Original Research

Degradation Mitigation Management of Recreational Watersheds by Selecting the Most Suitable Action Plan Based on Multi-Criteria Decision-Making Methods

Mir Masoud Kheirkhah Zarkesh[1], Esmaeel Sharifi[2], Nahid Almasi[1]*

[1]Department of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2]Soil Conservation and Watershed Management Research Institute, Tehran, Iran

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Abstract

Watersheds have been the foundation of all human activities for ages. There always has been a sustainable equilibrium among the ecosystem components in nature. Such a sustainable equilibrium can be disturbed by human manipulation. Tourism is included among the potential land uses established in a watershed. Any kind of recreational use without regard for environmental considerations will be followed by extensive damage to watersheds. The current study aims at presenting the most suitable action plan to mitigate degradation caused by unplanned recreational use. Accordingly, a region of 7,181 ha located on the Dohezar Watershed was selected as a case study. The criteria, including planning, legislation, structural features, and supportive factors, were recognized as the most important action plans for achieving sustainability in the watershed. Factors consisting of elevation, erosion, distance from surface water, pedology, land cover density, and distance from the fault were known to be the most important characteristics of the area affecting the selection of the action plans in the third level. Finally, five map layers including physical design, carrying capacity, evaluation standards and regulations, local organization, and evaluation and basic data guide the model toward successful degradation mitigation management. The Hierarchical Additive Weighting (HAW) method, a compensatory method of the multi-criteria decision-making model, was used to weight the action plans situated in the fourth level. By integrating the weighted matrices, the legislation plan (with the highest preference vector weight of 37.6%) was selected as the most suitable action plan to mitigate degradation in the study area.

Keywords: management, watersheds, tourism, ecological land capability evaluation, multi-criteria decision-making

Introduction

The tourism industry has been developed significantly around the world in recent decades. Its future expansion will be faster than today's trend [1]. Nowadays, audio-visual products, satellite programs, and other modern media in most countries have motivated a large number of audiences to go from one place to another with inducement of visiting and enjoying recreational resorts. Nowadays, countries are doing their best to set their development plans on the basis of tourism development in addition to observing environmental considerations as well as revival of cultural tradi-

*e-mail: almasi.nahid@gmail.com

tions [2]. Until the year 2005, nearly 270 million tourists visited the world's protected areas. Global annual revenue from tourism is more than $500 billion, covering about 12 percent of the general revenue of the world economy. According to WTO statistics in 2009, the USA is in first place in the world with $70 billion from tourism. In the same year, Spain, with $48 billion; France, with $44 billion; China, with $38 billion; and Italy, with $37 billion have assigned themselves the second to fifth positions in the case of world tourism income. Attracting 22.6 million tourists, Turkey ranked among the world's top twelve tourism destinations in 2009. Given the income generated by tourism, the country also rated eighth in the world with nearly $21 billion recorded in the same year [3]. Diverse climatic and natural conditions as well as the rich culture predispose Iran toward boosting its tourism industry. In addition to domestic tourism, Iran has a potential capacity for over 15.5 million foreign tourists. In terms of revenue generated by tourism, Iran was ranked 89th among 200 countries in 2007.

The northern parts of Iran play a key role in attracting tourists. The unique seashore, with a mild, humid climate as well as lush mountains and plains containing 20 large rivers, make the area Iran's most important tourism region. Considering the environmental fragility of the northern biomes as well as the universal value of the Mediterranean broadleaf forest in Iran, it is necessary to avoid the irrational recreational uses of land by promoting eco-tourism. It is also essential to manage the resorts and watersheds in accordance with land use planning programs. The recreational land capability and carrying capacity of the study areas should initially be specified to achieve sustainable tourism development. According to the experts' opinion, the northern regions could earn around $6 billion from eco-tourism annually, so this fortuity should not be neglected.

Material and Method

The Study Area

The Beles Kuh Hunting Prohibited Area, situated between the latitudes 36º60′-36º70′N and longitudes 50º80′-50º65′E, belongs to the Dohezar Basin in Tonekabon County. With an area of 7,181 ha, it is located in the western part of Mazandaran Province, the southeastern side of Tonekabon City. In 1997 the area was announced as a hunting-prohibited area, whereby shooting and hunting was banned for three years. Following the end of the period, it was extended for three more years. The surface water of the hydrologic network in the study area is released in the Dohezar River. The study area is considered a tourism focal point of Dohezar Basin in Tonekabon County. Fig. 1 demonstrates the situation of the study area in Iran.

Criteria for Tourism Site Selection

Tourism site selection criteria should be comprehensive and measurable. At macro level, they should include two major components: environmental and socio-economic characteristics, which in turn consist of several sub-criteria.

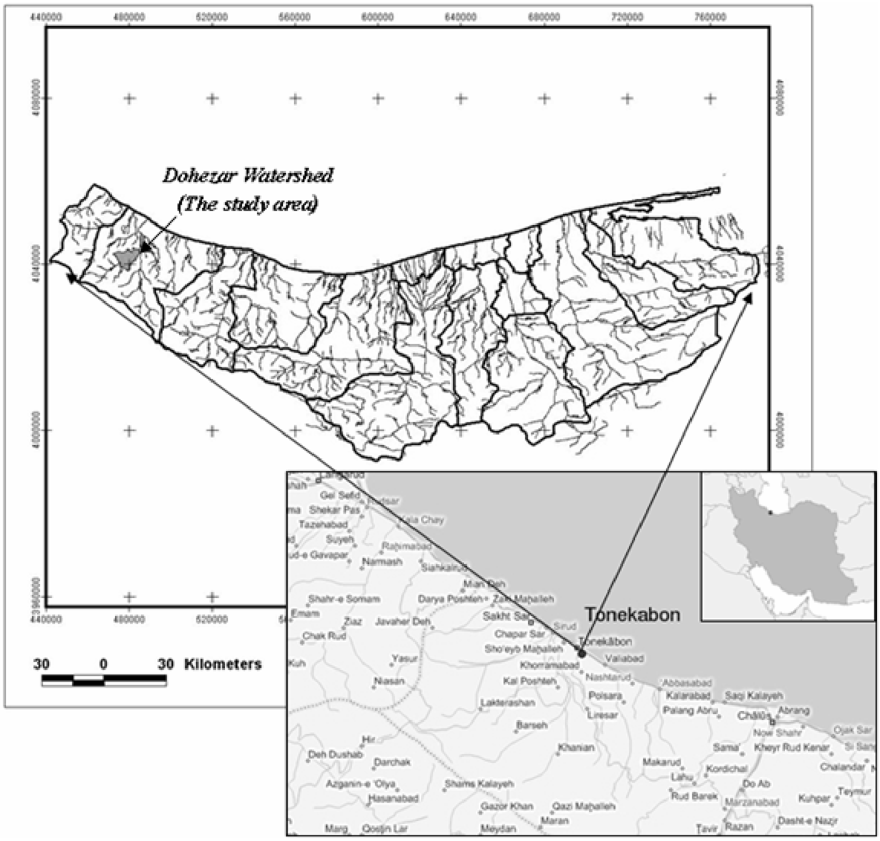

Fig. 1. The location of the study area in Iran.

The environmental features include physical and biological criteria [4]. In this study, physical criteria (including climate, topography, geology and pedology) are placed in the fourth level of the hierarchy. Climate ends with two sub-criteria: temperature and precipitation. Topography includes slope, aspect, and elevation. Geology consists of erosion and sediment, while pedology contains soil groups and soil hydrology [5]. The biological criteria include flora and fauna as well as two sub-criteria: land cover density and animal dispersion. Several criteria involve socio-economic features, including land use, buffer and distances, and aesthetics [6]. As can be seen in Fig. 1, the selected criteria are divided into three levels of recreational factors (the first level), natural characteristics (the middle level), and action plans (the last level).

Recreational Factors:

- Physical design

In physical design of a region, factors such as determination of development areas, design of facilities and services with minimal environmental degradation, compatibility of the construction materials with the environment, and appropriate solid waste dumping are of great importance [7].

- Carrying capacity

The number of tourists allowed to visit a region cause maximum satisfaction as well as minimal environmental damage.

- Standards and evaluation regulations

The standards and regulations associated with tourism affairs should be set in compliance with environmental considerations. Policy makers should pay simultaneous attention to both controlling and encouraging aspects. The regulations should also have measuring potentials to detect the violations.

- Local organization

The organization of tourism executive agencies and establishment of non-governmental organizations (NGOs) are necessary to monitor, assess and control responsible government agencies.

- Basic data

Comprehensive data from eco-tourists, comprehensive information on the natural features of the resorts, and comprehensive definition of sustainability indices of natural areas are included among the required basic information.

Natural Features:

- Elevation

The elevation of a watershed is its height above a fixed reference point (sea level). It specifies the situation of the peaks and valleys in a watershed.

- Erosion and sediment

Erosion would be an important criterion in terms of providing a safe environment for tourists. In general, factors affecting erosion and sedimentation in a watershed can be divided into two main groups: natural and resonator.

- Pedology

Pedology studies are to be carried out to specify the type of land cover and land capabilities.

- Land cover density

The type and density of land cover are so important in terms of economic and social tensions caused by the presence of livestock in a forested area.

- Distance from surface water

Water quality is considered a key criterion in recreational land capability evaluation. It is necessary to consider some buffer zones to avoid water quality from getting worse. Protection of water quality is vital for local communities, animals, and tourists.

- Distance to fault

Considering the existence of two faults in the study area, this criterion was given great importance. There must be some standard buffer zones to provide safety and security in tourist spots.

Action Plans:

- Planning

Planning is the most commonly accepted action for effective and efficient management. A good plan provides benefits for all levels of national, provincial, and local governments.

- Legislation

Tourism industry is one of the country's economic sectors. Environmental issues must be controlled by approving the relevant environmental laws and regulations. Legal regulations of areas under management should necessarily include such items as issue definition, final approval, responsible authority, attraction of public participation, and an examination of crime.

- Structural measures

Unfortunately, environmental management and tourism affairs are managed by different organizations. In other words, there is no integrated organization to simultaneously manage tourism affairs and environmental issues. This would be followed by some conflicts in a way the sectors are being managed. Therefore, issues caused by environmental management or regulations can only be reduced by direct assignment of responsibilities to the tourism sector [8].

- Other supportive measures

Data on the environment is often insufficient or collected inappropriately. Collection of accurate information at approval time of studies and research is of great importance.

The Research Methodology

In the present study, the hierarchical additive weighting (HAM) method was recognized as an appropriate method for choosing the most suitable action plan based on the multi-criteria evaluation approach. In this method, factors and sub-criteria affecting decision-making can be indicated hierarchically so that each level includes sub-criteria affected by the criterion or criteria available in the immediate previous level [9]. The hierarchical structure of the deterioration mitigation management plan of recreational areas in Dohezar is demonstrated in Fig. 2. The first level includes the only target of the current study, i.e. degradation mitigation management determined with preference 1. The second level of hierarchical decision making includes five features: physical design, carrying capacity, standards and regulations, local organization, and evaluation and basic data influenced by the goal. The preference vector (W^2) for these indices was calculated regarding the research goal through eigenvector technique obtained from Saaty Method. The third level includes the criteria related to the degradation mitigation issue in the recreational basins. Each criterion in this level is influenced by the attributes available in the second level. The preference matrix of the criteria (W^3) was calculated for each of the variables in the second level using the weighted matrix and eigenvector technique. Finally, the preference vector was computed for the lowest level using the following equation:

$$\text{Preference vector of the lowest levels (options)} \quad W = W^3.W^2.1 \tag{1}$$

It is supposed that D is a complete classification of decision making consisting of d levels, and C_k represents the preference matrix of the k^{th} level. It is also assumed that W^2 is the preference vector of the second level toward the element (target) available in the first level, then the general equation for calculation of the preference vector (W) would be as follows:

$$W = C_d.C_{d-1}.....C_3.W^2.1 \tag{2}$$

The HAW method is one of the sub-categories of the compensatory model and multi-objective decision-making (MODM) Methods. As regards the study, no decision-making matrix was available, hence the pair-wise comparisons of the AHP method was applied by the decision makers. In this study, the decision makers were a group of experts in the fields of tourism and watershed management [10, 11].

It is noteworthy that there are lots of other important criteria such as microbiological monitoring (to prevent water-born diseases), the establishment of wastewater treatment systems, public participation, and so on to manage the recreational watersheds. A lot of studies have yet to be done regarding the role of the above-mentioned criteria in sustainable management of resorts [12-18]. Considering that performing microbiological studies needs to spend a lot of money (time as well as a specialist group), all is beyond the scope of the authors' major as well as the study ahead. Therefore, the current study focuses on the application of MCDM in degradation mitigation management through presenting the most suitable action plan.

Result and Discussion

The weights of the second level attributes (L2) were determined toward the criterion in the first level (L1), for which the results are presented in Table 1.

Preference vector W^2 was calculated at approximately 0.0001 using MATLAB Software through 13 times multiplication of matrix 1 (Table 1) by itself as follows:

$$W^2=(0.402,0.2907,0.1271,0.1089,0.0712)$$

The entries of vector W^2 indicate that the physical design criterion (D) with the weight 0.402 and the basic data with the weight 0.0712 have the most and least effectiveness in mitigation degradation management, respectively. In the next steps the weights of matrices 2-6 were determined (Tables 2-4). The matrices in the third level (L3) are associated with the attributes in the second level (L2). In order to achieve steady-state weights of approximately

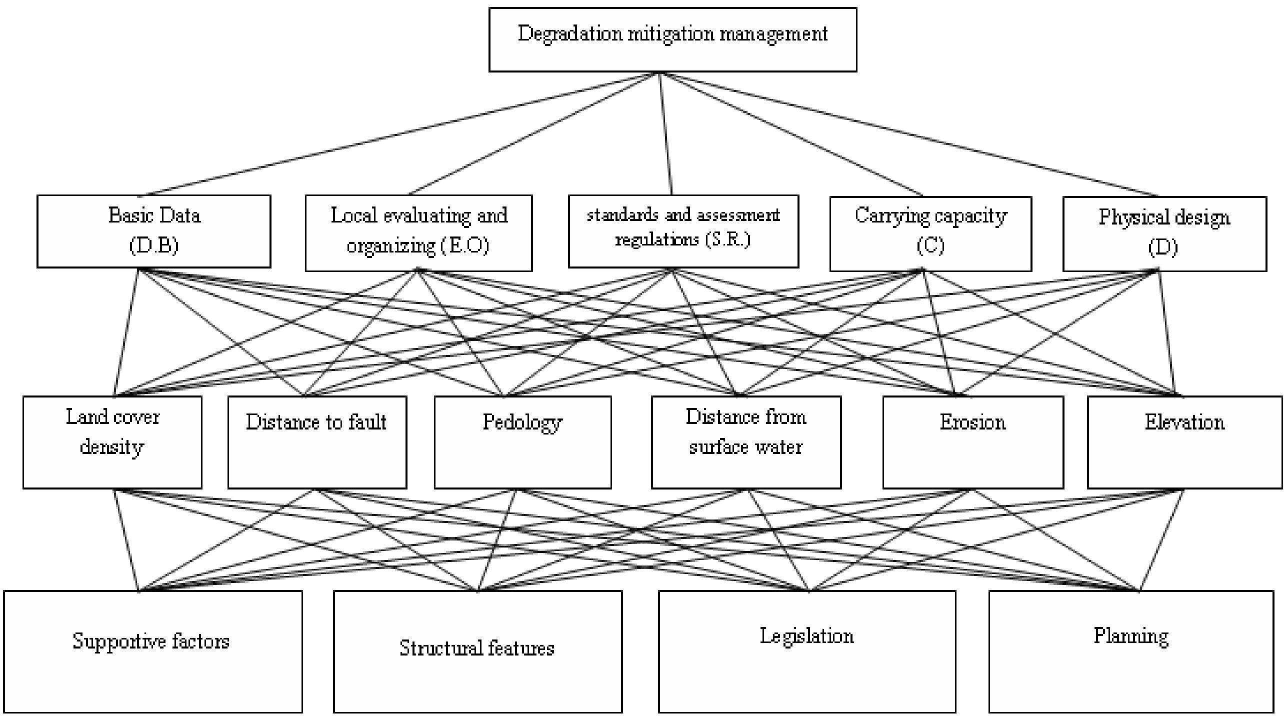

Fig. 2. The hierarchal structure of degradation mitigation measures.

0.0001, the calculation of the matrices was performed in the environment of MATLAB software.

The quantities of vector W_9 in the second matrix represents the most and least effects respectively related to factor elevation (with weight of 0.4894) and distance to fault (with weight of 0.0202). This analysis is presented in Tables 3-6.

Finally, Table 7 (the so-called C3 Matrix) was obtained as follows.

The weights of matrices 2-6 were collected in matrix 7 (Table 7) for final pair-wise comparisons. In the next step,

Table 1. The pair-wise comparison matrix of L2 toward level L1.

L2 compared to L1	D	C	S.R	E.O	D.B
D	1	2	7	9	5
C	1/2	1	5	9	3
S.R	1/7	1/9	1	7	1/2
E.O	1/9	1/9	1/3	1	9
D.B	1/3	1/3	2	1/9	1

Table 2. Pair-wise comparison of level L3 toward level L2 in terms of criterion D (physical design).

L3 compared to L2 in terms of D	Er.	E	D.S	P.	D.F	L.C.D.
Er.	1	7	5	7	9	4
E	1/7	1	6	5	5	2
D.S	1/5	1/5	1	4	9	2
P.	1/7	1/5	1/4	1	8	2
D.F	1/9	1/5	1/9	1/8	1	1/9
L.C.D.	1/4	1/2	1/2	1/2	9	1

W_9=(0.4894,0.2194,0.1192,0.0724,0.0202,0.0795)

Table 3. Pair-wise comparison of level L3 toward level L2 in terms of criterion C (carrying capacity).

L3 compared to L2 in terms of C	Er.	E	D.S	P.	D.F	L.C.D.
Er.	1	1/7	7	1/5	9	6
E	7	1	8	3	3	9
D.S	1/7	1/8	1	7	9	7
P.	5	1/3	1/7	1	5	7
D.F	1/9	1/3	1/9	1/8	1	3
L.C.D.	1/4	1/2	1/2	1/2	9	1

W_{13}=(0.1989,0.4101,0.183,0.1625,0.0297,0.0158)

Table 4. Pair-wise comparison of level L3 toward level L2 in terms of criterion E.V (standards and regulations).

L3 compared to L21 in terms of E.V.	Er.	E	D.S	P.	D.F	L.C.D.
Er.	1	1/7	9	5	9	1/3
E	7	1	7	5	7	2
D.S	1/9	1/7	1	1/5	5	1/3
P.	1/5	1/5	5	1	7	3
D.F	1/9	1/7	1/5	1/7	1	1/5
L.C.D.	3	1/2	3	1/3	5	1

W_9=(0.2044,0.4284,0.0404,0.1427,0.0214,0.1628)

Table 5. Pair-wise comparison of level L3 toward level L2 in terms of criterion L.O. (local organizing and evaluating).

L3 compared to L21 in terms of L.O.	Er.	E	D.S	P.	D.F	L.C.D.
Er.	1	1/3	9	3	5	1/5
E	3	1	5	5	7	3
D.S	1/9	1/5	1	1/3	5	1/3
P.	1/3	1/5	3	1	9	5
D.F	1/5	1/7	1/5	1/9	1	5
L.C.D.	5	1/3	3	1/5	1/5	1

W_{14}=(0.1906,0.3147,0.0684,0.1965,0.0884,0.1414)

Table 6. Pair-wise comparison of level L3 toward level L2 in terms of criterion D.B. (basic data).

L3 compared to L21 in terms of D.B.	Er.	E	D.S	P.	D.F	L.C.D.
Er.	1	5	3	9	9	7
E	1/5	1	5	9	7	3
D.S	1/3	1/5	1	7	5	5
P.	1/9	1/9	1/7	1	2	3
D.F	1/9	1/7	1/5	1/2	1	1/5
L.C.D.	1/7	1/3	1/5	1/3	5	1

W_8=(0.456,0.2643,0.1523,0.05,0.249,0.0525)

Table 7. C3 Matrix.

	D	C	S.R	E.O	D.B
Er.	0.4894	0.1989	0.2044	0.1906	0.456
E	0.2194	0.4101	0.4284	0.3147	0.2643
D.S	0.1192	0.183	0.0404	0.0684	0.1523
P.	0.0724	0.1625	0.1427	0.1965	0.05
D.F	0.0202	0.0297	0.0214	0.0884	0.0249
L.C.D.	0.0795	0.0158	0.1628	0.1414	0.0525

the weights of level L4 should be compared with the weights of the level L3. The weights calculated for the components of the fourth level are presented in Tables 8-13.

The final weights of each matrix were determined using eigenvector technique (presented by Saay) and MATLAB software (Table 14).

Conclusions

At the last stage, the final weights were determined through the general equation W^F.

$$W^F = [C_4]*[C_3]*[W^2]*1$$

$$W^F = (0.1016, 0.3760, 0.3390, 0.1834)$$

These weights (W(s)) are the same as the steady-state values obtained from pair-wise comparisons of L4 toward L1. Accordingly, matrix 14 (Table 14) contains the effects of all factors available in levels L4 to L3. Moreover, matrix 7 includes the impacts of all the attributes available in levels L3 to L2 . Likewise, W^2 contains the impacts of all the criteria that existed in levels L2 to L1, hierarchically. As the entries of the vector W^F suggest, legislation criterion with

Table 8. Pair-wise comparison of level L3 toward level L2 in terms of criterion H (height).

L4 compared to L3 from El viewpoint	P	L	S.C	S.F
P	1	7	2	3
L	7	1	2	3
S.C	1/2	1/2	1	2
S.F	1/3	1/3	1/2	1

W_7=(0.1929,0.5542,0.1594,0.0935)

Table 9. Pair-wise comparison of level L3 toward level L2 in terms of criterion Er (erosion).

L4 compared to L3 from Er viewpoint	P	L	S.C	S.F
P	1	1/5	1/7	1/7
L	5	1	1/3	5
S.C	7	3	1	3
S.F	7	1/5	1/3	1

W_8=(0.0437,0.3202,0.4856,0.1504)

Table 10. Pair-wise comparison of level L3 toward level L2 in terms of criterion D.S (surface water).

L4 compared to L3 from D.S viewpoint	P	L	S.C	S.F
P	1	7	1/7	1/5
L	1/7	1	1/9	1/7
S.C	7	9	1	3
S.F	5	7	1/3	1

W_8=(0.1110,0.0348,0.5671,0.2871)

Table 11. Pair-wise comparison of level L3 toward level L2 in terms of criterion P (pedology).

L4 compared to L3 from P. viewpoint	P	L	S.C	S.F
P	1	1/9	1/7	1/5
L	9	1	5	3
S.C	7	1/5	1	2
S.F	5	1/3	1/2	1

W_6=(0.0393,0.5885,0.2172,0.1549)

Table 12. Pair-wise comparison of level L3 toward level L2 in terms of criterion D.F. (distance from fault).

L4 compared to L3 from D.F. viewpoint	P	L	S.C	S.F
P	1	1/5	1/9	1/7
L	5	1	1/7	1/3
S.C	9	7	1	1/3
S.F	7	3	3	1

W_8=(0.375,0.1135,0.3665,0.4825)

Table 13. Pair-wise comparison of level L3 toward level L2 in terms of criterion L.C.D (land cover density).

L4 compared to L3 from D.P. viewpoint	P	L	S.C	S.F
P	1	1/7	1/5	1/5
L	7	1	1/5	1/3
S.C	5	5	1	1/3
S.F	5	3	3	1

W_9=(0.0498,0.1566,0.3266,0.4670)

Table 14. C4 matrix.

	Er.	E	D.S	P.	D.F	L.C.D.
P	0.1929	0.0437	0.111	0.0393	0.0375	0.0498
L	0.5542	0.3202	0.0348	0.5885	0.1135	0.1566
S.C	0.1594	0.4856	0.5671	0.2172	0.3665	0.3266
S.F	0.0935	0.1504	0.2871	0.1549	0.4825	0.467

weight of 0.376 has the highest effectiveness in mitigating recreational degradation in the study area. Criterion planning with weight of 0.106 imposes the lowest impact on mitigating the degradation. These figures suggest to regional managers the fact that each investment unit on "legislation" will be 3.7 times more effective than "planning." Therefore, "legislation" would be the first-priority action plan for mitigating recreational degradation in the study area. The next priorities were respectively allocated to the criteria "structural features," "supportive factors," and "planning."

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