International Journal of Environmental Science and Technology (2020) 17:2583–2592
https://doi.org/10.1007/s13762-020-02633-z

ORIGINAL PAPER

Identifying optimal location of ecotourism sites by analytic network process and genetic algorithm (GA): (Kheyroud Forest)

J. MirarabRazi[1] · I. Hassanzad Navrodi[1] · I. Ghajar[1] · M. Salahi[1]

Received: 21 November 2018 / Revised: 10 December 2019 / Accepted: 14 January 2020 / Published online: 27 January 2020

Abstract

The development of ecotourism as one of the most economical ecosystem services requires the evaluation, planning, and management of sustainable development. By considering the challenges facing the management of touristic zones, especially in forested areas, the need to use an integrated approach to optimize "recreational activities" versus "conservation of natural resources" is inevitable. Therefore, in this study location of appropriate areas for developing ecotourism was analyzed with the use of combined analytic network process (ANP) and genetic algorithm (GA). A three-level network comprising the target, five main clusters (biodiversity, climatic and climatic resources, soil and geology, topography, and socioeconomic factors), and sub-selection criteria in the studied forest areas, are designed. Subsequently, standardized and related maps were provided as selection criteria in the GIS. Accordingly, the genetic algorithm was found to consider feasible sites and 10 optimal responses including 5 appropriate and 5 inappropriate sites. In order to ensure the optimality of the proposed GA, the desirable ratio between the superior and inappropriate sites and the comparison of the results with the zones obtained by the WLC method was used. The comparative results confirmed the efficiency of GA for identifying appropriate sites for ecotourism.

Keywords Ecotourism location · Analytic network process (ANP) · Weighted linear composition (WLC) · Genetic algorithm (GA) · Optimization · Kheyroud

Introduction

Today, tourism is known as a high-performing industry in the global economy. The recent worldwide increased demand for recreation and tourism experiences has faced the managers with some challenges regarding the effects that visitors may have on the natural and environmental resources of protected areas. Recreation is one of the psychological requirements of modern life that eliminates exhaustion through relaxation. Among different types of tourism, ecotourism is one of the worldwide broadest activities that have experienced substantial growth (Bali et al. 2015). The most important features of this type of development are the lack of infrastructure, facilities, and macroeconomic investments. Ecotourism development is one of the effective factors that provide many direct and indirect economic, social, cultural, and environmental benefits to the hosts (Ghahroodi Tali and Sadoogh 2012).

On the other hand, mismanagements in the field of ecotourism development in protected areas have shown damaging the ecotourism and culture of local communities. Therefore, in order to create reasonable and optimal balance and facilitate ecotourism administration, it is necessary to develop and use criteria according to dominant conditions and situations in that area, keep sustainability to preserve the environment in a way that maintains it for the use of future generations, and fulfill current recreational needs. Forest is one of the most crucial ecotourism resources. In this regard, Caspian forests located in the north of Iran offer a tremendous genetically, ecological, and landscape variety, enriched by the presence of various microcultures and lifestyles (Ahmadi et al. 2014). Accordingly, the recreational opportunity of ecotourism should be utilized as a parallel approach for forest exploitation, sustainability maintaining, and natural resources protection while providing economic

Editorial responsibility: M. Abbaspour.

✉ I. Hassanzad Navrodi
iraj.hassanzad@gmail.com

[1] Department of Forestry, Natural Resources Faculty, University of Guilan, P/O Box 41635-19141, Rasht, Iran

revenue, in particular in time spans in which logging activity is hibernated. According to the necessity and importance of proper design, the methods that will provide the best results for managers and users of natural resources (reducing the conflicts and the negative effects of human applications without limiting them) are prioritized (Parolo et al. 2009). There have been several studies on the evaluation of the land potential for ecotourism and recreation. For instance, Bagheri and Mohammadzadeh (2016) ranked ecotourism attractions of the Jask port in the southern coasts of Iran (Mafi-Gholami et al. 2019) using a multi-criteria decision-making method and determined water supply, vegetation, and distance from human settlements as the most important factors. Ahmadi et al. (2014) studied the application of multi-criteria decision making for the identification and development of ecotourism potential, where vegetation type, infrastructure, and climate were the most influential factors. Ghahroodi Tali and Sadoogh (2012) evaluated the ecotourism infrastructures in the Miankaleh Gulf in northern Iran using a multi-criteria method based on 5 main criteria and 19 sub-criteria and identified the security, distance from the road, and the type of geological formations as the most important factors. Among the nine criteria applied by Bunruamkaew and Murayam (2011), those related to landscape and attractions, type of vegetation, land use, slope angle, and elevation were considered as the most important criteria. The results of the research by Parolo et al. (2009) indicated that among 12 studied criteria, the safety of visitors, secure areas, wildlife habitats, and threatened plant species were the most important ones.

One of the major advantages of evolutionary methods can be to optimize the situation in the context of conflicting goals. The main aim of optimization is to maximize the benefits versus minimizing costs under different scenarios. Among the elite and intelligent algorithms proposed by researchers in recent decades, methods such as the development of dispersed sets (Duan et al. 1992, 1993, 1994) and Rosenbrock method (Rosenbrock 1960; Podger 2005) have provided accurate results. The random genetic algorithms (GAs) proposed by Holland (1975) and Goldberg (1989), which are inspired by biological knowledge, provide a systematic search in the space of environmental controller variables (Song and Chen 2018). The purpose of this search is to provide a series of optimal responses for controlling the system in the desired state (objectives and target functions). Unlike conventional multi-criteria methods, the GA processes have the ability to provide a dynamic simulation and advantage, considering the evaluation units together, not solely in isolation. So far, some studies have used the GA in the environmental sciences (Dreyfus-Leon and Chen 2007; Peacor et al. 2007; Sweeney et al. 2007) and few studies have been devoted to the use in genetics, environmental sciences, and GIS (Holzkamper et al. 2006; Parolo et al. 2009). Rahimi et al. (2014) developed a method based on using combined analytic hierarchy process (AHP) and GA in artificial groundwater site selection. Optimization using GA applied to the selection of the ideal number and location of suitable areas for the artificial groundwater recharge. Results showed to indicate the ability of the developed framework. Ahmadipari et al. (2018) offered an analytical framework to industrial site selection through GA and fuzzy AHP (FAHP). They used GA as an optimization method applied for natural site selection. Their results showed that GA with FAHP is able to produce very satisfactory results for site selection under complex situations. Hence, there is great potential for solving environmental problems and applying GAs. Accordingly, the present study was conducted to develop ecotourism along with improving the livelihood of residents and taking conservation requirements in forest areas into account. The following objectives were specifically addressed in the present research:

- Identifying and prioritizing appropriate criteria for the development of ecotourism in the study area using the analytic network process (ANP).
- Providing a conceptual model based on the genetic algorithm (GA) to minimize the environmental hazards of ecotourism development.
- Evaluating the efficiency of each proposed solution.
- Comparing the results obtained from ANP and GA with those produced using the weight linear composition decision making (WLC).

Materials and methods

The methodology of this study consists of three main sections: (1) selection and prioritization of criteria, (2) thematic mapping in a GIS environment, and (3) optimization, evaluation, and analysis of the model results.

Study area

The study area is the educational and research forest of the Faculty of Natural Resources of the University of Tehran, located 7 km east of the Nowshahr city in the Mazandaran Province at 36°27′ to 36°40′N and 51°32′ to 51°43′E. This 10,000 ha area is limited from the north to the Najjar Deh village, from the south to the Kalik village, from the east to forest basin 46, and from the west to the Mashalak forests. Kheyroud-kenar River is the main drainage of this basin and is fed by different rivers related to other connected sub-basins. The Kheyroud-kenar forest is composed of 7 districts of Patam, Nam Khaneh, Gorazbon, Chelir, Baharbon, Darno, and Maniyasang (Fig. 1). This Hyrcanian forest, as the relic of the third geological period, has a rich biodiversity, which

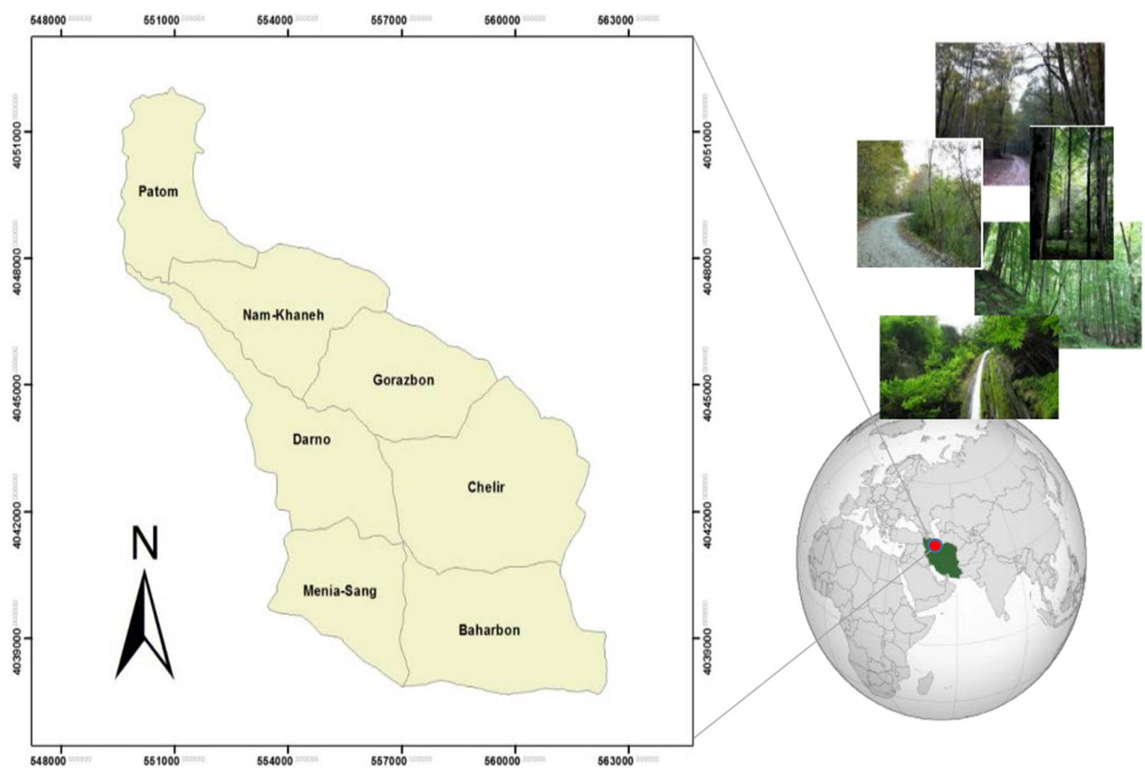


Fig. 1 Location of study area

makes the management of the area a critical issue in terms of both conservation and recreational aspects (Naqinezhad et al. 2018). The woody species such as Yew (*Taxus baccata*) and wildlife such as *Panthera pardus* are of particular protective, recreational, and conservation importance (Jaafari et al. 2014, 2015).

Selection and prioritization of ecotourism development criteria

In the present study, identification of appropriate criteria and sub-criteria for zoning ecotourism was based on the review of the corresponding literature (e.g., Aliani et al. 2017; Ahmadi et al. 2014, Bali et al. 2015; Hajehforooshnia et al. 2011; Parolo et al. 2009). Based on these studies, a three-level ANP model was presented in terms of the objective, criteria, and sub-criteria of effective development of tourism in protected areas (Fig. 2). Subsequently, the range of selected criteria for the survey was compiled by 18 experts in environment, ecotourism, water resource management, geology, economy, and social science in the form of paired questionnaires. For this purpose, SPSS (for measuring the validity of questionnaire data) and Super Decisions (for ranking the criteria and sub-criteria) were used.

Thematic mapping

The next step was the spatial integration and mapping of the adjusted criteria derived from ANP in the GIS environment. The feasible areas for ecotourism development in the Kheyroud forest area were delineated based on the weights obtained from the pairwise comparisons subjected to the constraints defined by the fuzzy standardization (Table 1) (Aliani et al. 2017). Then, the best five and the worst five solutions were selected as the input data of the GA.

Optimization and analysis

Since the positive (i.e., suitability) and the negative (i.e., unsuitability) aspects of each criterion were already taken into account during the fuzzification of the thematic maps of the criteria (Table 1), in the next step of the methodology, GA was used to search for the best combination of the weighted criteria for delineating the study area to different levels of suitability for ecotourism development. To do so, GA was designed based on the best and worst solutions and the site conditions were analyzed accordingly. This approach allows for identifying potential areas within an unsuitable zone. To ensure the accuracy of the algorithm performance, the superiority of each one of the best five sites was compared to those obtained from the worse five sites.

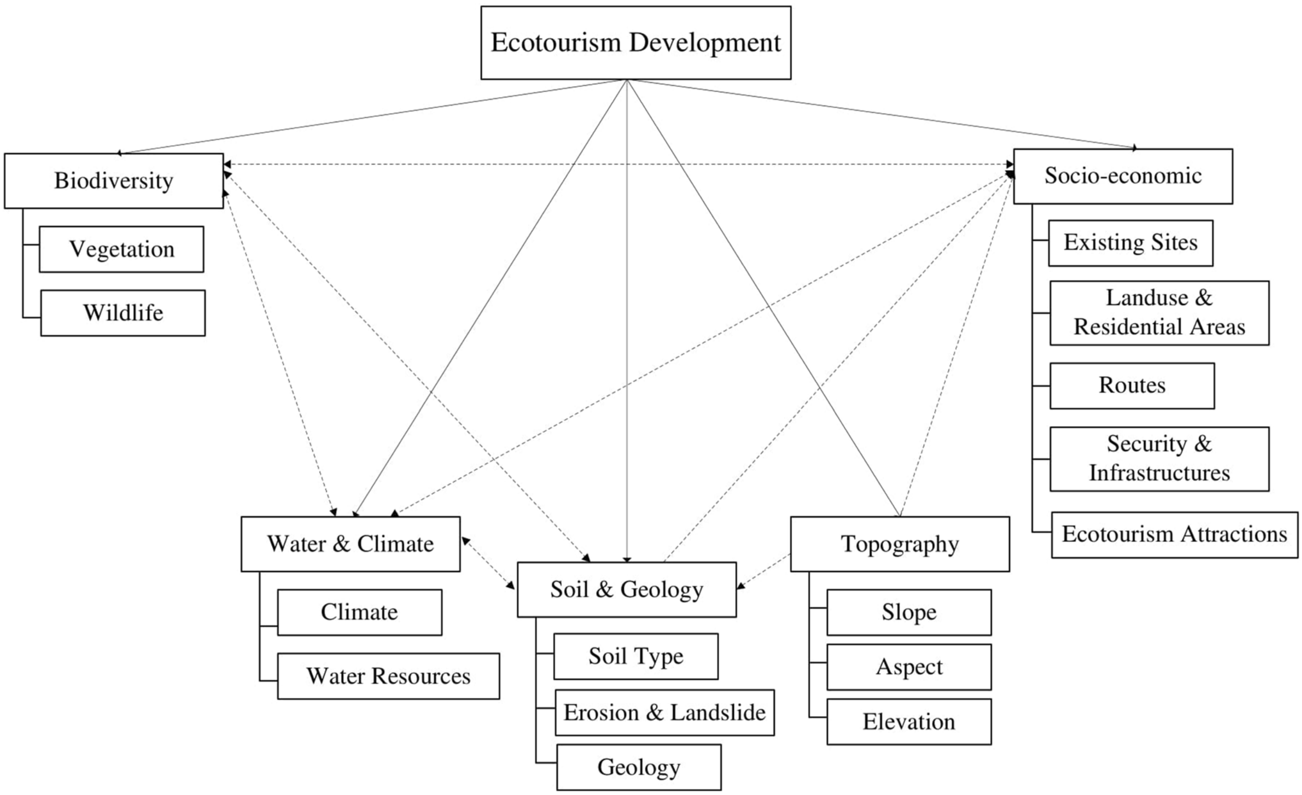


Fig. 2 Network model indicators effecting the development of ecotourism

Table 1 Membership functions used to normalize the thematic maps

No.	Factor	Suitability	Fuzzy membership function
1	Vegetation (density)	0–%5 = 0, 5–%40 = 0 to 255, 40–60% = 255, 60–%80 = 255 to 0, More than %80 = to 0	Asymmetric trapezoidal
2	Wildlife habitat	0–500 m = 0, 500–1000 m from 0 to 255, more than 1000 m = 255	Uniform increasing
3	Water resources	0–50 m = 0, 50–500 m from 0 to 255, 500–2000 m from 255 to 0, more than 2000 m = 0	Asymmetric trapezoidal
4	Geology	0–500 m = 0, 500–1500 m = 0–255, more than 1500 m = 255	Uniform increasing
5	Slope	0–%15 = 255, 15–%50 from 255 to 0, more than %50 = 0	Uniform decreasing
6	Aspect	Eastern orientation = 255, North = 200, without aspect = 150, western 100, south 50	Discrete
7	Sea Level	0–100 m from 0 to 255, 100–1500 m = 255, 1500–2500 m from 255 to 0, more than 2500 = 0	Asymmetric trapezoidal
8	Available villages	0–250 m = 0, 250–500 m from 255 to 0, more than 5000 m = 0	Asymmetric trapezoidal
9	Access routes	0–150 m = 0, 150–300 m from 0 to 255, 300–5000 m from 255 to 0, more than 5000 m = 0	Asymmetric trapezoidal
10	Attractions and natural scenery	0–30 m = 0, 30–50 m from 0 to 255, 50–2000 m from 255 to 0, more than 2000 = 0	Uniform decreasing

Results and discussion

Analytical network process

Following the collection and identification of the evaluation criteria, weighing and prioritizing the criteria were performed according to the network analysis and the results are presented in Table 2.

Mapping and WLC

Following the previous steps, the appropriate criteria for extracting potential ecotourism areas were integrated and mapped. In this step, due to the partial lack of the required information from the study area, normalized weights (Table 2) were reviewed. On this basis, a map of the climate and existing infrastructures, the type of the soil, and also security and infrastructures of the area were deleted and related weights were integrated into subgroups. Finally, maps that need to identify potential development areas are integrated (Fig. 3). The applied functions and the data normalization approach in the integration of matching maps are presented in Table 3. In addition, descriptive statistics related to identifying spots were extracted and presented in Table 4. Moreover, the linear integration of the map to reach the general utility map was performed based on the WLC method.

GA

The GA with the statistical characteristics presented in Table 3 was applied to search for optimal spaces between the ranges of region values. The optimization results of solutions are presented in accordance with the diagrams presented in Fig. 4. In this procedure, the lowest and the highest costs were identified in 300 iterations. Further, the visual representation of the location of the optimal solution for implementing the algorithm is also presented in Fig. 5. Table 4 and the diagrams presented in Fig. 6 provide the status of each of the optimal solutions found by the GA.

The development of ecotourism as one of the most profitable industries of the present age requires evaluation, planning, and management consistent with sustainable development. Therefore, in this study, the location of susceptible fields was determined with the simultaneous approach of ecotourism and conservation.

Selection and network analysis criteria

The following criteria can be used as the most important indicators used by researchers as tourism designation criteria. Regarding the slope criterion, the major distribution of slopes is observed in the north to the northeastern part of the region. Regarding the criterion of direction and according to the main section of the visitors' visit to the natural forest parks, the scoring in this research was considered as the basis for the spring and summer productivity chapters (the highest score was in the northern and eastern directions). In the height criterion, a limited section of the highlands of the northwestern and southeastern parts of the region falls within the appropriate altitude range for development. Regarding the water resources criterion, major sectors with high water resources were found only in the northern parts of the region. The reason for this result is the proximity and high density of the sub-basins of the river within the region (with environmental considerations). Concerning the criterion for access

Table 2 Results of prioritizing criteria and sub-criteria of ecotourism development assessment

Cluster	Cluster score	Node	Normal score	Score
Biodiversity	14.0	Vegetation (density)	11.0	80.0
		Wildlife (diversity, habitat shield, areas under the grave)	03.0	20.0
Climate resources	24.0	Climate (temperature, precipitation, and wind	04.0	16.0
		Water resources	20.0	84.0
Soil and geology	4.0	Soil type	01.0	33.0
		Erosion and slip	02.0	47.0
		Linguistics	01.0	21.0
Topography	13.0	Slope	11.0	85.0
		Aspect	01.0	06.0
		Sea level	01.0	09.0
Economic-social	45.0	Distance to existing sites	00.0	01.0
		Land use and residential areas (city–village)	11.0	24.0
		Access routes	06.0	14.0
		Security, infrastructure, and services (sanitary–welfare)	05.0	11.0
		Attractions and natural landscapes (natural–historical–cultural)	23.0	51.0

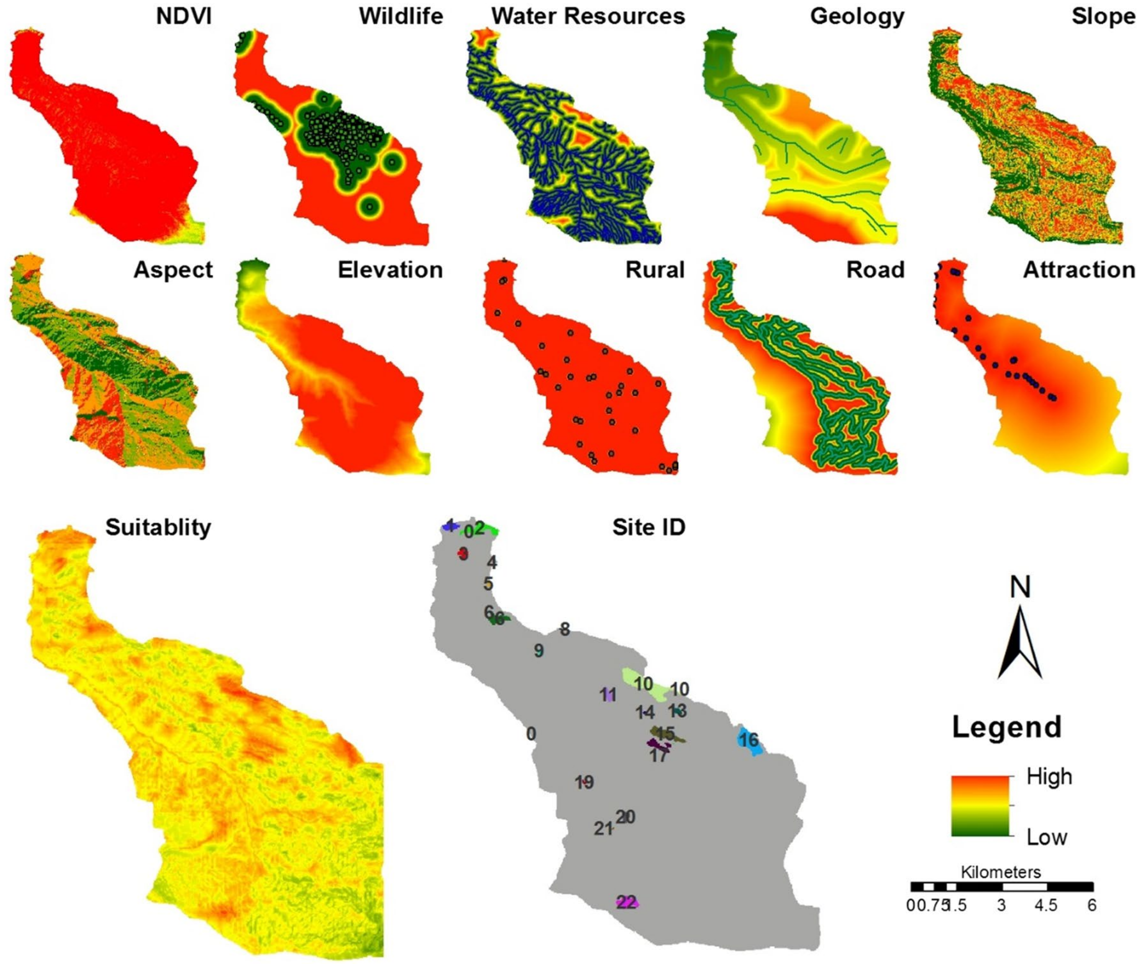


Fig. 3 The ecotourism criteria and result of WLC method

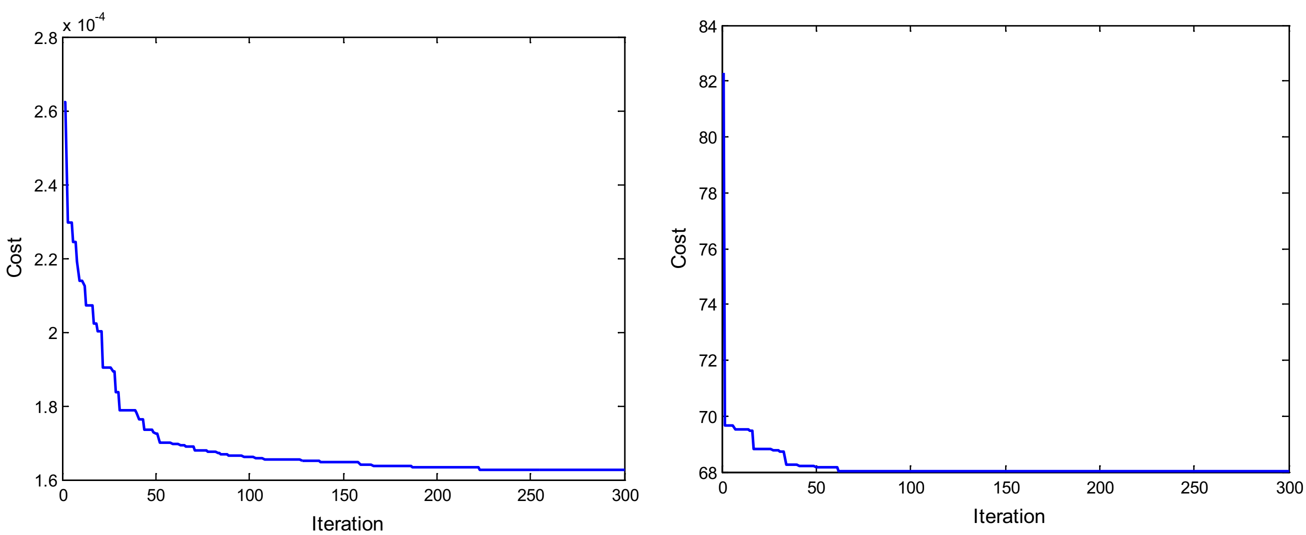
Table 3 GA parameters

No.	Parameter	Value
1	Maximum number of iterations	300
2	Population size	100
3	Crossover percentage	0.80
4	Number of offsprings	2 * round(pc * nPop/2)
5	Mutation percentage	0.30
6	Number of mutants	round (pm * nPop)
7	Gamma	0.05
8	Mutation rate	0.02

routes, these parts are prone to recreational development in terms of access to different sizes in the northern and eastern parts of the region. It is relevant that, due to the mountainous nature and pristineness of the area, forest roads constructed with a specific traffic volume per year have provided a decent opportunity for tourists to enter the area. The criterion of attraction and prospects is that the parts susceptible to recreational development from the point of view of recreational attraction in the center, north, and west of the region. Regarding the vegetation criterion as one of the most important indicators for attracting tourists, about 95% of the total area of the region has an appropriate coverage for ecotourism development. In terms of soil and the geological criterion (erosion and landslide), a large part of the region, except some parts in the north and the south of the region, was found to lack the attitude to develop ecotourism. Regarding the biodiversity and wildlife criteria, most parts of the region (except the central parts), especially the southern part of the region, have the ability to provide tourists with biodiversity services. In terms of land use criterion, most of the suitable area has an appropriate distance with these areas. Accordingly, a network with a collaborative goal (ecotourism and nature conservation) consisting of five major clusters or groups in the studied forests was designed. One of the most important features of this network is the internal communication of elements or nodes with one another and with other nodes in other groups. It has to be noted that the allocation of options and comparison of them are the basics of networks.

Table 4 The optimal solutions provided using the genetic algorithm fuzzy quantities and absolute values

Ecotourism sites	Aspect	Attraction	Elevation	Wildlife	Water resources	Slope	Villages	Roads	NDVI	Geology	Suitability
Top best>>>											
1	0.80	0.86	1	0	1.00	0.98	1	0.99	1	0.79	0.92
	N	1891 m	1347 m	182 m	499 m	16%	1154 m	418 m	0.45%	2287 m	
2	0.40	0.73	1	1	0.99	1	1	1	1	0.62	0.91
	W	3271 m	1292 m	1054 m	495 m	10%	908 m	319 m	0.53%	1080 m	
3	1	0.67	1	1	1.00	0.99	1	0.85	1	1	0.91
	E	3805 m	1406 m	2730 m	499 m	15%	484 m	1025 m	0.49%	1965 m	
4	0.20	1	0.04	0	0.99	0.99	1	1	0.94	0.05	0.90
	S	458 m	35 m	210 m	511 m	15%	789 m	309 m	0.38%	30 m	
5	0.40	0.99	0.77	1	0.63	1	1	0.90	1	0.19	0.86
	W	607 m	774 m	1691 m	335 m	14%	918 m	285 m	0.59%	484 m	
<<<Top worst											
6 ($n-4$)	0.20	0.94	1	0	0	0	0.34	0	1	0.40	0.39
	S	1150 m	1083 m	458 m	30 m	52%	85 m	30 m	0.54%	484 m	
7 ($n-3$)	0.40	1	1	0	0	0.08	0	0	1	0.50	0.38
	W	120 m	1036 m	67 m	30 m	47%	0 m	85 m	0.53%	816 m	
8 ($n-2$)	0.40	0.53	0.75	1	0	0	1	0	0.72	0.67	0.38
	W	5289 m	1746 m	2666 m	42 m	51%	1170 m	150 m	0.30%	841 m	
9 ($n-1$)	0.20	0.68	1	1	0	0.07	0.27	0	1	0.35	0.36
	S	3742 m	1380 m	1195 m	30 m	47%	67 m	120 m	0.51%	42 m	
10 (n)	0.40	0.42	0.44	1	0.04	0.51	0.34	0	0.39	0.50	0.30
	W	6393 m	2059 m	4119 m	67 m	32%	85 m	30 m	0.19%	420 m	



(A) **(B)**

Fig. 4 Cost function for finding the top 5 sites (**a**) and 5 sites worse (**b**)

However, considering the study conditions (i.e., the lack of pre-recommended sites) and the research objective, namely the extraction of the top sites that were prone to ecotourism and conservation development, the option was not considered and the priority was given to criteria and sub-criteria as an option in the network. This result is consistent with the results of studies by Ahmadi et al. (2014), Bali et al. (2015) and Aliani et al. (2017).

One of the most important points of view of the recreational areas is the combination of maps. In this regard, some

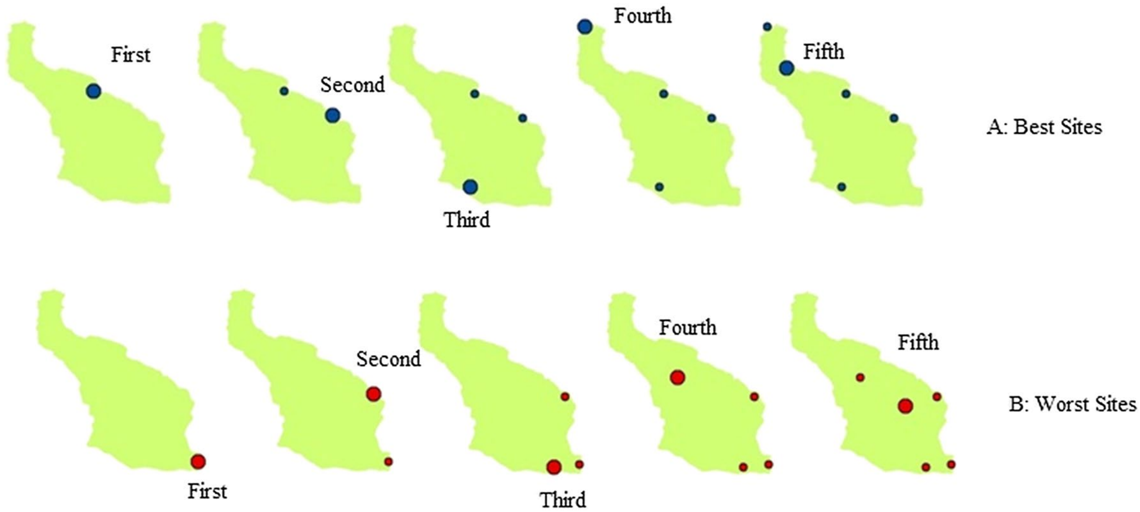


Fig. 5 The distribution of the solutions provided by GA (**a**: best sites, **b** worse sites)

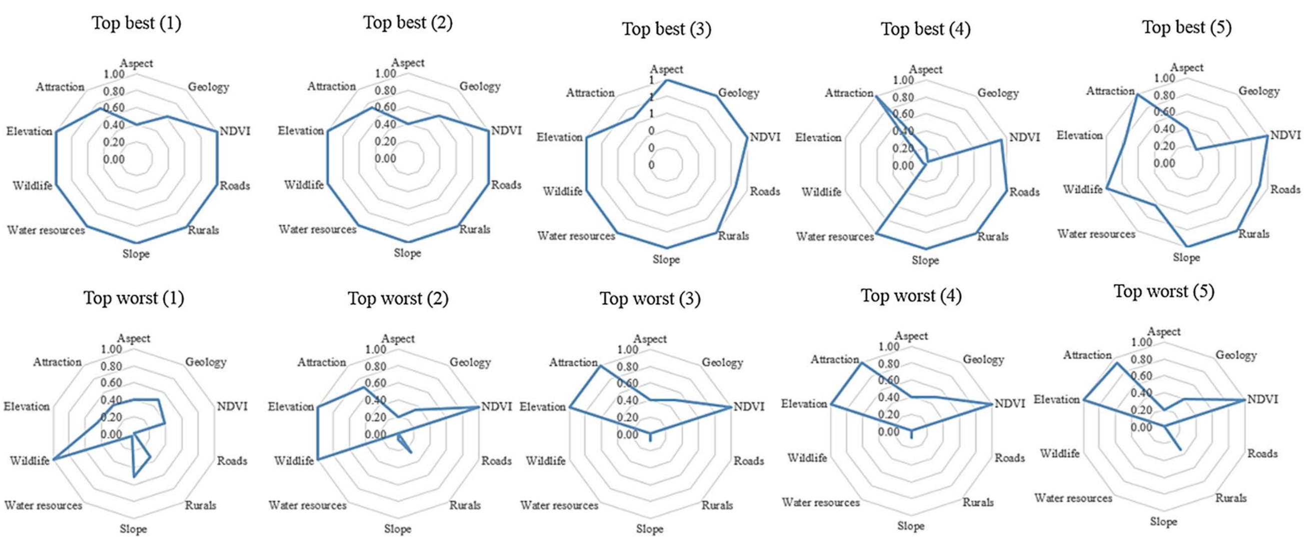


Fig. 6 Standardized specifications for optimal genetic algorithm solutions (top 5 sites and worse)

scholars in the first stage have started to discriminate and provide discriminatory classes of proportions of the region based on land models, and, in the next step, for each criterion and sub-criterion, they have prepared the corresponding discrete maps (Bali et al. 2015). It is believed that the discretization and increasing complexity in the process of reconnaissance of recreational areas (along with other systematic and random errors) lead to the increasing complexity of the system and fuzzy maps as a complete source and the basis for the preparation and integration areas prone to recreational development (Parolo et al. 2009; Hajehforooshnia et al. 2011). Accordingly, in the present study, the integration of fuzzy maps was considered. Another important point in centralized ecotourism is the range of numbers and varieties considered by the researchers. In this regard, a sample distance up to a few kilometers away up to less than one kilometer (Bali et al. 2015) is considered. Accordingly, there is no definite standard for determining this distance such that it can only be quantified by available information of the region and the expected range of the recreational range (expert method). Another distinguishing feature of this research conducted in the field of tourism is the ranking of existing sites (as system options) based on expert standards. In this regard, Bagheri and Mohammadzadeh (2016) prioritized existing areas with specific nature-specific criteria. Since there were no official registered sites in the study scope of the research, the aim was to identify new areas and therefore to locate susceptible fields (instead of evaluating existing recreational options).

Optimization

In this section, the genetic algorithm was used to find optimal solutions for 5 sets of desirable and undesirable points. In this routine, two types of concept were designed to maximize utility (to select top points) and minimize utility (to select worse points). The number of repetitions, initial population, mutation, and related parameters was also selected based on the range of values selected by researchers such as Parolo et al. (2009) and others, and the availability of hardware. According to the research findings, the final general suitability range of the highest points ranged from 0.86 to 0.92 and the final general range of the lowest points between 0.30 and 0.39 was selected. It should be noted that although the distance with existing sites or, in other words, the level of distance between sites was ranked low in the weight (i.e., lack of suitable sites in the region), it was considered as a limiting factor in the process of implementing the algorithm. Accordingly, the algorithm only selects points greater than 2000 m apart from each other as an optimal solution. This limitation is due to the distribution of pressure and the operational capability of the establishment of ecotourism structures in the region. In order to determine the model's efficiency in identifying sites that are prone to development, we also measure the relative superiority of identified sites, i.e., dividing the final utility of each top site into the corresponding site detected as worse. Comparing the utility ratio of the top solution 1 to the worse solution n (92/30) 3.07, the ratio of the utility of the superior solution 2 to the worse solution $n-1$ (91/36) 2.53, the ratio of the utility of the superior solution 3 to the worse solution $n-2$ (91/38) 2.39, the ratio of the superior solution 4 to the worse solution is $n-3$ (90/38) 2.37, and the utility ratio of the superior solution 5 to the worse solution is $n-4$ (86/39) 2.21 confirms the optimality of the solutions, which is 2 to 3 times the final utility rate in the higher points than the worst points. It needs to be explained that the ratios obtained by Parolo et al. (2009) are far greater than the results of this research, probably due to the very high public utility and the smaller extent of the study area of the two studies. Given the results presented in Figs. 3 and 5, the top sites of the GA are identified in zones 1, 6, 10, 16, and 22 by the WLC. Given that all these zones derived from WLC have a high priority, the results of both methods are well matched. To the best of our knowledge, this kind of comparison between network analysis results and GA has not been studied before.

Conclusions

One of the most important features of the study area is the high capability of the ecosystem for constructing ecotourism sites and, at the same time, lack of infrastructural facilities to provide services to tourists. Considering the importance of tourism in conservation, economy, and culture of the region under study, it is of great necessity to develop infrastructure and infrastructure facilities.

The most important reason for the use of the GA, in addition to the higher general efficiency of this evolutionary algorithm, is the ineffectiveness and inability of multi-criteria decision-making methods in solving interactive problems and multistate modes, i.e., selection of a range of solutions with consideration of other site conditions. Among the most prominent features of this issue, we can refer to independent isolated methods of conventional multi-criteria methods. Dynamic genetic simulation (Parolo et al. 2009), the brute-force search, and exhaustive search are methods that can be used to solve such problems (Menon 2004). The volume of processing in this mode is equal to the area of the region in terms of search units (pixels) to the number of expected solutions (in the present study $233{,}680^{5+5}$). The optimization process carried out in this study is similar to the design of the network and the protection locator (similar to Parolo et al. 2009), but much different than that in the CAPS conservation model (Sheikh Goodarzi et al. 2017), MARXAN (Possingham et al. 2000), and ResNet (Sarkar et al. 2002). The search performed in this study, in addition to being independent for each unit, simultaneously takes the interaction and the status of the sites measured relative to each other into account. Other unique features of this study are the flexibility of the modified model compared to the performance of different areas and criteria, as well as the use of criteria with different interpretations. In this routine, in addition to the biodiversity criterion, we also used the cluster criteria of climatic, soil and geological, topographic, and socioeconomic criteria. In order to evaluate the performance of the model, in addition to applying the best cost in a range of repetitions (error thresholds), the optimality of the model in choosing the best possible responses was also measured by identifying the best and worst responses (solutions) and ensuring that optimum solutions were achieved.

The findings of this research are in accordance with the fourth category in the classification system of the World Conservation Union for the management of protected areas that are consistent with the recreational focus in the various classes of management areas. This information can be used in the design process (assessment of the zone's ability) after landing units. Moreover, solving the challenges of this study, in addition to the need for a comprehensive plan to improve the level of infrastructure (such as security, access, and sanitation), requires the active participation of local communities in all developmental stages. This, in many cases, leads to damage to natural resources as well as the livelihood sustainability of indigenous peoples. In this regard, the participation and productivity of local communities, which are inextricably linked with the dynamics and sustainability of natural resources, can entail the preservation of natural resources, ecotourism, and the economy of local communities.

Acknowledgements The authors wish to thank all who assisted in conducting this work.

References

Ahmadi M, Faraji Darabkhani M, Ghanavati E (2014) A GIS-based multi-criteria decision-making approach to identify site attraction for ecotourism development in Ilam Province, Iran. Tourism Plan Dev 12(2):176–189

Ahmadipari M, Hoveidi H, Jafari HR, Pazoki M (2018) An integrated environmental management approach to industrial site selection by genetic algorithm and fuzzy analytic hierarchy process in geographical information system. Glob J Environ Sci Manag 4(3):339–350

Aliani H, BabaieKafaky S, Saffari A, Monavari SM (2017) Land evaluation for ecotourism development—an integrated approach based on FUZZY, WLC, and ANP methods. Int J Environ Sci Technol 14:1999–2008

Bagheri M, Mohammadzadeh M (2016) Ranking of areas with ecotourism attractions using multiple criteria decision making (MCDM) (Case Study: Jask province). Q Geogr (Reg Plann) 7(1):7–16

Bali A, Monavari SM, Riazi B, Khorasani N, Kheirkhah Zarkesh MM (2015) A Spatial decision support system for ecotourism development in caspian hyrcanian mixed forests ecoregion. Bol Ciênc Geod Sec 21:340–353

Bunruamkaew K, Murayama Y (2011) Site suitability evaluation for ecotourism using GIS & AHP: A case study of Surat Thani province, Thailand. Procedia-Soc Behav Sci 21(1):269–278

Dreyfus-Leon M, Chen DG (2007) Recruitment prediction with genetic algorithms with application to the Pacific Herring fishery. Ecol Model 203:141–146

Duan QY, Sorooshian S, Gupta VK (1992) Effective and efficient global optimization for conceptual rainfall–runoff models. Water Resour Res 28(4):1015–1031

Duan QY, Gupta VK, Sorooshian S (1993) Shuffled complex evolution approach for effective and efficient global minimization. J Optim Theory Appl 76:501–521

Duan QY, Sorooshian S, Gupta VK (1994) Optimal use of the SCE–UA global optimization method for calibrating watershed models. J Hydrol 158(3–4):265–284

Ghahroodi Tali M, Sadoogh MN (2012) Site selection for ecotourism with emphasis red list IUCN case study Miankaleh peninsula Iran. In: 32nd International geographical congress in cologne. Germany

Goldberg DE (1989) Genetic algorithms in search, optimization, and machine learning. Addison Wesley, Boston

Hajehforooshnia Sh, Soffianian A, Salman Mahiny AR, Fakheran S (2011) Multi objective land allocation (MOLA) for zoning Ghamishloo Wildlife Sanctuary in Iran. J Nat Conserv 19(4):254–262

Holland JH (1975) Adaptation in natural and artificial systems. The University of Michigan Press, Ann Arbor

Holzkamper A, Lausch A, Seppelt R (2006) Optimizing landscape configuration to enhance habitat suitability for species with contrasting habitat requirements. Ecol Model 198(3–4):277–292

Jaafari A, Najafi A, Zenner EK (2014) Ground-based skidder traffic changes chemical soil properties in a mountainous Oriental beech (*Fagus orientalis* Lipsky) forest in Iran. J Terramech 55:39–46

Jaafari A, Najafi A, Rezaeian J, Sattarian A (2015) Modeling erosion and sediment delivery from unpaved roads in the north mountainous forest of Iran. GEM Int J Geomath 6(2):343–356

Mafi-Gholami D, Zenner EK, Jaafari A, Ward RD (2019) Modeling multi-decadal mangrove leaf area index in response to drought along the semi-arid southern coasts of Iran. Sci Total Environ 656:1326–1336

Menon A (ed) (2004) Frontiers of evolutionary computation. Kluwer Academic Publishers, Dordrecht

Naqinezhad A, Ramezani E, Djamali M, Schnitzler A, Arnold C (2018) Wild grapevine (*Vitis vinifera* subsp. sylvestris) in the Hyrcanian relict forests of northern Iran: an overview of current taxonomy, ecology and palaeorecords. J For Res 29(6):1757–1768

Parolo G, Ferrarini A, Rossi G (2009) Optimization of tourism impacts within protected areas by means of genetic algorithms. Ecol Model 220(8):1138–1147

Peacor SD, Allesina S, Riolo RL, Hunter TS (2007) A new computational system, DOVE (Digital Organisms in a Virtual Ecosystem), to study phenotypic plasticity and its effects in food webs. Ecol Model 205(1–2):13–28

Podger G (2005) Rainfall Runoff Library (RRL). Catchment modeling toolkit prepared by the © CRC for catchment hydrology, Australia, p 110

Possingham HP, Ball IR, Andelman S (2000) Mathematical methods for identifying representative reserve networks. In: Ferson S, Burgman M (eds) Quantitative methods for conservation biology. Springer, New York, pp 291–305

Rahimi S, Shadman Roodposhti M, Abbaspour AR (2014) Suitable areas for the artificial groundwater recharge. Environ Earth Sci 6:1979–1992

Rosenbrock HH (1960) An automatic method for finding the greatest or least value of a function. Comput J 3(3):175–184

Sarkar S, Aggarwal A, Garson J, Margules C, Zeidler J (2002) Place prioritization for biodiversity content. J Biosci 27:339–346

Sheikh Goodarzi M, Sakieh Y, Navardi S (2017) Measuring the effect of an ongoing urbanization process on biodiversity conservation suitability index: integrating scenario-based urban growth modeling with Conservation Assessment and Prioritization System (CAPS). Geocarto Int 32:834–852

Song M, Chen D (2018) An improved knowledge-informed NSGA-II for multi-objective land allocation (MOLA). Geo-spatial Inf Sci 21(4):273–287

Sweeney AW, Beebe NW, Cooper RD (2007) Analysis of environmental factors influencing the range of anopheline mosquitoes in northern Australia using a genetic algorithm and data mining methods. Ecol Model 203:375–386