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Ecotourism sustainability assessment using geospatial multiple approach in the Kurdistan region of Iraq

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Abstract Identifying the potential of ecotourism sustainability is one of the priorities of many countries, it is a goal for effective and efficient resource use on earth. Analyzing the growth of the economy and conservation methods for sustainable developing countries can be achieved by determining the possibility of ecotourism sustainability. And, it is essential to base the evaluation on sustainable development. This study assesses and maps the potential for sustainable ecotourism development using geospatial multiple approaches. Using 28 casual indicators within the three major groups of criteria of natural attraction, human attraction, and service tourism attraction were determined and integrated according to geospatial multi-criteria decision analysis. The indicators were prepared from different resources and standardization, criteria ranking, weighting, and spatial aggregation were performed to carry out the ecotourism suitability map in the Kurdistan region of Iraq (KRI). The result has produced a map to identify areas with a high potential for ecotourism sustainability in (KRI). The ecotourism sustainability map shows that about (54%) of the study area has a rating of very high, very good, and good suitability. This means the majority of the study area has a high potential for sustainable ecotourism development. It can be concluded that GIS—Multi-criteria decision analysis (MCDA) has a good ability in combining multiple datasets to produce suitability maps. The results could be used as a basis for tourism-related development plans by the Kurdistan region government and private sector.

Keywords Tourism · GIS · Multi-criteria decision analysis (MCDA) · Analytical network process (ANP) · Fuzzy logic

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Introduction

Tourism is one of the world's fastest expanding and most competitive industries (Elliott, 2020; Nilashi et al., 2019). The term "tourist" by MacCannell (2001) is defined as "people on transitory vacations

away from home who also spend money generated from their home region rather than the location being visited". This is considered to be one of the oldest definitions (Ghanem, 2017; Schwarzenegger & Lohmeier, 2021). There is not a specific definition for tourism, the term is defined according to various sciences, and some think that tourism is defined as the transitory short-term movement of individuals to destinations other than their usual locations of residence and work, as well as their activities and experiences while on these excursions. Travel is undertaken for a variety of purposes, including enjoyment, entertainment, culture, business, conferences, visiting friends and family, adventure, shopping, dining, challenge, and self-development, or a mix of these (Camilleri, 2018). United Nations World Tourism Organization (UNWTO) defined a tourism destination as a physical area, with or without administrative functions, where a tourist can stay overnight which influences its market competitiveness (UNWTO Tourism Definitions, 2019). According to UNWTO, International visitor arrivals increased by 58 times in the past 70 years. Visitors range from 25 million in 1950 to 286 million in 1980; 680 million in 2000, and 1.466 billion in 2019. It is predicted that the number of tourists in the world will reach nearly 1.8 billion by 2030 with the associated income amounting to US$1.26 trillion in 2015, a 630-fold increase over the US $2 billion recorded in the year 1950 (Gautam, 2011; Highlights, 2017; UNWTO, 2019).

Tourism is seen as one of the important worldwide economic fields and participates in the world's economic growth and exchange. The tourism sector has a direct impact on the economies of most countries, in the twenty-first century, tourism has become an essential part of the global economy. Transforming it into a worldwide business in which nations compete in many connected industries is one of the economic growth's core priorities. Tourism has shown significant resilience in the face of economic and social shifts, prompting the United Nations (UN) to establish the world tourism organization (WTO) (AL-Najjar & Ishwara, 2018). Every year, millions of people travel to view and enjoy the natural environment (Thapa et al., 2022). Nature-based tourism, often known as ecotourism, refers to tourist activities that rely on the utilization of natural resources that are still largely underdeveloped (Wang, 2022), such as landscape, picnic and site attraction, terrain, streams, waterfalls, bodies of water (lakes), vegetation, and cultural heritage (Deng et al., 2002; Iskakova et al., 2021).

Ecotourism has become a key driver of socio-economic progress through creating employment and businesses, increasing export earnings, and improving infrastructure (Liu et al., 2019; Sánchez López, 2022). Ecotourism is seen as a way to conserve natural regions, educating the public about environmental issues like pollution, soil degradation, global warming, overpopulation, natural resource depletion, waste disposal, and deforestation (Gumal et al., 2022; Phil, 2022). Sustainable ecotourism is a kind of tourism that generates economic benefits, encourages a positive experience for visitors as well as hosts, minimizes the impact of tourism on the environment, encourages conservation by providing financial benefits in its favor, and boosts employment and financial opportunities for local people (Giampiccoli et al., 2022; Štrba et al., 2022). Unsustainable ecotourism is the outcome of unsuitable development in environmentally vulnerable areas, like the outcome of incorrect development in environmentally vulnerable areas. As a result, the environmental consequences of overpopulation, overdevelopment, pollution, and wildlife disturbances. (Majdak & de Almeida, 2022). Ecotourism is a phrase that has to describe a sustainable kind of tourism that focuses on environmental protection, tourist education, cultural preservation and experience, and economic advantages for the local community (Šiljeg et al., 2019).

World tourism organization WTO defined ecotourism as a type of nature-based tourism activity in which the visitor's primary motivation is to examine, learn, discover, experience, and respect biological and cultural diversity (Buonincontri et al., 2021). While maintaining a responsible attitude toward the ecosystem's integrity and the well-being of the surrounding area (Mandić, 2019). Ecotourism activity raises awareness of biodiversity, the natural environment, and cultural assets among both residents and visitors, it needs specific organization to reduce detrimental impacts on the ecosystem (UNWTO Tourism Definitions, 2019). Recognizing ecotourism development possibilities is an unavoidable challenge in each situation. Earlier scholars provided a number of ways for identifying regions with the potential to undertake ecotourism strategies and activities in order to achieve this aim (Aneseyee et al., 2022; Asadi et al.,

2022; Sobhani et al., 2022; Swangjang & Kornpiphat, 2021). Based on geographical conditions and features, the various areas indicate categories of potentiality ranging from "low" to "powerful", That is, some areas, due to their geographical condition, have less access to ecotourism and vice versa, offer the highest level of ecotourism. Using quantitative methodologies in conjunction with expert knowledge in the decision-making and assessment process helps us to get a superior outcome (Aliani et al., 2017). Ecotourism must thus be implemented by utilizing a plan in conjunction with Geographical Information Systems (GIS) and spatial decision-making tools that may act as decision support systems (Shokati & Feizizadeh, 2019). Because of the difficulties of deciding whether a piece of land is suitable for the creation of tourist facilities, researchers have used a range of methodologies, including the analytical network process (ANP), fuzzy logic, and its integration with GIS decision rules (Ghorbanzadeh et al., 2018).

In the last several years, the multi-criteria decision analysis (MCDA) paired with GIS has become a widely used model for natural resource and tourist planning and development (Masoud et al., 2022). The combination of an MCDA technique with GIS is a tool for methodically and fully analyzing the situation ecotourism of the study area. The fundamental value of an MCDA process is an expert assessment and comparison of criteria significance (Gigović et al., 2016). There is no contribution to the ecotourism evaluation studies in the KRI, except the Asaad and Balaky (2021) study that evaluates the geotourism potential of the Akre area in the northern part of the region (Asaad & Balaky, 2021). The main objective of this paper is to identify areas with high potential for ecotourism development. KRI has faced decades of war where over 4000 villages were destroyed by the Iraqi government knowing that those areas are the main and most suitable places for ecotourism development (O'Leary, 2002). KRI has faced a number of economic challenges and it is understood that developing sustainable ecotourism will make a significant contribution to the economy of the country, therefore results of this research can be used for this goal. Another objective of this study is to apply the integrated GIS–MCDA for creating an ecotourism map based on natural resources and selecting the most suitable sites for ecotourism and the development of sustainable ecotourism in KRI. The research questions that are addressed in this paper are: What are the potentials for ecotourism in the Kurdistan region? Is there a balance between the lack of tourism facilities and economic infrastructure with the abundance and strength of nature-based tourism in the area? What are the GIS spatial decision-making systems capabilities for nature-based tourism sustainability mapping? Are there any constraints to the development of ecotourism plans for the sustainable development of ecotourism in the area? Can the nature-based tourism potentials of the Kurdistan region provide the opportunity for sustainable ecotourism throughout the year? This research will address the gap in this area by creating datasets on this particular subject which has importance for future decision-making and ecotourism development in the region.

Materials and methods

Case study area

The study area is the Kurdistan Region of Iraq (KRI), situated in the northern and northeastern regions of Iraq (Fig. 1). According to the Iraqi constitution from Article five, part one, in article 117, the KRI is one of the federal regions in Iraq. It includes three provinces (Erbil, Sulaimani, and Duhok) (The IRAQI constitution, 2005) (Yaseen Taha, 2018). It has an area of (39,602.58 km^2), equivalent to (%9.03) of the total area of Iraq; it has a population of about 5.8 million people (Ministry of planning, 2020). KRI is rich in various natural characteristics such as natural plants, water resources, climate, as well as differences in topography between the southern and northern parts, which reflect the region's natural resources. In general, the KRI is impacted by the Mediterranean climatic system (Abdulla, 2006).

The study area has a suitable climate for different tourism activities in all seasons, the summer season is dry and warm with an average temperature of (31.9 °C), cold and rainy in winter with an average temperature of (7.8 °C). There is comfortable weather in both Spring and Fall seasons, temperatures in the months (October, November, March, April, and May) are moderate and the area has moderate and cool weather with an average temperature of (19.3 °C) (General directorate of meteorology and earthquake of KRG 2019). Precipitation ranges from (310 to

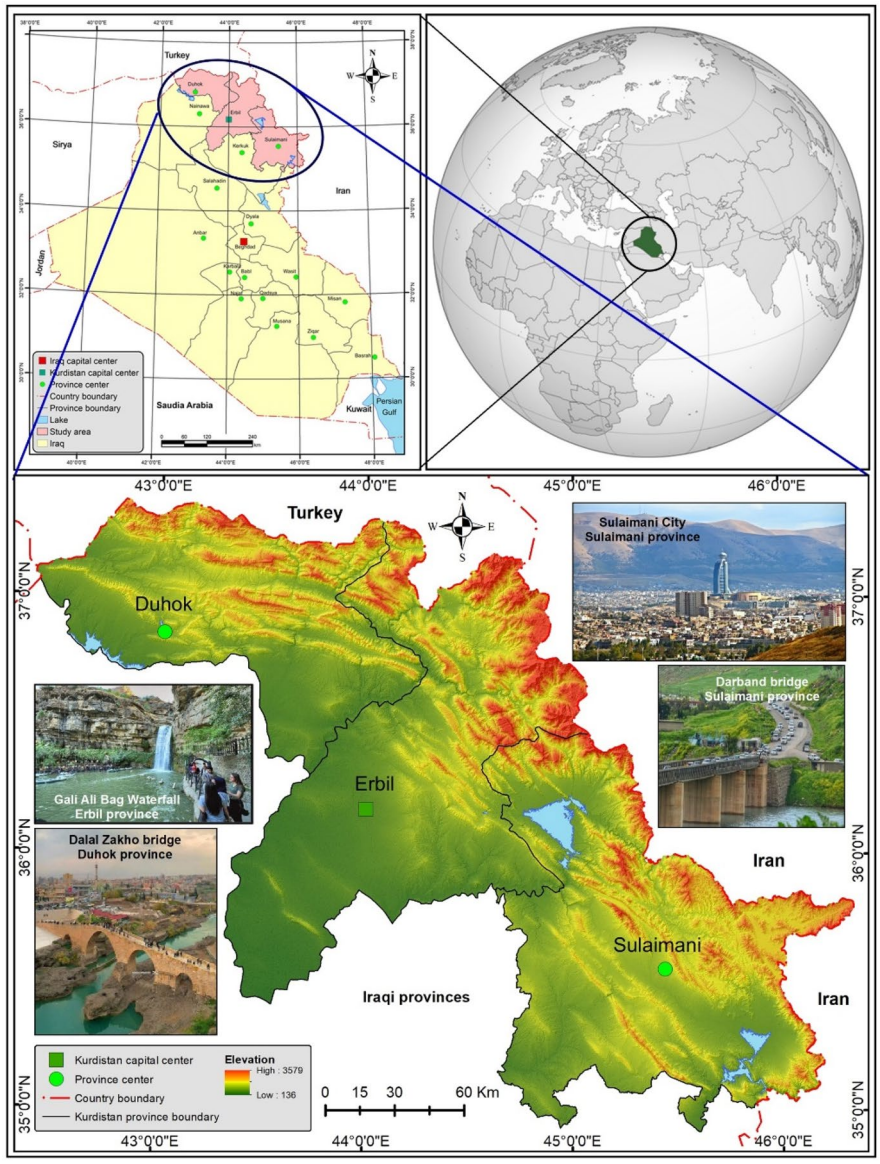


Fig. 1 Location of study area

1170) mm/year. In the areas of high precipitation amounts, grass and trees grow and spread widely, which affects the ecotourism movement (General directorate of meteorology and earthquake of KRG 2019). Ecotourism movements in KRI have become a public norm in all seasons. Culturally, the spring season means the season of travel and outdoors. One of the characteristics of the spring season in KRI is that the weather is very pleasant, the plains and mountains are green and filled with vegetables and various flowers. Also, most lakes are filled with water and rivers flowing through the valleys. This is a major contributing factor that boosts the tourism movement in KRI (General Board of KRG tourism, 2020). Relative humidity has a direct effect on the body and human calmness, during travel season relative humidity ranges between (32%) and (55.4%) (General directorate of meteorology and earthquake of KRG, 2019). Which makes tourists feel comfortable and relaxed (Rashid, 2012; Mohammed, 2015).

In terms of topography, the region consists of a series of high and complex mountains, plains, valleys, and hills, with an average height of (2000) meters above sea level (MASL), a maximum point is

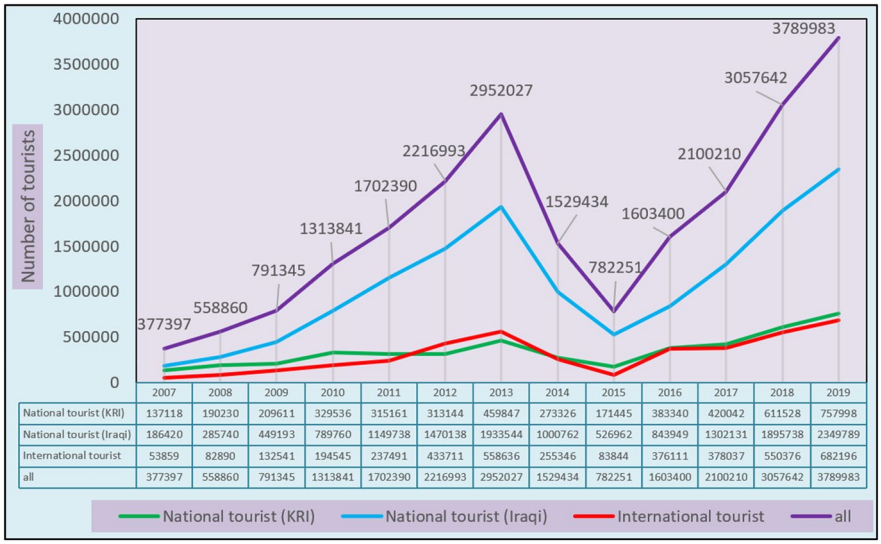
(3607) MASL, and a minimum point is (136) MASL (Sulaimani Statistical directorate, 2020). In addition, the region is rich in biodiversity including different types of flora and fauna. This topography has also led to the creation of many famous caves, most of which have a very ancient history and are of great importance to tourism. In terms of water resources, the existence of 4120 springs, 27 metal springs, 41 waterfalls, 3 major rivers, and 2 big dams that make up the Dukan and Darbandikhan Lakes. Also, one medium dam in Duhok and five small dams in different areas of KRI (Ministry of Agriculture and Water Resources—KRG, 2021).

After the 2003 war, KRI was opened to tourists, especially after the opening of both Erbil and Sulaimani international airports between 2003 and 2007. KRI has three types of tourists, (National tourists), are tourists who travel inside KRI, (National tourists—Iraqi), who are in the outer regions of KRI, meaning they are from within Iraq in the middle and south of Iraq, are traveling to the KRI. (International tourists) are tourists who reach the tourist areas of KRI outside Kurdistan and Iraq, like (the Middle East, Turkey, Africa, Europe, America and etc.) Fig. 2 shows the number of tourists visiting KRI, in 2007, all three types combined is about s 377,397 tourists which significantly increased to 2,952,027 in 2013, but in 2014–2015 number of tourists dramatically decreased to 1,529,434 in 2014 and 782,251 in 2015. There were fewer tourists to KRI in 2014 and 2015 as a result of the war between KRI and the Islamic State in Iraq and Syria (ISIS). The mobility of tourists resumed with the end of the war, and in 2019 there were 3,789,983 tourists overall (General Board of KRG tourism, 2020). Despite security and other challenges, it can be clearly seen that the number of tourists is increasing in KRI. Therefore, it can be stated that sustainable ecotourism development is significant for KRI.

Dataset and software

To achieve the objectives of the study, 28 different datasets were chosen. Datasets were derived from various sources based on the initial resource of the selected indicators. Some of the data is obtained from the official organization of KRG, like the Ministry of planning of KRG, the general board of KRG tourism, the general directorate of meteorology and earthquake of KRG, and the board of environmental protection and improvement of KRG. Most of the data from KRG is non-spatial information (hardcopy), like maps on papers, books, brochures, leaflets, banners, and tourism guide papers.

Another source of data collection for this paper was online data from the web internet (open data source), which are open street maps, Google maps, ArcGIS online, and the United States Geological Survey (USGS) (earthexplorer.usgs). In addition, direct visits and interviews were another means of data collection including interviewing the Director-General of the directories, university professors, and other



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
National tourist (KRI)	137118	190230	209611	329536	315161	313144	459847	273326	171445	383340	420042	611528	757998
National tourist (Iraqi)	186420	285740	449193	789760	1149738	1470138	1933544	1000762	526962	843949	1302131	1895738	2349789
International tourist	53859	82890	132541	194545	237491	433711	558636	255346	83844	376111	378037	550376	682196
all	377397	558860	791345	1313841	1702390	2216993	2952027	1529434	782251	1603400	2100210	3057642	3789983

Fig. 2 Number of national and international tourists in KRI from 2007 to 2019

stakeholders. For a comprehensive and accurate quality dataset from all of the resources, researchers visited the field to check and gather the spatial information in (X, Y, and Z) and converting to vector format in the shape of (shapefile or Geodatabase) format, using ArcGIS and ArcGIS-Pro environment.

28 types of criteria were selected based on the literature; interviews with 30 experts, university professors, and authorities. The datasets are divided into three main categories of group of criteria, including Natural Attractions with 14 criteria, Human Attractions with 4 criteria, and Service-Tourism Attractions with 10 criteria. The list of considered criteria is shown in (Table 1).

Natural attractions

Natural resources are tourist attractions. That has been made by nature without human hands in its creation, such as there are mountains, forests, and lakes that attract tourists in different seasons from all over the region. The most significant factors used in this study are natural attractions, because the KRI is characterized by natural landscapes and tourism geosites (Asaad & Balaky, 2021). The impact of these factors is clear when considering the definition of nature tourism. Since nature tourism is a form of a trip into nature with the goal of environmental management policy and enhancing the quality of life for communities (Arsić et al., 2017; Ghorbanzadeh et al., 2019; Nahuelhual et al., 2013; Omarzadeh et al., 2021).

Human attractions

Human resources are tourist attractions. That has been made by people, such as cities, museums, villages, or historical and archeological sites. Often, tourists travel to places where people have been involved in building to be experienced those places. Sometimes human resources become complementary to natural attractions and ecotourism will be produced. Although there are natural resources, if there are no human resources, this ecotourism movement will not be completed (Nahuelhual et al., 2013; Zografos & Oglethorpe, 2004).

Table 1 Criteria used in the paper

Group of criteria	Criteria	Data resource	Group of criteria	Criteria	Data resource
Natural attractions	Cave	Kurdistan board of tourism	Human attractions	City	Ministry of interior
	Dam	Ministry of planning		Historic and archaeological	Kurdistan board of tourism
	Elevation	DEM Data 15 Meters		Museum	
	Forest	Land use/cover map		Village (5 km away to cities)	Ministry of interior
	Humidity	Ministry of planning	Service-tourism attractions	Accommodation	Kurdistan board of tourism
	Lake			Airport	Ministry of interior
	Picnic and site attraction	Kurdistan board of tourism		Border Markets	
	Main River	DEM Data 15 Meters		Gas Station	Ministry of planning
	Slope	DEM Data 15 Meters		International road	
	Spring	Kurdistan board of tourism		Main and Side Road	
	Spring (Healthy)			Park	Kurdistan board of tourism
	Temperature	Ministry of planning		Restaurant	
	Viewpoint	Kurdistan board of tourism		Ski Resorts	
	Waterfall			Teleferic	

Service-tourism attractions

Service tourism attractions are the country's infrastructure that makes it easier for tourists to get to the resorts. Although there are many natural and human resources attractions in every place, if there are no attractions of tourism services, that place will not be a tourist attracting area, for example, if there is a beautiful waterfall and river in an area, but if there no roads to get the tourists to the scene there will be no tourism value. One of the most important reasons for creating an ecotourism movement with natural and human resources tourism attractions is service tourism attraction. Natural and human resources attractions are always valued by service tourism attractions in many publications (Hunt et al., 2015; Ullah & Hafiz, 2014).

In order to improve the quality of the dataset, some preprocessing steps must be applied. Preparing all the criteria in point, polyline, and polygon formats. Some of the layers need topological and geometric correction. All dataset layers have the same coordinate system, which is critical to getting accurate results about the distance of many layers when the Euclidean distance function in ArcGIS software is performed. After that, all the layers were converted to raster layers in the same coordinate system with WGS 1984/UTM zone 38 N and the same pixel size with a 30-m resolution. Accurate in overlay computing is very higher with the raster layers. All steps were performed in the ArcGIS environment. For spatial aggregation, the factors were generated as a GIS dataset and stored in a Geodatabase file. The spatial distribution of the selected factors is shown in (Figs. 3, 4, and 5).

The legend on these figures includes standardized values from 0 to 1 for all indicator maps. The number 0 indicates the area that has the least relevance to ecotourism, while the value 1 indicates that the place has the greatest importance for ecotourism.

Methodology

In order to produce the suitability map of the study area, and to better assist in the decision-making process of assessing the ecotourism sustainability potential, several factors were grouped into three main criteria groups that are natural, human, and service attraction factors. Also, GIS is used in integration with MCDA techniques, including ANP, and fuzzy logic (Mobaraki et al., 2014). The main schema process of the research methodology is represented in Fig. 6.

GIS—multi-criteria decision analysis

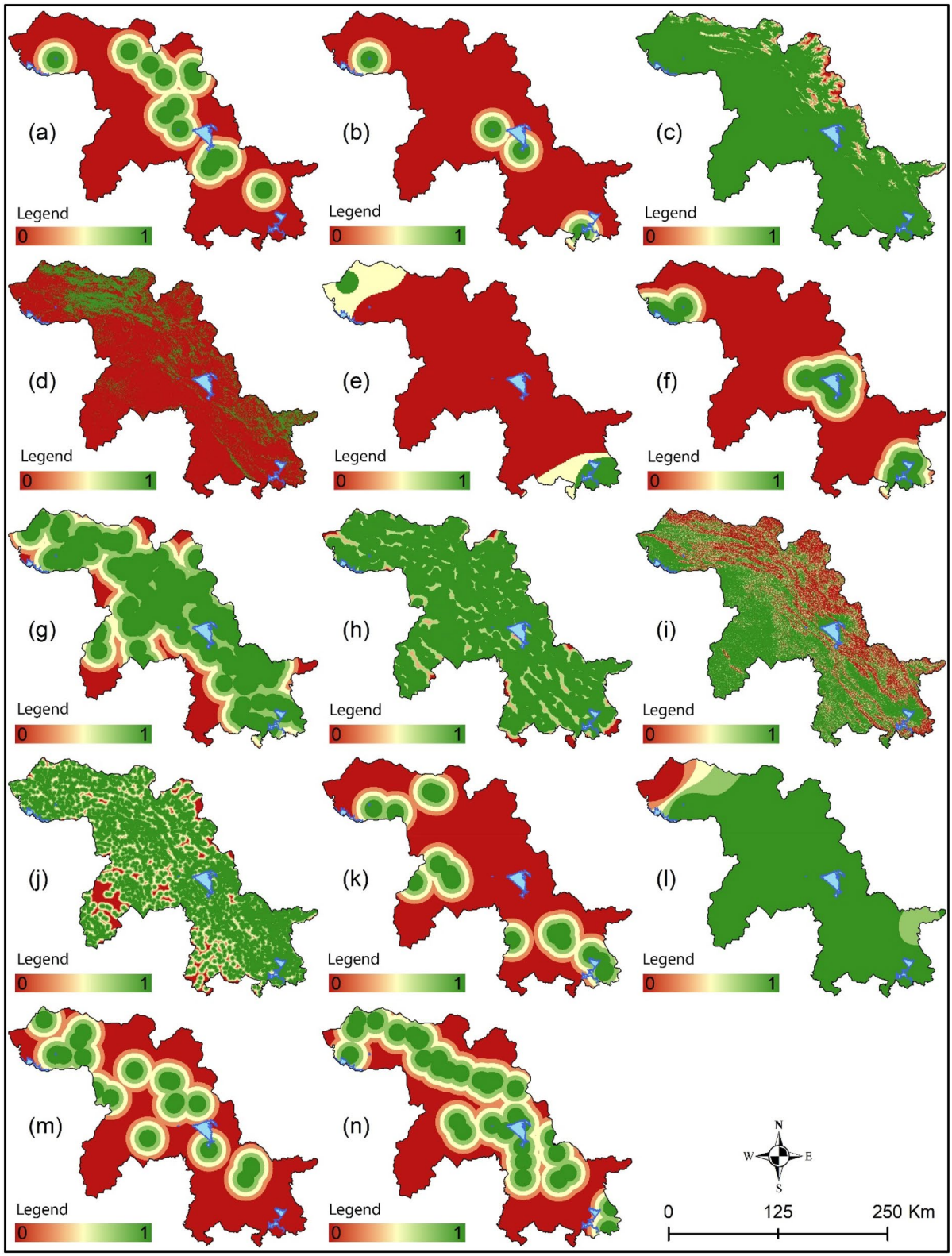
MCDA is one of the approaches used to this facilitates the consideration of multiple criteria by decision-makers. It is most applicable to fixed problems that are marked as a choice among options. It is used to logically evaluate and compare multiple criteria that are often conflicting to make the best possible decision. MCDA is a general framework for supporting complex decision-making situations with multiple and often conflicting objectives (de Brito et al., 2019; Sahani, 2019).

GIS-MCDA is a process that transforms and combines geographical data and value judgments to solve spatial problems (). This is accomplished by taking into account geographic data models, the spatial dimension of the evaluation criteria, and choice alternatives while assessing the criteria. Vehicle routing, site selection, scenario evaluation, land appropriateness, shown, impact assessment, and location allocation to a range of sectors are some illustrations of GIS-MCDA applications. (Jeong et al., 2016; Omarzadeh et al., 2021).

The GIS-MCDA model described in the study is a multi-group evaluation method for ecotourism sustainable mapping criteria, the model was applied to twenty-eight criteria classified into three groups, natural, human, and service tourism attractions and the criteria weight was judged by 30 participants through the print questionnaire forms, were distributed among tourism experts, geographers and GIS experts at the University of (Raparin, Sulaimani, Koya, Salaheddin, Duhok). The application combines authentic information (geospatial data) with a piece of worth-based information (criteria weightings) through the ANP method to derive the criteria weights.

Criteria weighting

The analytical network process (ANP) is one of the GIS-MCDA methods utilized in this article. The ANP methodology enables the modeling of complex levels and attributes interdependences. The majorities of real-world situations are not linearly defined and


(a)
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◂**Fig. 3** Natural attractions; **a** Cave; **b** Dam; **c** Elevation; **d** Forest; **e** Humidity;(**f**) Lake; (**g**) Picnic and site attraction; **h** Main River; **i** Slope; **j** Springs; **k** Springs (Healthy); **l** Temperature; **m** Viewpoint; **n** Waterfall

are interconnected. These issues are best solved using network-based modeling approaches. The network dependency of indicators aids in better modeling of real-world situations (Omarzadeh et al., 2021).

ANP was employed to compute the significance of each criterion. The ANP technique is the most fundamental MCDA feature of the GIS. It is commonly used to compute criterion weights and fix a variety of problems in the real world (Feizizadeh et al., 2021). The ANP was first suggested by Saaty (1996) as a powerful and comprehensive method for decision-making to overcome the problems associated with interdependence and feedback among criteria and sub-criteria. It also gives decision-makers a practical method for selecting the best potential answer to their situations (Saaty, 1996; Feizizadeh et al., 2021; Abedi Gheshlaghi et al., 2020). ANP is effective because of its capacity to evaluate highly intricate connections between multiple criteria. The ANP approach has several qualities, including the use of quantitative and qualitative criteria, the capacity to assess consistency in judgments, and adaptability. (Gheshlaghi & Feizizadeh, 2017; Tian & Peng, 2020).

The main purpose of using the ANP technique in this study was applied to weight the criteria. The criteria were weighted based on expert opinion by the ANP method using the Super Decision software. The pairwise comparison analysis is one of the most important steps in decision-making. This method allows experts' preferences for each pair of criteria to be aggregated in two-way comparison matrices. Comparison of criteria is possible using the pairwise comparison matrix (Ci and Cj) (Ghorbanzadeh et al., 2019; Omarzadeh et al., 2021; Sevkli et al., 2012). Pairwise comparisons now have an implicit scale with a range of crisp values from 1, for equally important, to 9, for extremely important, as well as the integers that exist between them (Saaty, 1980, 1996).

After pairwise, the consistency ratio (CR) for each matrix is calculated. CR is used to calculate the consistency of pairwise comparisons straight. The comparisons are admissible in judgment if the CR is less than 0.1, otherwise, it is not acceptable and the judgment must be reconsidered (Ayağ & Özdemir, 2007; Saaty, 1980). Inconsistent measurements can be used to identify potential judgment mistakes and actual inconsistencies in judgments (Gandhi et al., 2016). All steps in the hierarchical process are listed in Table 2 (Coyle, 2004; Gandhi et al., 2016; Omarzadeh et al., 2021). In our study, the CR value for the pairwise matrix was computed to be 0.07425, which is a satisfactory CR standard. The result of the research study by (Hajizadeh et al., 2020) showed, the consistency ratio (CR) value for the pairwise matrix was calculated to be 0.053, which is an acceptable CR overall and indicates the correct criteria weighting. Also, (CR) was also calculated and found to be 0.05 in the result of the research study (Bunruamkaewa & Murayamaa, 2011).

Super matrix formation

In the ANP approach, there are three matrix analyses: super matrix, weighted super matrix, and limit matrix, as in the loop, to get global weights in a system with interdependent influences (Saaty, 1996; Yüksel & Dagdeviren, 2007).

- Initial (unweighted) super matrix two-dimensional matrix composed of the relative-importance weight vectors and normalize it, so that the numbers in every column sum up to one.
- Weighted Super matrix obtained by multiplying the initial super matrix values by the cluster weight matrix.
- Limit matrix, the required limit of the weighted super matrix is used to calculate the constant values for every value. Or limit super matrix obtained by raising the weighted super matrix to the strength of an arbitrarily big number. (Büyüközkan & Çifçi, 2012; Saaty, 1996; Yüksel & Dagdeviren, 2007).

By normalizing each cluster of this super matrix, the final weights of all criteria in the matrix could be calculated, and the results are derived from the limit matrix scores. Specialists and experienced individuals should appreciate the criteria and options in order to achieve more regular and trustworthy outcomes. (Saaty, 1999; Saaty, 2003). The final normal ANP weights of all criteria are shown in Table 3.

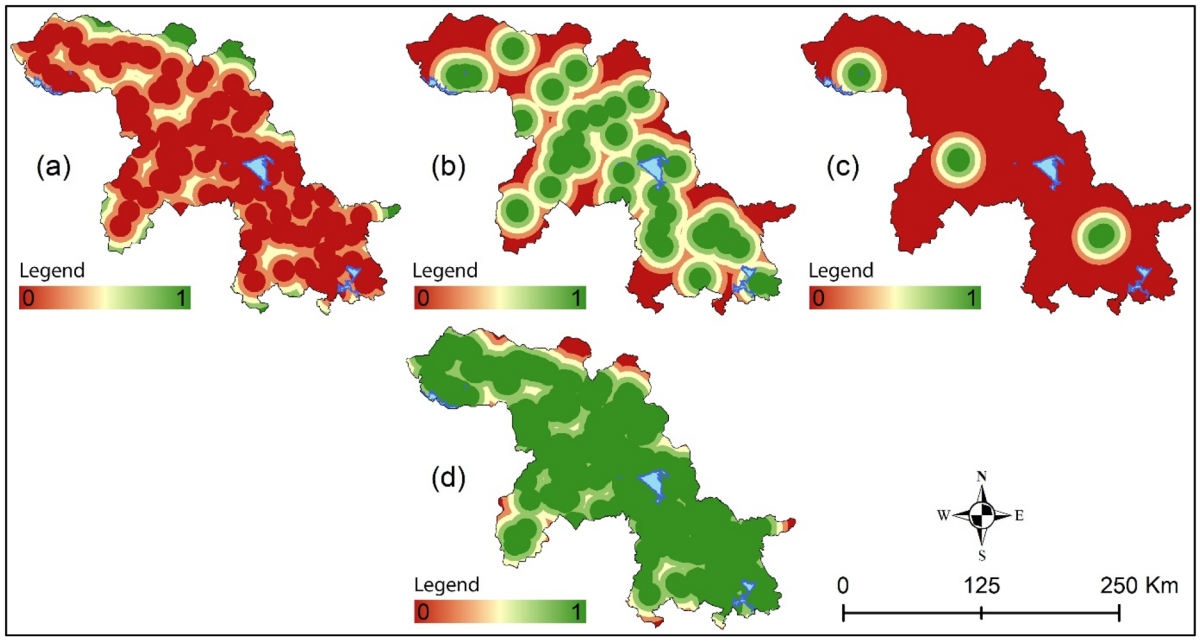

Fig. 4 Human Attractions; **a** City; **b** Historic and archaeological; **c** Museum; **d** Village (5 km away to cities)

Fuzzy logic

The fuzzy logic idea is adaptable and useful for data modeling where there are no precise boundaries between the set's members, first introduced by Zadeh (1965). It has a significant impact in bringing the outcomes closer to reality. Fuzzy logic is used in the process of data sets standardization of criteria. Standardization of criteria is based on fuzzy logic at the byte scale (0–255) and standardization of bans on the Boolean logic (0 and 1) (Gigović et al., 2016; Hajizadeh et al., 2020; Zadeh, 1965). Fuzzy logic depicts a hazy view of reality, attempting to draw the external actuality. If white is represented by 1 and black is represented by 0, then grey will be a number between 1 and 0 (Gheshlaghi & Feizizadeh, 2021).

Fuzzification should be utilized to bring modeling outcomes closer to human perspectives in multi-criteria decision models since human perception is not certain and clear The benefits of fuzzy membership functions (FMFs) for assessing criterion weights and increasing the reliability of the findings can be combined with ANP to give a framework for minimizing inherent uncertainty and using the advantages of fuzzy membership functions (FMFs) for assessing criteria weights and increasing the reliability of the findings (). Fuzzy set theory is a modeling method that is commonly used for complicated systems that are difficult to characterize precisely in crisp numbers. It is simple to comprehend and use, and it has been successfully connected with GIS-MCDA. In a number of study fields, GIS-based MCDA may be used with fuzzy set theory to describe imprecise aims. In the context of MCDA in general, fuzzy sets have been used. Fuzzy sets are commonly used to normalize criteria maps by giving degrees of membership or non-membership to each criterion ().

The membership function is used in fuzzy set theory to indicate the degree of membership value with regard to a particular attribute of interest. The attribute of interest is often measured across discrete intervals in this method, and the membership function, which is set as a table connecting map classifications to fuzzy membership values, is inscribed as a table linking map classifications to fuzzy membership values (Gheshlaghi & Feizizadeh, 2017).

In such situations, the set's elements are specified according to the degree of membership of a specific function (Sigmoidal, J-shaped, Linear, or user-defined). Whether any of the membership functions will be utilized is determined by the nature of the data, as well as specialist choices and judgments.

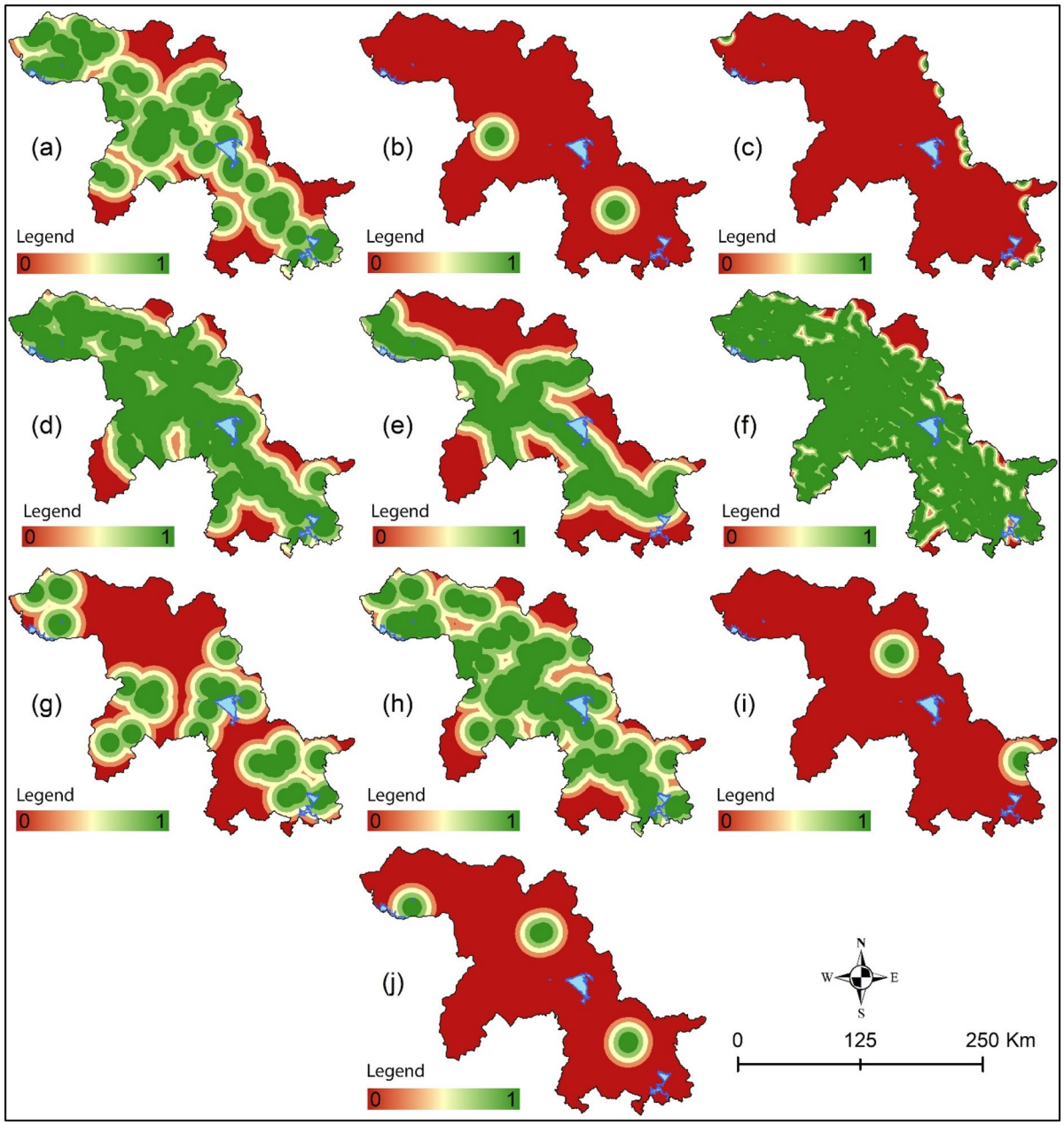

Fig. 5 Service-Tourism Attractions; **a** Accommodation; **b** Airport; **c** Border Markets; **d** Gas Station; **e** International Road; **f** Main and Side Road; **g** Park; **h** Restaurant; **i** Ski Resorts; **j** Teleferic

Linear or sigmoidal functions are usually adequate. Each criterion must have either 0 or 1 as the membership degree (Feizizadeh et al., 2014a, 2014b; Morteza et al., 2016: Gigović et al., 2016). This operation in our research was performed using the fuzzy membership command in the Arc GIS software by applying the linear fuzzification function. Fuzzy input values are transformed linearly on a 0 to 1 scale, with 0 being the minimum input value and 1 representing the highest input value. All of the in-between values are allocated a membership value predicted by the linear scale, with the bigger input values being assigned a

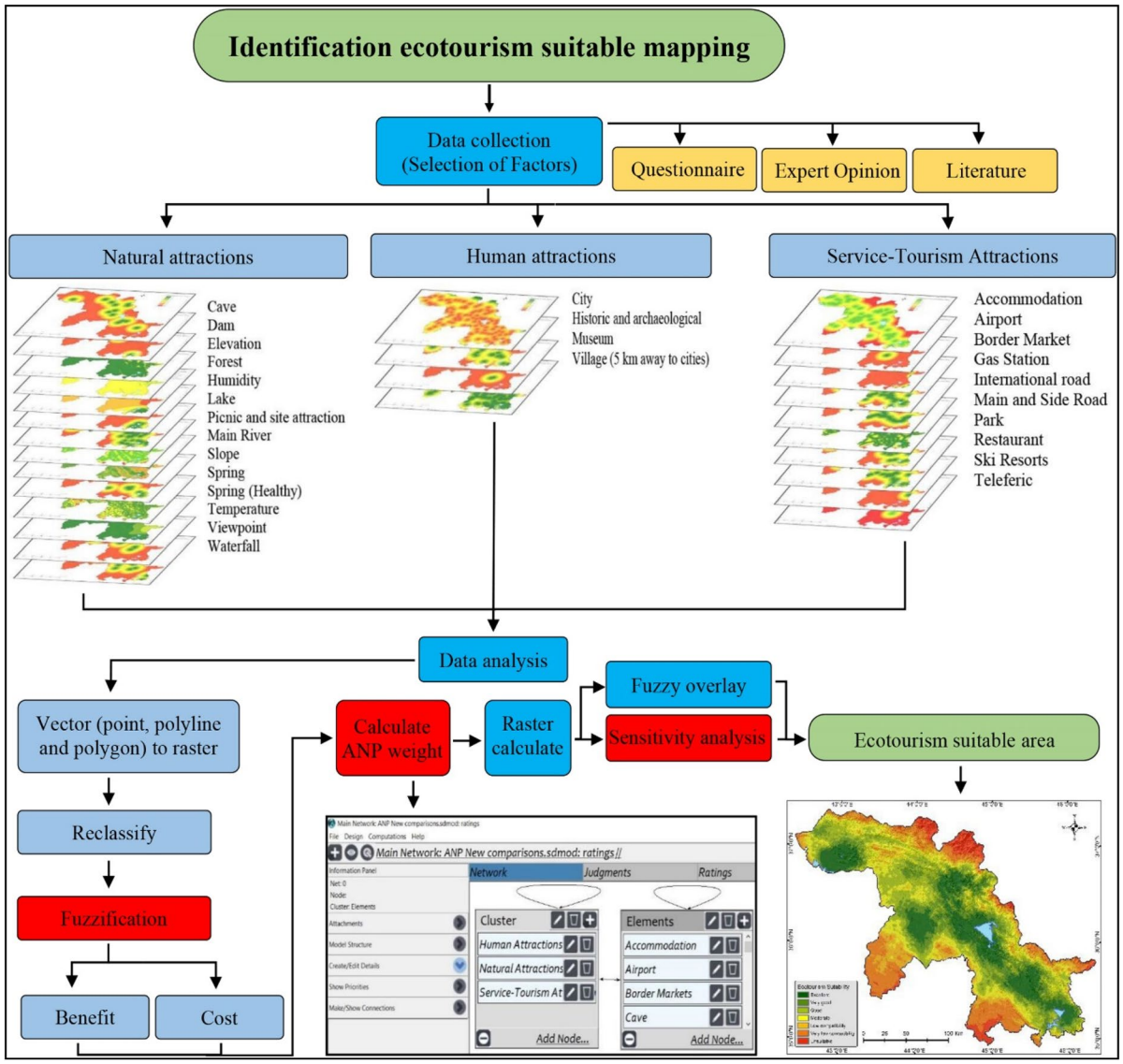

Fig. 6 Research main schema process

higher possibility, or closer to 1, and the smaller input values being assigned a lower possibility, or closer to 0 (Feizizadeh 2017; Najafi et al., 2019).

Lastly, the criteria weights were selected based on the integrated approach through the fuzzy analytical network process (FANP) (Table 3). To apply this final step, we need the fuzzy overlay tool. The Fuzzy overlay tools are often used to merge different factors of a model (Mesgari et al., 2008). In a multi-criterion overlay analysis, the fuzzy overlay technique allows for assessing the potential of a phenomenon belonging to several sets, as well as the relationship between the memberships of the different sets (Çakıt & Karwowski, 2018). The available methods in Arc GIS software are fuzzy and, fuzzy or, fuzzy Product, fuzzy Sum, and fuzzy Gamma. Each method contributes a distinct component of each cell's membership to the various input criteria; thus, a suitable overlay type should be chosen based on the final map's desired consequences (Raines et al., 2010). In the research presented we applied fuzzy overlay by using the gamma operator. The fuzzy Gamma kind is the

Table 2 The hierarchical process equations

Equation	Description	Components
$CI = \frac{\lambda_{max-1}}{n-1}$	Coefficient index	CI: compatibility index λ_{max}: maximum eigenvalue of the judgment matrix
$CR = \frac{CI}{RI}$	Compatibility rate	CR: consistency ratio CI: compatibility index RI: random index
$AW = \lambda_{max} W$	Eigenvector matrix	A: pair-wise comparison matrix W: eigenvector λ_{max}: maximum eigenvalue of the judgment matrix
$W_L = \lim_{K \to \infty} w^{2k+1}$	Limit super matrix	W: weighted super matrix K: exponent determined by iteration

algebraic outcome of fuzzy Product and fuzzy Sum, both increased to the gamma level. (Ghosh et al., 2012).

Result

The final comparison was performed among the criteria, based on the reports of tourism expert opinion, questionnaires, and literature, the research set out to evaluate the sustainability of ecotourism of the KRI. We used 28 criteria in this research, divided into three groups of criteria. Some criteria were the most significant for identifying suitable areas for ecotourism (Fig. 7).

In the group of criteria of natural attractions, the first rank is sprung (0.0521%), the second rank is a river (0.0491%) and the third a waterfall (0.0475%) were identified as the most important indicators. Compared to the results of the study (Ghorbanzadeh et al., 2019), the category "special sights" obtained the most importance (0.25%) among the other nature-based tourism factors. This means that special sights are the most attractive places for tourism in this research study. In the results of our research, picnic and site attractions' fourth most influential factor in the natural attraction group is (0.046813). Other results papers, similarly, (Omarzadeh et al., 2021) are close to the result obtained in the natural attraction, springs (0.062%) in the first rank of all groups of criteria. In human attraction, the first rank is a village (5 km away from cities) (0.0391%) and the second rank is historic and archaeological sites (0.0283%) turned out to be the most important criteria. While, within the group of criteria related to Service-Tourism Attractions, the first rank is Main and Side Road (0.0742%) the second rank is the International road (0.0486%) and the third is Ski Resorts (0.0311%) obtained the highest weight. However, the main and side road is the best criteria overall on all three main group of criteria. This means that main and side roads are the most significant indicator of ecotourism. Similarly, according to the results of the study (Fernando, & Shariff, 2017), road networks ranked first with (0.0611) in the group of service attractions.

On another hand, the final map of ecotourism suitability in KRI is presented on a scale of 1/20,000 in Fig. 8. The potential map was created utilizing the ANP approach's criterion weighting and the fuzzy overlay (Gamma function) method for criteria aggregation. The result is raster layer integration to every pixel assigned a value ranging from Low: 0.094446 to High: 0.84091, with high values suggesting high ecotourism sustainability potential and low values showing lesser levels of possibility. Then we classified the result into seven ecotourism suitability zones with the value and area of all zones in square kilometers as shown in Table 4. This classification for different number zones is up to understanding researchers, experts, and areas. Research (Ullah & Hafiz, 2014) conducted four types of suitable locations for ecotourism development in the study area, which are highly suitable, moderately suitable area minimum suitable area, and not suitable area.

The resultant suitability ecotourism map clearly shows that a large area in KRI has a very high potential for long-term ecotourism sustainability. As shown in Fig. 8, the dark green areas show very high potential for sustainable ecotourism and

Table 3 ANP weight, fuzzy membership, Consistency ratio (CR) results for all criteria

Group of criteria	criteria	Distance in km	ANP Weight	Fuzzy membership	CR
Natural Attractions	Cave	>5-10-15-20-25-30-131.89	0.031366	0-0.16-0.33-0.50-0.66-0.83-1	0.07369
	Dam	>5-10-15-20-25-30-132.42	0.038181	0-0.16-0.33-0.50-0.66-0.83-1	0.07327
	Elevation	>1.4-1.6-1.8-2-2.5-3-3.58 (Sea level, KM)	0.036377	0-0.16-0.33-0.50-0.66-0.83-1	0.07479
	Forest	>-0.6-0.2-0.2-0.6-1 (NDVI 0-1)	0.03665	0-0.25-0.50-0.75-1	0.07322
	Humidity	>35-40-45-50-55.41 (%) Humid—Sub-humid—Very humid—Semi-dry-Mediterranean	0.027318	0-0.25-0.50-0.75-1	0.07248
	Lake	>5-10-15-20-25-30-130.59	0.045224	0-0.16-0.33-0.50-0.66-0.83-1	0.07333
	Picnic and site attraction	>5-10-15-20-25-30-65.46	0.046813	0-0.16-0.33-0.50-0.66-0.83-1	0.076
	Main River	>2-4-6-8-10-12-18.03	0.049134	0-0.16-0.33-0.50-0.66-0.83-1	0.07377
	Slope	>5-10-13-16-20-25-80.41 (degree)	0.036775	0-0.16-0.33-0.50-0.66-0.83-1	0.07356
	Spring	>1-2-3-4-5-6-12.65	0.052072	0-0.16-0.33-0.50-0.66-0.83-1	0.07309
	Spring (Healthy)	>5-10-15-20-25-30-106.71	0.028869	0-0.16-0.33-0.50-0.66-0.83-1	0.0757
	Temperature	>15-16-17-18-19-20-21.6 (Celsius degree)	0.030777	0-0.16-0.33-0.50-0.66-0.83-1	0.07324
	Viewpoint	>5-10-15-20-25-30-95.46	0.045486	0-0.16-0.33-0.50-0.66-0.83-1	0.0733
	Waterfall	>5-10-15-20-25-30-101.88	0.047248	0-0.16-0.33-0.50-0.66-0.83-1	0.07333
Human attractions	City	>5-10-15-20-25-30-41.71	0.025559	0-0.16-0.33-0.50-0.66-0.83-1	0.0741
	Historic and archaeological	>5-10-15-20-25-30-63.2	0.028338	0-0.16-0.33-0.50-0.66-0.83-1	0.07333
	Museum	>5-10-15-20-25-30-125.08	0.023924	0-0.16-0.33-0.50-0.66-0.83-1	0.07307
	Village (5 km away to cities)	>5-10-15-20-25-30-39.73	0.039127	0-0.16-0.33-0.50-0.66-0.83-1	0.07309
Service-tourism attractions	Accommodation	>5-10-15-20-25-30-66.01	0.027	0-0.16-0.33-0.50-0.66-0.83-1	0.07414
	Airport	>5-10-15-20-25-30-169.53	0.023034	0-0.16-0.33-0.50-0.66-0.83-1	0.07381
	Border market	>2-4-6-8-10-12-186.17	0.025517	0-0.16-0.33-0.50-0.66-0.83-1	0.07333
	Gas station	>5-10-15-20-25-30-58.01	0.022999	0-0.16-0.33-0.50-0.66-0.83-1	0.07637
	International road	>5-10-15-20-25-30-80.71	0.048676	0-0.16-0.33-0.50-0.66-0.83-1	0.08756
	Main and side road	>2-4-6-8-10-12-39.83	0.074213	0-0.16-0.33-0.50-0.66-0.83-1	0.07333

Table 3 (continued)

Group of criteria	criteria	Distance in km	ANP Weight	Fuzzy membership	CR
	Park	>5-10-15-20-25-30-99.98	0.022541	0-0.16-0.33-0.50-0.66-0.83-1	0.07374
	Restaurant	>5-10-15-20-25-30-64.02	0.026831	0-0.16-0.33-0.50-0.66-0.83-1	0.07341
	Ski resorts	>5-10-15-20-25-30-196.32	0.031153	0-0.16-0.33-0.50-0.66-0.83-1	0.07324
	Teleferic	>5-10-15-20-25-30-157.74	0.028798	0-0.16-0.33-0.50-0.66-0.83-1	0.07374

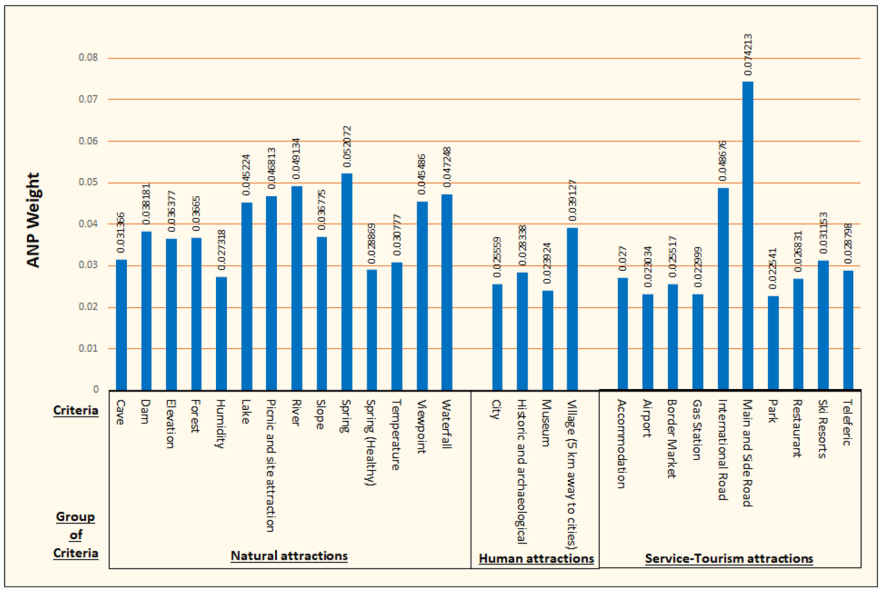

Fig. 7 Criteria weights obtained from ANP

the red color areas indicate lower levels or unsuitable areas of potential for sustainable ecotourism in KRI. Based on the fuzzy variables (54%) all the study areas has the rank of (very high suitable, very good suitable, and good suitable), this percentage covers an area of (21,400.9) km^2. Quite near to the results of our study, the results study (Omarzadeh et al., 2021) is a raster layer in which 7 classes were represented with fuzzy verbal values. Based on the fuzzy verbal variables, 57.14% of the area of the study area has moderate to high potential for sustainable ecotourism development. This percentage covers an area of square kilometers (20,987.8 km2).

Discussion

In order to better discuss and illustrate the outcome of the KRI ecotourism suitability map, areas with high suitability are enlarged and divided into six maps (a, b, c, d, e, and f) as shown in Fig. 9. Each zone is discussed in detail.

A

Looking at part (a) of the map, it is located in the northwestern of KRI, it is the area of Duhok province and Zakho city. Which is near the border of Turkey, one of the most important borders

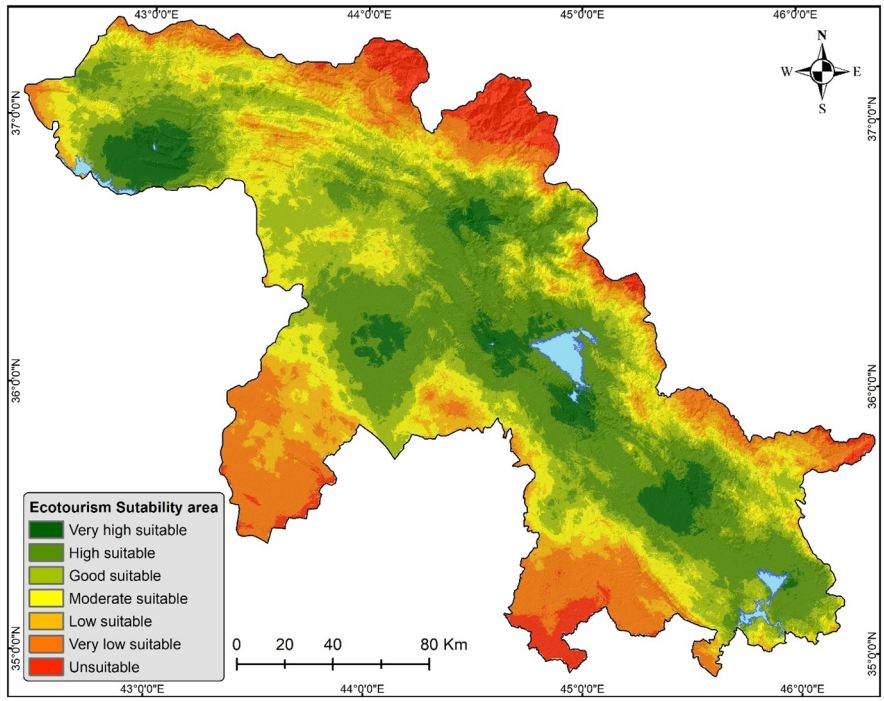

Fig. 8 Result of ecotourism potentiality sustainable map in the study area

Table 4 Classes of ecotourism potentiality sustainable map in the study area

No	Ecotourism suitability level	Value	Area in Km^2	Area %
1.	Very high suitable	0.601 – 0.841	2563.342	6.514
2.	High suitable	0.551 – 0.6	10474.159	26.616
3.	Good suitable	0.501 – 0.55	8363.398	21.252
4.	Moderate suitable	0.451 – 0.5	6412.613	16.295
5.	Low suitable	0.401 – 0.45	4191.031	10.650
6.	Very low suitable	0.301 – 0.4	5302.573	13.474
7.	Unsuitable	0.0944 – 0.3	2045.670	5.198
	Sum	0.094446 – 0.84091	39352.786	100

between KRI and Turkey. The main route for tourists to travel, because it has the international road which connects Turkey to KRI and Iraq. Every year, a large number of tourists from Turkey and Europe travel through this border to KRI and vice versa. The area includes the famous resorts in the KRI, including the Resorts of Sarsang, Solav, and Anishke, which have the capacity to accommodate a large number of foreign, local, and Iraqi tourists. This is mainly due to the presence of natural forests, rivers, waterfalls, and favorable weather conditions, especially in the summer. So the area has become a summer resort. Also, the Duhok Dam in the north of the city has created more tourism movement in that area. There is also Lake Mosul in the western part of the region, which is partly located region. This has improved the tourism situation in the region. On the other hand, the area has a high level of natural forests, as well as the presence of a nature reserve in Barzan, which is very famous in the region. One of the main problems facing ecotourism in the region is the fighting between the PKK and Turkey, especially on the border between Turkey and Kurdistan. It made instability in the region, this has led to a decline in the ecotourism value of the region and the expulsion of tourists.

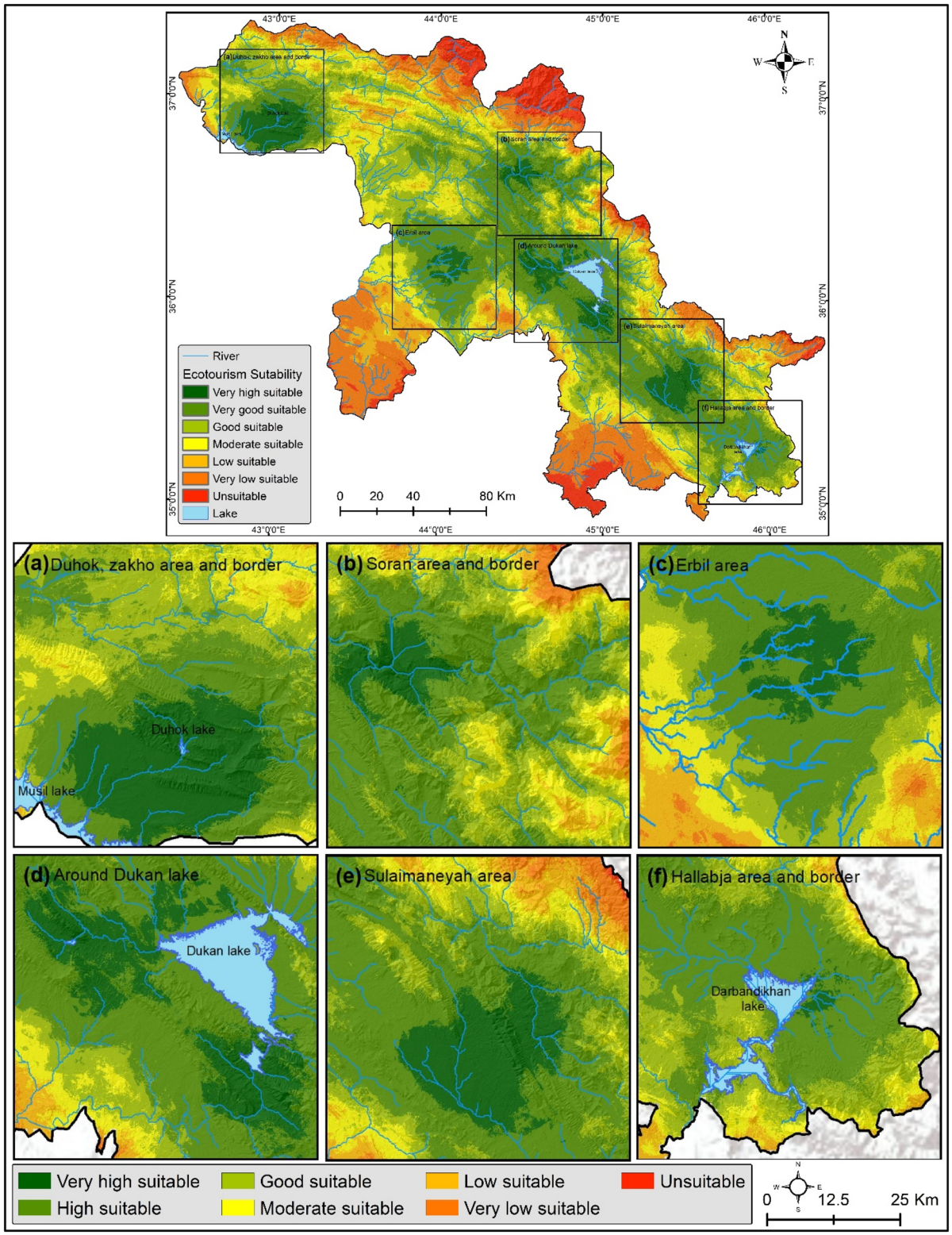

Fig. 9 High potential areas of ecotourism sustainable development in the study area

B

Part (b) of the map, is located in northeastern KRI, it is the area of Soran city which borders Iran. It has created a border market, one of the most important borders between KRI and Iran, named the Hajioamaran. This area has Hamilton International Road, which is a famous historical route that ran from Erbil city, through Rawandiz—Soran, to the Iranian border near Piranshahr city (Minorsky, 1937; Wilkinson, 1958). Every year, a large number of tourists from Iran travel through this border to KRI. Along this road, there are many important tourist resorts, including Bekhal, Jundian, Rawandiz, and Gali-Ali-Bag. Bekhal resort has the biggest waterfall in the region and it has a high potential attraction for tourism. One of the most attractive isKRI proposed Halgurd-Sakran National Park in this area. First is a designated national park in Iraq, which has very attractive geodiversity and biodiversity (Hamad et al., 2018). Also, on Korek Mountain, there is a popular teleferic, which has a good reputation at the level of KRI that welcomes tourists in all four seasons. In winter, snow accumulates in that area and creates a good environment for skiing activities. In the spring season, it has beautiful scenery. In the summer season, the temperature is very low compared to the cities and tourists feel relaxed when they visit the resort. In addition, there are many other resorts between mountains and along the rivers in the valley, such as resorts in (Balakayati area, Qasre, Choman, Gallalla, Sakran Nature Reserve Warte, Alana valley, Shaqllawa, resorts of Balisan valley), that are famous and attracts tourists all over the region. One of the most famous and ancient factors of natural attraction there is Shanidar cave; it is an archaeological site in the Bradost Mountain in the Erbil Governorate. With the help of Kurdish laborers, anthropologist Ralph Solecki led a team from Columbia University to the site, where they dug the Shanidar Cave and discovered the bones of eight adults and two newborn Neanderthals dated from about 65,000-35,000 years ago (Solecki, 1957). The cave has become one of the top attractions in the region for foreign visitors and scientists.

C

Area (c) shows the high level of potential for ecotourism in the Erbil area, Erbil, Iraq's 4th largest city, the capital of the KRI, has huge potential ecotourism and impacts the influx of tourists to the area, including several large quarters of the city, accommodation, restaurants, gas station, international road, main and side roads, museums, historical and archeological sites, including the most important historical site is Erbil castle in the center of the city. It has a very ancient history. Erbil Citadel, from a historical point of view, is thought to be around 7000 years old. The Erbil stronghold is located above the city at a height that overlooks the entire city. It has an oval shape and stands at a height of 28-32 m. The east-west axis measures around 430 m, while the north-south axis measures approximately 340 m. The castle is 10 hectares in size. The castle, which dominates the city's profile, is likewise becoming more visible as new structures spring up around it. The Citadel of Erbil has been the most crucial component in the city's ecotourism growth (Al Jaff et al., 2017). Also, it has an international airport, Air travel is an essential component of tourism since it provides the quickest connectivity between tourists and their venues (Fernández et al., 2018). Erbil international airport (EIA) after 2003, Erbil city was becoming the destination area for foreign investments (Hammodat et al., 2020). The airport has since its official opening in 2005, and it is a 24/7 operation (Ahmed & Najmadin, 2016). This airport, an important reason for the continued travel of tourists, made foreign tourists visit KRI and played a key role in the tourism movement. There are several natural areas that attract ecotourism. Especially in the eastern part of the region, including the resort of Massif-Salahuddin, as well as Shaqlawa resort, which has many natural potentials such as plant cover, forest, water, and cool-medium weather in the summer. Also in the northern part of the region, there is the Great-Zab River, which has become a tourist attraction.

D

Area (d), show cases of water resources' ability in attracting tourism. Water is a resource that has a high potential for attracting visitors. Various sorts of bodies of water can support a wide range of tourism activities. Tourists who want to appreciate this natural phenomenon during their vacations can do so by visiting habitats where water is the most important element (wetlands, beaches, rivers, lakes, waterfalls,

islands, glaciers, or snowfields) (Asyraf et al., 2013; Folgado-Fernández et al., 2019). When we look at that map carefully, we will see the area has a lot of water resources, like the Dukan lake, Smaqulli lake, Lesser Zab river (Zeibchuk), springs, Smaqulli hot springs, waterfalls, and Dukan dam, all of them included in the map (d) create a high potential area for sustainable ecotourism development. This area has many ancient cities such as (Qalladze, Ranya, Koya, Dukan) districts which complement the natural attractions by providing services that are essential for the tourism movement. There are many famous resorts, landscapes, and picnic site attractions such as (Jolanan, Dawzhan waterfall, Hallsho, Darband, Sarsyan, resorts of Shawre valley, resorts around Dukan lake, Dukan city, ChamiRezan, and Zewe).

E

Area (e) shows the Sulaimani area including Sulaimani city which is the 2nd largest city in KRI after Erbil. This area has many forests and abundant villages scattered around. This has become a major ecotourism attraction for many people where they travel to villages and some of them build a second home for weekends and family vacations. The villages among forests provide a unique and quiet experience for visitors. It also has suitable temperatures and they are not far from cities which makes it easier for visitors to reach the area of their desire without traveling too far. Furthermore, Sulaimani has an international airport, the construction of the airport began in November 2003, and it was inaugurated in July 2005. The opening of the airport facilitated and improved tourism movement in this area. Also, Sulaimani city is named the cultural capital of the KRI, which made the are even more attractive to visitors (Shafiq, 2018). Another landmark in this area is the HazarMerd Cave is around 12 km southwest of Sulaimani city, on the top of Qaradag mountain. It is a series of caverns, but the largest is known as HazarMerd and is (30X20X10 meters) in length, breadth, and height (Mohammad et al., 2017). Many local and international tourists visit there. In addition, this area has a famous attraction called QopyQaradag mountain resort which is famous for its beautiful landscape and views. There are more resorts in this area including (Sarsir, Sitak, Azmar, Goizha mountain, Mergapan valley, and Qaradag) that all attract tourists in various seasons that is despite having other human and service attractions.

F

Area (f) represents Halabja, Sharazur, and Darbandikhan lake area. This area is rich in natural attractions, such as dense forests, waterfalls, rivers, and the Darbandikhan dam. The largest waterfall is the Zallm in Ahmed-Awa village. It can be argued that this is the most famous and attractive area in KRI which attracts thousands of local, Iraqi and international tourists. Besides the breathtaking views of the waterfall and surrounding landscape, temperatures are low which makes it a relaxing area in the generally hot summers in the region. The area is also rich with dense forests that have grown in the valleys and mountains sides. Service and human attractions are relatively well developed in this area including cabins for overnight stays. Additionally, many local and cultural products are showcased and available for sale. Another famous ecotourism spot in this area is Khurmal hot/health springs. It attracts people that seek medical benefits from the springs from the entire region in all four seasons. From a water resource attraction standpoint, Darbandikhan Lake is located in this area, which is one of the largest manmade lakes in the region. The formation of the lake has led to the creation of many famous resorts around the lake that attract tourists, especially in the summer and spring seasons. In addition, this area has three border points with Iran. Although these points are not international but have they have raised the economic value of the area, which later had an impact on the economic level of the population and the ecotourism sector of the region. Some other locally famous resorts are located within this area including (Ababaile, Shameran, Byara, Tawella, Hawraman, Bakhakon, Balkha, Ahmed-Awa, and Hawar). The city of Halabja is also located within the parameters of this map. The city became famous for the tragic events of 1988. Saddam Hussein launched a devastating offensive against the Kurds near the end of the decade-long Iran-Iraq war. On March 16, 1988, in the Kurdish city of Halabja, one of the greatest crimes of genocide happened. On that day, the city was suffocated by sweet-smelling poison gas, which killed at least 5,000 people (Szanto, 2018). This caused Halabja to be known all over the world. Annually, many ceremonies

are held in the city to commemorate the tragic events which attract thousands of tourists to the city.

Conclusion

This paper aimed at assessing and mapping the potential of sustainable ecotourism in KRI. The research used the ANP approach and fuzzy logic, as a GIS-MCDA method. The results indicate that about (54%) of all the study area has a grade of (excellent, very good, and good), which means a large portion of the study area has a high potential for sustainable ecotourism development. This percentage covers an area of (21,400.9 km^2). This research for the first time created a database for all the relevant ecotourism matters in KRI which combined with the results of the study should benefit both public and private sectors in future decision-making and development plans. Based on the results of this study, we can understand the ecotourism situation in KRI at the current time and lays a solid foundation for future sustainable ecotourism development. Additionally, it can be concluded that GIS-MCDA techniques are powerful tools in assessing and mapping the potential of sustainable ecotourism mapping as it allows for user friendly decision making while dealing with complex issues and large data sets and different criteria.

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