalities	Fuzzy functions	Criteria	Sub-criteria
			Elevation (m)	-33 – 300
				310 - 1,000
Physical	Increasing-Decreasing			1,100 - 2,000
				2,100 - 2,900
				3,000 - 4,000
	Decreasing		Slope (percentage)	0-10
				10-30
				> 30
	Decreasing		Precipitation (mm)	45-80
				80-120
				> 120
			Temperature (°C)	-6- 6
	Increasing-Decreasing			6-18
Natural				18-28
			Geology Units	Superficial marsh deposits (Qm)
				Black carbonaceous shale (Kbv)
	User-Defined			limestones, slates/siltstones (TRjs)
				Igneous rock (JI)
			Landform	Mountain
				Hill
				Vally
				Plain
				River-Delta
				Floodplain
			Distance to river (m(	200-1500
				1500-3500
				3500-5500
				> 5500
	Decreasing		Distance to stream (m)	0-9000
				9000-24000
				24000-38000
				> 38000
Environ-mental			Distance to road (m)	0-5000
				5000-10000
				10000-20000
				20000-30000
				> 30000
			Distance to fault (m)	0-2000
	Increasing			2000-4000
				4000-6000
				> 6000
	Decreasing		proximity to the hotspots of the village (m)	0-1000
				1000-3000
Socio-economic				3000-6000
				> 6000

is approaching 1. The third point mark (c) shows the location where the membership grade begins to drop again below 1, while the fourth point mark (d) indicates where it returns to 0, as shown on Tables 4 and 5.

The Table 5 summarizes fuzzy threshold algorithm based on possibility clustering assumes an initial partition and iteratively evaluates the memberships until there is no appreciable change in the partition. In short, these fuzzy threshold schemes yield a soft partition while minimising the factor function.

Total weights based on the experts' importance ratings were calculated using Eq. (3), Eq. (4) and Eq. (5), respectively. This yielded a fuzzy decision matrix and fuzzy aggregated decision matrix of criteria with corresponding weights (Table 6) which allowed deducing that *Landform* is considered most important for determining ecotourism suitability. Conversely, *Fault* had the least importance and was consequently assigned the lowest total weight. The weights that were calculated in the F-AHP model using the results of the questionnaire

Table 5
Range of values of selected suitability factors and corresponding fuzzy thresholds used for ecotourism suitability analysis in Babol, Iran.

Indices	Criteria	Range	Fuzzy Threshold			
			a	b	c	d
	Elevation	-34 - 3984	300	1500	2000	2500
Physical	Slope	0 - 100			10	25
	Precipitation	37 - 68			30	60
	Temperature	11 - 18			15	25
Natural	Geology	1 - 6	2	4		
	Landform	1 - 6	2	4		
	Distance to river	0 - 7111			500	1000
Environmental	Distance to stream	0 - 2524			200	1000
	Distance to road	0 - 44026			2000	5000
	Distance to fault	0 - 7875	3000	5000		
Socio-economic	proximity to the hotspots of the village	0 - 6825			1000	2000

responses given by experts including the corresponding fuzzy functions are shown in Table 6.

4.2. Suitability maps of ecotourism in Babol

Our methodology allowed us to successfully create suitability maps to identify regions that fulfil the requirements for ecotourism in Babol. Figure 5 shows the maps created for each sustainability factor. For example, map (A) for elevation layer presents the degree to which an area is suitable for ecotourism development or provides an opportunity to demonstrate the importance of ecotourism activity. In addition, accessibility (distance) to river, stream, road, faults (from maps including G, H, I, J) means the level of accessibility by ecotourism for the purposes tourism and recreation. Regarding geology units and landform (maps of E and F) means the degree to which an area the potential of an area to be appreciated by tourists and others. Ultimately, the final map derived by overlaying the 11 suitability factors then clearly shows the potential zones for ecotourism. Fig. 5 deemed as moderately to highly suitable versus unsuitable regions.

Moreover, ecotourism potentials were classified into 3 classes of highly suitable, moderately suitable and unsuitable. Our results (Fig. 6) show that 16.6% (251 km^2) of the study area is highly suitable for ecotourism development, 75.6% (1142 km^2) is moderately suitable, while 7.8% of the study area (117 km^2) is unsuitable (Fig. 6) in terms of ecotourism development. The middle and southern regions of Babol are the most suitable regions for ecotourism development while the unsuitable region's cluster in the northern parts of Babol. Figure 6 illustrates overall zonation maps of Babol by incorporating GIS in terms of four main categories includes 11 critical factors for the ecotourism development.

4.3. Sensitivity analysis using the proposed F-AHP model

This Section aims to validate the performance of the proposed F-AHP method through sensitivity analysis which is an essential component of F-AHP decision-making modelling. The purpose of this is to measure the consistency in selecting the best alternative from multiple options. In the current study, the F-AHP model was developed by considering 11 factors. Hence, model validation and sensitivity analysis were conducted based on 11 criteria. Figure 7 shows the relative efficiency obtained by the proposed of the fuzzy sum model. The relative efficiency of factors is defined as the ratio of the weighted sum of outputs to that of inputs. From the perspective of ecosystem reliability analysis, the higher efficiency level factors have, the higher reliability or performance level operators. As depicted in Fig. 7, the relative performance efficiency of decision-making units (DMUs) lies in the range

Table 6
Calculated fuzzy aggregated decision matrix of criteria and the normalized priority weights.

Village	Fault	Road	Stream	River	Landform	Geology	Temperature	Precipitation	Slope	Elevation	Layers
(3,5,7)	(0.14,0.2,0.33)	(3,5,7)	(0.14,0.2,0.33)	(3,5,7)	(0.14,0.2,0.33)	(3,5,7)	(0.14,0.2,0.33)	(3,5,7)	(0.14,0.2,0.33)	(1,1,1)	**Elevation**
(1,2,4)	(0.25,0.5,1)	(1,2,4)	(0.25,0.5,1)	(1,2,4)	(0.25,0.5,1)	(1,2,4)	(0.25,0.5,1)	(1,2,4)	(1,1,1)	(3,5,7)	**Slope**
(4,6,8)	(0.12,0.17,0.25)	(4,6,8)	(0.12,0.17,0.25)	(4,6,8)	(0.12,0.17,0.25)	(4,6,8)	(0.12,0.17,0.25)	(1,1,1)	(0.25,0.5,1)	(0.14,0.2,0.33)	**Precipitation**
(5,7,9)	(0.11,0.14,0.2)	(5,7,9)	(0.11,0.14,0.2)	(4,6,8)	(0.11,0.14,0.2)	(5,7,9)	(1,1,1)	(4,6,8)	(1,2,4)	(3,5,7)	**Temperature**
(1,3,5)	(0.2,0.33,1)	(1,3,5)	(0.2,0.33,1)	(4,6,8)	(0.2,0.33,1)	(1,1,1)	(0.11,0.14,0.2)	(0.12,0.17,0.25)	(0.25,0.5,1)	(0.14,0.2,0.33)	**Geology**
(7,9,11)	(0.09,0.11,0.14)	(7,9,11)	(0.09,0.11,0.14)	(4,6,8)	(1,1,1)	(1,3,5)	(5,7,9)	(4,6,8)	(1,2,4)	(3,5,7)	**Land form**
(3,5,7)	(0.14,0.2,0.33)	(3,5,7)	(0.14,0.2,0.33)	(1,1,1)	(0.12,0.17,0.25)	(0.12,0.17,0.25)	(0.12,0.17,0.25)	(0.12,0.17,0.25)	(0.25,0.5,1)	(0.14,0.2,0.33)	**River**
(1,3,5)	(0.2,0.33,1)	(1,3,5)	(1,1,1)	(3,5,7)	(7,9,11)	(1,3,5)	(5,7,9)	(4,6,8)	(1,2,4)	(3,5,7)	**Stream**
(7,9,11)	(0.14,0.2,0.33)	(1,1,1)	(0.2,0.33,1)	(0.14,0.2,0.33)	(0.09,0.11,0.14)	(0.2,0.33,1)	(0.11,0.14,0.2)	(0.12,0.17,0.25)	(0.25,0.5,1)	(0.14,0.2,0.33)	**Road**
(2,4,6)	(1,1,1)	(3,5,7)	(1,3,5)	(3,5,7)	(7,9,11)	(1,3,5)	(5,7,9)	(4,6,8)	(1,2,4)	(3,5,7)	**Fault**
(1,1,1)	(0.17,0.25,0.5)	(0.09,0.11,0.14)	(0.2,0.33,1)	(0.14,0.2,0.33)	(0.09,0.11,0.14)	(0.2,0.33,1)	(0.11,0.14,0.2)	(0.12,0.17,0.25)	(0.25,0.5,1)	(0.14,0.2,0.33)	**Village**
0.04	**0.01**	**0.02**	**0.16**	**0.1**	**0.17**	**0.05**	**0.15**	**0.10**	**0.08**	**0.14**	**Weight**
9	**11**	**10**	**2**	**5**	**1**	**8**	**3**	**6**	**7**	**4**	**Rank**

[0, 1] with an interval of 0.1. Consequently, the efficient DMUs should reduce their inputs by their respective efficiency scores in percentage to become efficient.

The results of the F-AHP analysis revealed that landform was the key parameter with a major impact on the ecotourism suitability assessment of land in Babol. This can be seen in Fig. 7 which shows that landform had the highest value of the efficiency intercept coefficient due to relative (performance) efficiency. The relative (performance) efficiency (refer to Charnes et al., 1978) of a DMU is defined as the ratio of the weighted sum of outputs (called virtual output) to the weighted sum of inputs (called virtual input).

Ecotourism development in Babol is also dependent on other natural features such as distance to stream. Findings of this study ascertained that landform and distance to stream, followed by temperature and elevation (as physical, environmental and natural features) were the most important factors for calculating the suitability index for ecotourism suitability mapping (ESM). In fact, these factors should not be neglected by policy-makers, planners. This findings support prior studies (Buckley, 2009, Dhami et al., 2014, Diamantis, 1999, Geneletti et al., 2003, González-Gómez et al., 2016, Honey, 2008, Malczewski, 1999, Reimer and Walter, 2013, Saarinen, 2006, Ties, 2015).

The findings of this study also revealed that the influence of stream and landform are significant and may possibly affect the ranking pattern of the other factors. Finally, the findings of this study also confirm that by applying sensitivity analysis, two fuzzy risk factors i.e., stream and landform can have a significant influence on the average of fuzzy weighted risk priority number.

Furthermore, Fig. 7 shows that the relative efficiency of distance to fault (obtains lower values) have a relative efficiency of -0.23. Hence, this factor may not possibly affect the ranking pattern of the other factors.

In this study, ESM was performed using using F-AHP coupled with GIS analysis. MCDM methods adopt expert knowledge and fuzzy mathematics for weight calculation, thereby thirty-five experts (decision makers) were involved in the construction of an individual pairwise comparison matrix (PCM). Fuzzy numbers with triangular functions were used. The fuzzy evaluation matrix was calculated, and the result with respect to the criteria is shown in Table 6.

This study was conducted with the aim to explore the key factors that could assist the ESM through experts' opinions using F-AHP coupled with GIS analysis. Besides, this study intended to develop a theoretical model and identify crucial factors in successful development of tourism industry in Babol, Iran.

Generally, this study made two contributions. First and foremost, it developed a model of ESM in which critical ecotourism factors (CFs) were identified and evaluated along physical, natural, environmental, and socio-economic dimensions. Also from a case study perspective, it specifically determined the ecotourism suitability factors of the tourism industry in Babol, Iran and revealed their level of importance showcasing the value of F-AHP modelling coupled with GIS analysis.

The results of groups/criteria aggregation, F-AHP and sensitivity analysis were generated different spatial patterns with physical, natural, environmental and socio-economic groups. They indicate that this approach can reveal the highest suitable areas for ecotourism planning and can provide an initial ranking of them as well. The methodology and the results proposed, therefore, can be applied to tourism management strategies at all government levels and private sectors in the decision-making process due to its flexible character. Furthermore, it is expected that the results will lead to better understanding of ecotourism planning whose possibilities for sustainable tourism planning have not been used sufficiently yet.

5. Conclusion and future scope of work

Tourism is a sector with significant economic relevance in Iran. Despite the attention afforded by the government to develop tourism,

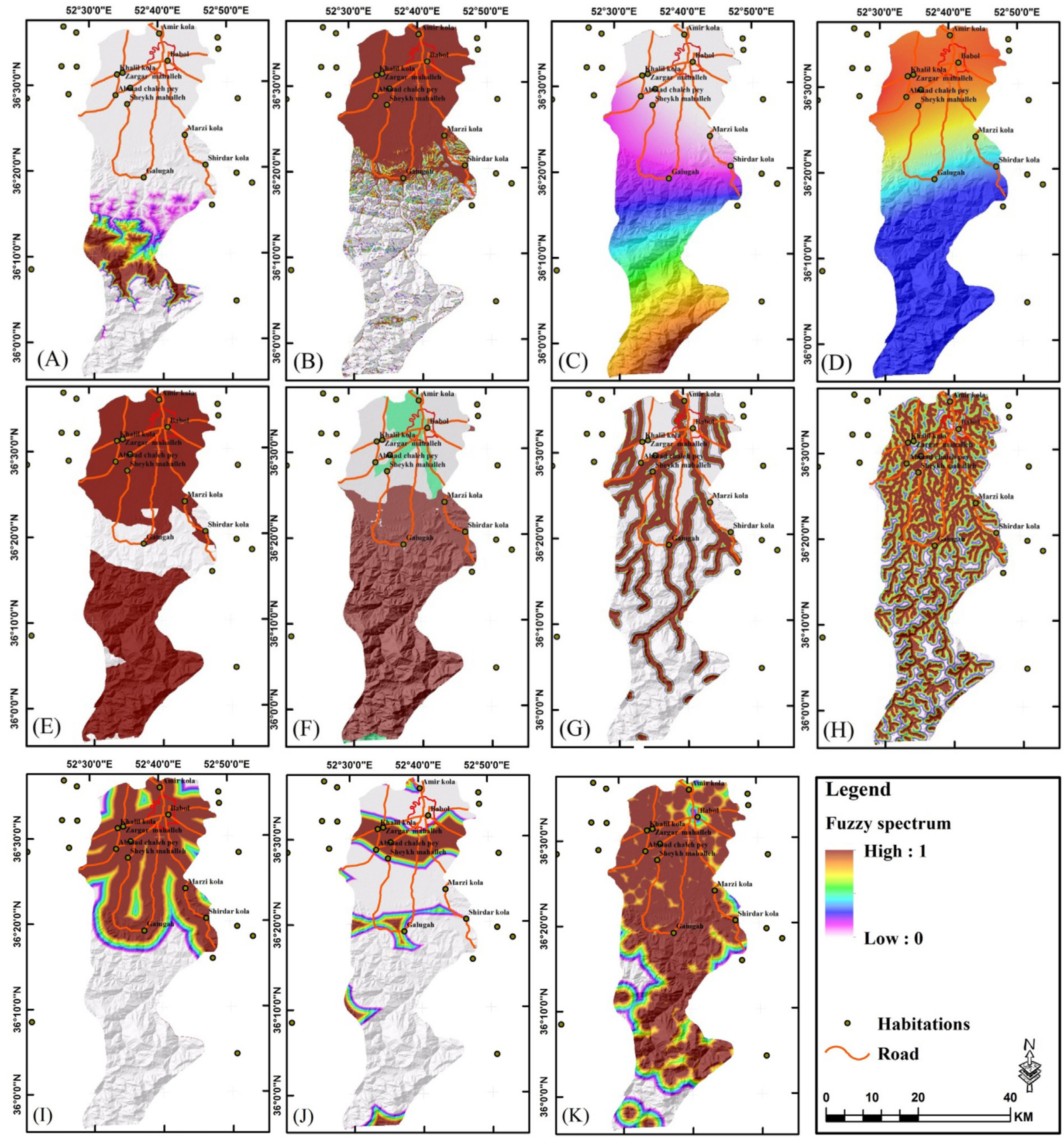

Fig. 5. Factors relevant for determining ecotourism suitability in Babol, Iran: (A) elevation, (B) slope, (C) precipitation, (D) temperature, (E) geology units, (F) landform, (G) distance to river, (H) distance to stream, (I) distance to road, (J) distance to faults, (K) proximity to village, using F-AHP based on the data presented in Table 4.

little attention has been given to better understand critical planning factors that should influence the choice of ecotourism sites. Such knowledge would greatly benefit strategic planning for sustainable tourism development. This article analyzed the opinions of experts regarding the relative importance of critical factors to determine ecotourism suitability of land in Babol, Iran. The primary objectives of this study were then to implement this knowledge and identify ecotourism sites via the identified 11 factors by integrating GIS with F-AHP for modelling and mapping of ecotourism sites. This study offered the first attempt of an ecotourism suitability assessment of land using F-AHP coupled with GIS analysis. This paper succeeded in developing this novel method and showcased how efficiently land can be zoned into areas more or less suitable for ecotourism development.

This study showed that there were three key factors for ecotourism site selection, namely, landform, distance to a stream and ambient temperature. Also, this study provided insights into the approach for identifying the ecotourism suitability factors, and discussed its strengths and weaknesses. A detailed framework was developed to guide future applications of this methodology.

The advantage of the proposed GIS-linked F-AHP approach is, firstly, that it can include various states of truth between two extremes. This way, F-AHP becomes a useful methodology for multiple criteria decision-making in fuzzy environments (Wang and Chin, 2011). Secondly; it shows simplicity and a natural structure. Consequently, it can be efficiently combined with other intelligence methods to form hybrid models. In addition, the coupling with GIS enabled an efficient visualisation and communication of the results which is particularly critical in land use planning for ecotourism where many stakeholders are

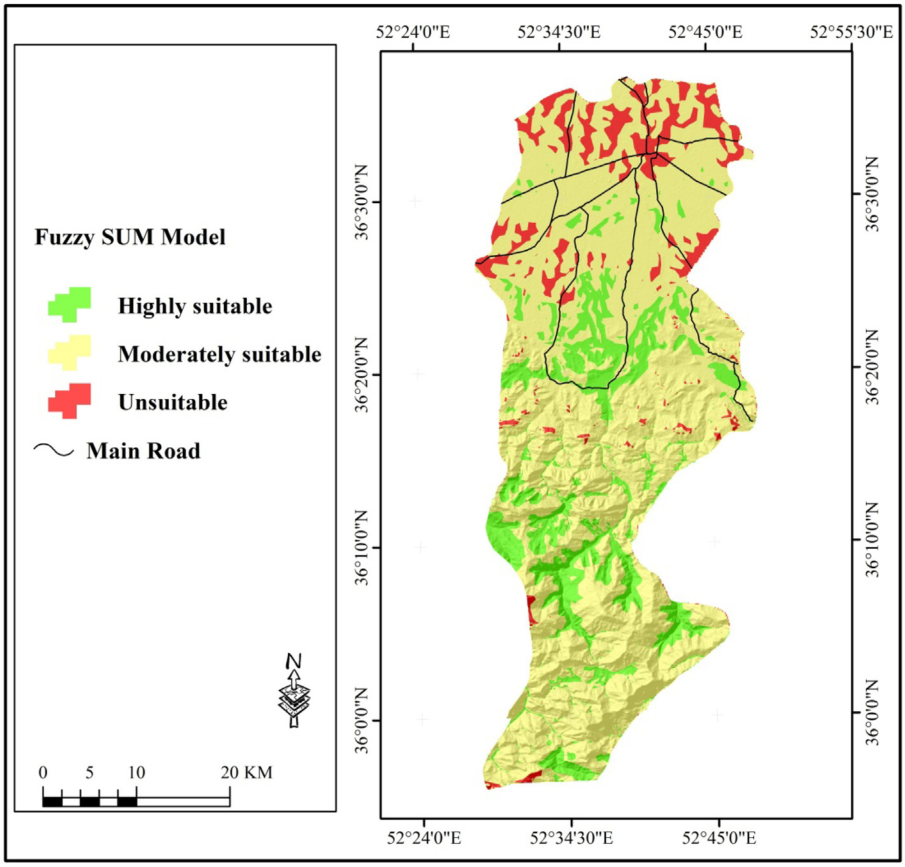

Fig. 6. Final map showing suitability of ecotourism regions in Babol, Iran.

involved with varying degrees of literacy in the techniques applied in this study. The proposed method also performed well in the sensitivity analysis which is a promising result that confirms robustness. Consequently, applying this method overcame many of the deficiencies and drawbacks of classical AHP method as stated in Section 2 and therefore increases the preciseness and reliability of the final decision making.

Our approach enabled us to demonstrate how to locate ecotourism regions in order to inform tourism strategies and policies on where to concentrate efforts for development. It further highlighted the factors which had the most positive or negative influence on assessing the ecotourism suitability of land, knowledge which can guide investment and education programs. Importantly, future studies can apply this method for analyzing and weighting multiple critical factors in different areas of tourism management, as well as in other regional and cultural contexts.

On the other hand, suitability analysis for land use development always needs to be considered in a political context. Within a political economy, the social system including land use is embedded in a complex array of interconnected factors (Jessop, 2008). In Iran, varying governance modes and corresponding tourism development perspectives have strongly influenced the politics and policies around sustainable tourism development and implementation (for more information refer to Morakabati, 2011; Khodadadi, 2016b). In this case study for instance, although the southern parts of Babol were deemed moderately suitable for ecotourism, sustainable development needs to be pursued cautiously because of the local political situation that favours mass tourism over ecotourism and requires educational input to capitalise on ecotourism potential. In such an environment, our framework

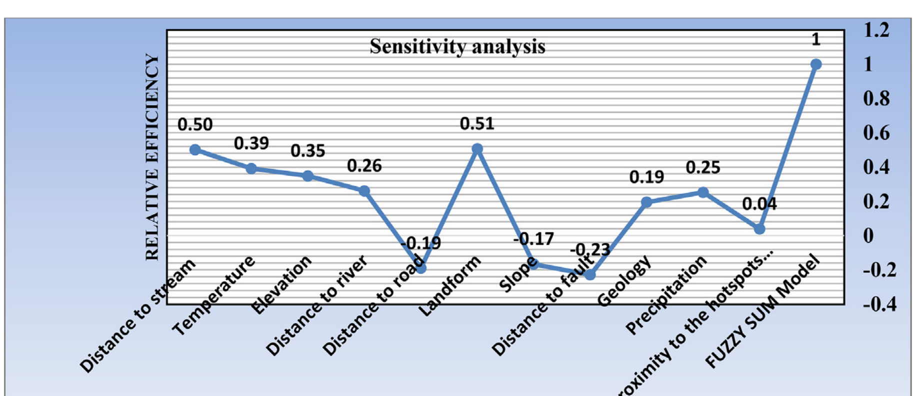

Fig. 7. Sensitivity analysis of the propped fuzzy SUM.

provides useful guidance for a more unified approach to efficient ecotourism management.

As a recommendation, future research may conduct related studies on ecotourism by applying other MCDM techniques such as Analytic Network Processes (ANP) and Analytic Neural Networks (ANN) to compare the results between modelling outcomes and planning recommendations attained by different techniques. Further to this, to identify suitability factors for land use development, one could harness the knowledge of local residents and tourists alike to add value to decision making based on expert opinion.

Declaration of Competing Interest

None.

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