Available online at www.elixirpublishers.com (Elixir International Journal)

Geoscience

Elixir Geoscience 70 (2014) 23916-23921

ISSN: 2229-712X

The Evaluation of Integrated Model of GIS and MCDM for Watershed Management: The Joneqan Watershed, Iran

Khalil Rezaei[1,*], Shahla Yavari[2] and Hamideh Noroozpour[3]

[1]Geology Department, Kharazmi University, Tehran, Iran.

[2]Sedimentology, Bou Ali University, Hamadan, Iran.

[3]Young Researchers and Elites club, Science and Research Branch, Islamic Azad University, Tehran, Iran.

ARTICLE INFO

Article history:
Received: 30 March 2014;
Received in revised form:
23 April 2014;
Accepted: 2 May 2014;

Keywords
MCDM,
GIS,
Watershed,
Erosion,
Joneqan,
Iran.

ABSTRACT

With the consideration of sustainable development, three major objectives of watershed management in Iran are to lessen disaster, to secure local residents and their properties, and to conserve natural resources. Many single-objective management projects have applied to Iran’s watersheds for the last several decades to achieve those objectives, including soil conservation projects. However, conventional planning methods are not capable to handle the complexity and conflicts of mutli-objective watershed management projects. In this study, an integrated model combining Geographic Information Systems (GIS), Remote Sensing (RS), soil erosion model, and multiple criteria decision making (MCDM) is developed and applied for the planning of reservoir watershed management in Joneqan watershed, Iran. Performance of individual objective for each alternative is first estimated with the aid of GIS, RS, and soil erosion model. After the procedures of MCDM, a compromising solution is suggested based on the identified preferences on project objectives and their performances of all objectives. Besides, a list of alternatives with their priorities can provide further information on the trade off relationships among our objectives.

© 2014 Elixir All rights reserved

Introduction

Seen as one major kind of sensitive natural environment, reservoir watersheds may provide the public with benefits from various functions such as water resource conservation, recreation and tourism, mining industry, forest industry and other land uses (Jabbra, 1997; Zhang et al., 2012; Dolnicar et al., 2012). However, reservoir watersheds in Iran often face threats of losing environmental balance for their unique hydrologic characteristics (i.e., uneven distributed precipitation and rapid flow), unstable geologic conditions, and improper human activities (Sadeghi, 2009).

In order to efficiently prevent potential disasters and maintain the functions of reservoirs, various approaches including structure and non-structure measures were applied to the major reservoir watersheds for the last several decades (Darghouth, 2008). Without explicit definition on watershed management and appropriate planning techniques, many projects were implemented for different purposes within the same watershed such that some missions were over-emphasized and some were ignored. Besides, data for the assessment of management project are hard to collect for watersheds of large area and remote location, especially in Iran.

To overcome these hurdles, Geographic Information Systems (GIS) database and Remote Sensing (RS) techniques were employed to analyze essential factors for different objectives in this paper. With appropriate assessments on the criteria values, Multiple Criteria Decision Making (MCDM) analysis then was utilized to provide ranked alternatives from perspectives of natural resources conservation and sustainable development (Suling et al., 2010; Zhang et al., 2012).

Integrated planning methodology for watershed management

For conventional single objective optimization approach, limited resources are distributed to meet all the constraints and provide the answer of decision variables to generate optimum value for the objective function of the problem (Steiguer, 2003; Mendoza and Martins, 2006; Zhang et al., 2012). Based on the characteristics of the objective function, constraints, and problem-solving techniques, many popular methods such as linear programming, nonlinear programming, and dynamic programming are applied to solve various problems both in social and natural sciences. Different from single objective optimization measures, multiple criteria decision making is the procedures to conduct the most preferred alternative from the perspective of decision maker considering several objectives to be achieved at same time In this way, the solution of MCDM is a compromised alternative that will not hugely maximize certain objective and ignore the others Usually, three operation phases are included in the MCDM: generation of non-dominated solutions, assessment of preference weight and priority, and multiple criteria evaluation (Nijkamp et.al., 1990; Tabucanon, 1992). However, the objectives of decision making and their evaluation criteria should be delineated and defined before proceeding MCDM. As mentioned above, three major objectives are usually fulfilled through various watershed management projects. Based on the needs of reservoir watershed, different criteria may be utilized to reflect the performances of alternatives on those objectives. However, watershed spatial database is critical and essential for both constitution of criteria and evaluation of watershed management alternatives.

Tele:
E-mail addresses: khalil.rezaei@yahoo.com

© 2014 Elixir All rights reserved

In this study, GIS and RS techniques were applied to analyze and collect the current watershed information for this large-area and continuous-changing subject. Combining the result of priorities/preferences assessment, various approaches of multiple criteria evaluation then can be proceeded for final operation phase based on the types of information (i.e., cardinal, qualitative, or mixed) and multiple objective method (i.e., discrete or continuous). No matter what kind of approach is selected for multiple criteria evaluation, ranking relationship of the alternatives is always available for decision maker to scrutinize. Of course, any further modification on the priorities/preferences assessment can also be progressed if the ranking relationship does not epitomize decision maker's conception on this matter. Figure 1 illustrates the integrated model of GIS and MCDM.

In this paper, one of outranking methods, the analytic hierarchy process (or AHP) as a simple multi-criteria decision making (or MCDM) method for dealing with unstructured, multi-attribute problems. AHP was developed by Saaty (1980, 1989) and widely studied by their authors (Bolloju, 2001; Kablan, 2004; Lipovetsky& Conklin, 2002). It consists of breaking down a complex problem into its components, which are then organized into levels in order to generate a hierarchical structure. The aim of constructing this hierarchy is to determine the impact of the lower level on an upper level, and this is achieved by paired comparisons provided by the decision maker. The hierarchical structure of the AHP model attempts to estimate the impact of each alternative on the overall objective of the hierarchy (Fig.1). Another advantage of the AHP is that it uses a consistency test to filter inconsistent judgments. Taking into account these advantages, many outstanding works have been published based on AHP (Hua et al.,2010; Suling et al.,2010; Mingwu et al.,2010; Qilin et al.,2011; Ge and Jun-yan,2011; Zhang et al.,2012). They include applications of AHP in different fields, such as planning, selecting a best alternative, ranking alternatives as in our case, resource allocation, resolving conflicts, optimization, etc., as well as numerical extensions of AHP (Garcia-Cascales & Lamata, 2009). An important bibliographic review of MCDM tools was carried out by Steuer (2003).

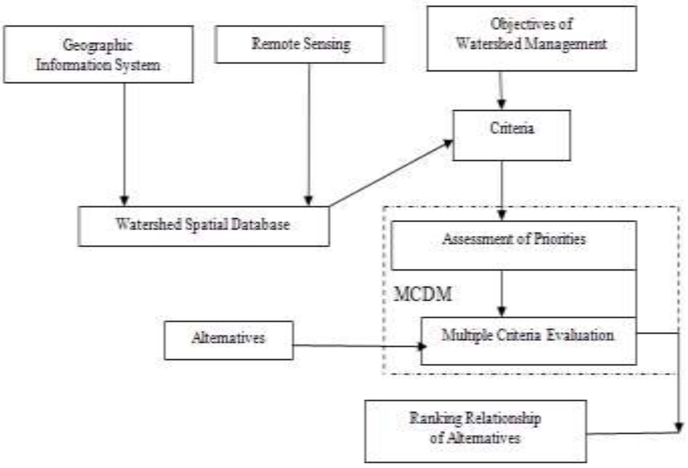

Figure 1: Integrated Model of GIS & MCDM for Joneqan Watershed Management

Case Study

The Joneqan sub-catchment area (50°,22'-50°,47' north, 32°,4' -22°,29' east) is a part of the great basin of the Karun River, and covers an area of about 903.92 km^2, to the west and south west of ChahrMahal-Bakhtiari Province, SW Iran (Fig. 2). The relief of the area decreases from high mountains (3500 m) in the northwest, to hills (1900 m) in the south. The area is mostly semi-humid, with an annual rainfall ranging from 512.21 mm. From geological point of view, The Joneqan sub-catchment is located in High Zagros of the Zagros Mountains, and Sanandaj–Sirjan zone. The oldest rock units in the area are Cretaceous limestone of the Sarvak Formation and the youngest are Plio-Pleistocene conglomerates of the Bakhtiari Formation. The lithology units are lime-marl, limestone, shale, marl, sandstone, and conglomerate (Yavari, 2007) (Fig.3&4).

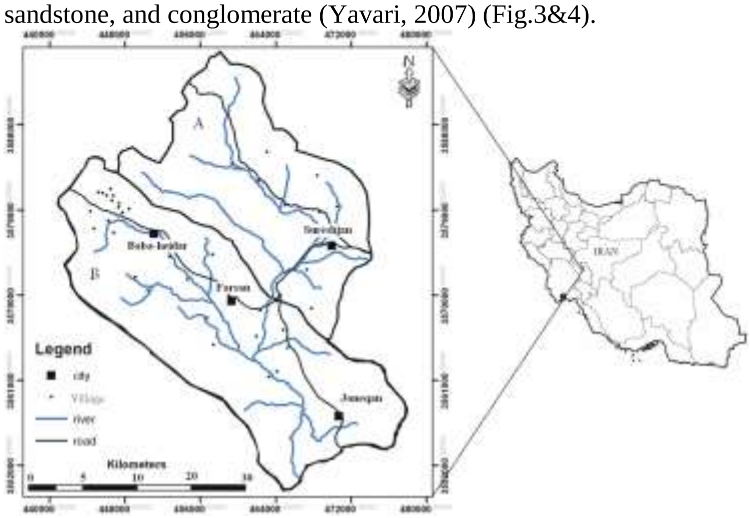

Figure2: Geographic Location of Study Area

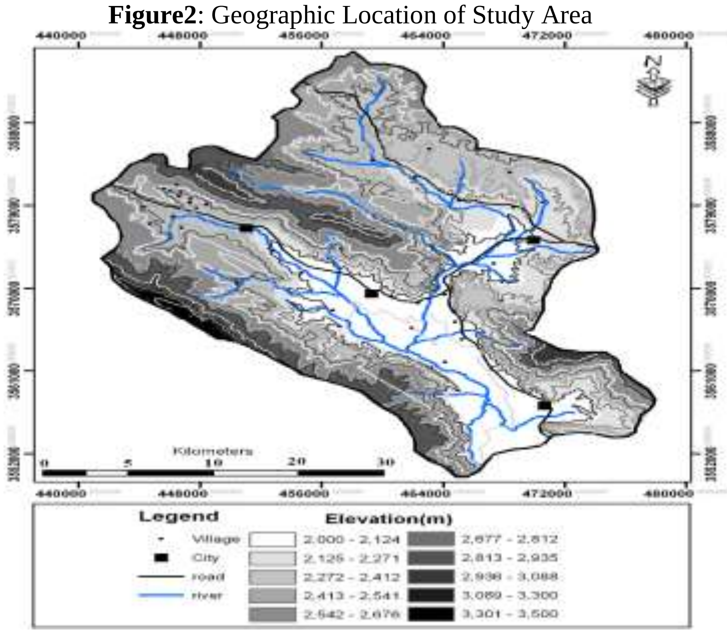

Figure 3: **Topography map of two Sub-watersheds in Joneqan catchment**

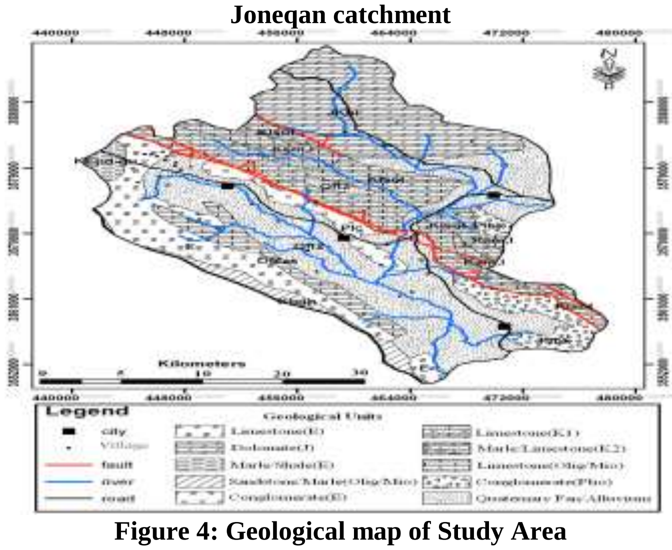

Figure 4: Geological map of Study Area

Table 1: Surface Erosion of Each Sub-watershed Estimated by USLE (Unit: tone/hectare/year)

No. of Sub-watershed	geology	soil	climate	runoff	slop	Land cover	Land use	Surface erosion	Gully erosion	R	Erosion class
1(A)	6	5	5	6	15	6	6	12	9	70	IV
2(B)	5	7	6	5	12	4	6	12	10	67	III

Evaluation Criteria of Watershed Management for Joneqan Watershed

In this paper, the alternatives for Joneqan watershed management are assumed as the two sub-watersheds themselves such that result of MCDM represents the treatment priorities of these sub-watersheds. From the applied management projects, three major management objectives for Joneqan Reservoir are concluded as water resources conservation, sedimentation control, and water quality sustainment. As main habitat of animal and plant species, watershed also attacks more attention for its efforts on ecology conservation. In this way, completeness ratio of soil erosion control, water resources conservation, water quality, land use regulation, and ecology conservation were chosen as evaluation criteria.

Completeness Ratio of Soil Erosion Control

Completeness ratio herein is defined as the ratio of completed treatments to planned treatments needed to achieve objectives of watershed management (Creek, 2004; Gumiere, et al., 2009; Webb and Strong, 2011). The ratio can be calculated based on budget, number of construction works, or protection area. For soil erosion control, completeness ratio (CR) is estimated from the controlled volume of sediment (SC, in units of m3), sediment yield (SY, in units of m3), and allowable soil loss (SL, in units of m3) of the target watershed: CR = SC / (SY – SL) (1)

From Equation (1), it is clear that both completeness ratio and the controlled volume of sediment will increase with more control measures applied to the watershed while increasing sediment yield from surface erosion, landslide, and channel sedimentation will decrease the completeness ratio. Therefore, the treatment priority of a sub-watershed with low completeness ratio of soil erosion control is higher than those with high CR values. In this paper, sediment yield was estimated from two major sources: surface erosion and landslide. To avoid sediment depositing in the reservoir, the allowable soil loss is set to zero for entire watershed (Takashikoi, 2008; Gumiere, et al., 2009)

Erosion

Since soil erosion is a product of few different interacting factors, there is not a simple model to assess all the contributing elements in the same time (Daroussin and King, 2001; Gumiere, et al., 2009; Webb and Strong, 2011) The MPSIAC model (modified PSAIC, 1986) was developed primarily for application in arid and semi-arid areas in the southwestern USA, and is believed to appropriate for the same environmental conditions in Iran (Sadeghi, 1993). The Pacific Southwest Inter-Agency Committee (PSIAC) method estimates total annual sediment yield, not just sheet and rill erosion (PSIAC, 1968). The method is based on a review of a few representative points within a given sub-catchment, which are then used to project average values for the entire sub-catchment area. The procedure considers nine factors that depend on surface geology, soils, climate, runoff, topography, ground cover, land use, channel erosion, and upland erosion. Although the procedure was developed for sub-catchments in the western United States greater than30 km^2; however, it has also been applied to smaller basins. Erosion is its lack of accuracy in processing the huge number of data which should be digitalized by GIS system and analyzed by mathematical models MPSIAC is an empirical model to estimate the quantity and quality of sediment. In fact quantifying and digitalizing the sediment data is an important breakthrough in sediment assessment models development. This problem could be partially solved by estimating models (Lufafa et al., 2003). Compared to other empirical methods, the PSIAC model considers the greatest number of factors, so the results are more realistic. Each factor is subdivided into different categorical classes, and based on the degree of impact of each factor class, a weighting value will be assigned to each class using the model tables ((PSIAC, 1968) Johnson and Gembhart, 1982) Tables 1–6. The sum-of-weights is calculated for each integrated unit by the use of Eq. (2):

$$Ei = \sum_{i}^{n} Wi$$

In which, Ei=erosion weight summation for the ith map unit; Wi=erosion weight for each factor class; n=number of factors (9) for the PSIAC model. The erosion severity and the annual sediment yield are estimated, based on the total sum of weights. In order to control the accuracy of interpolations and extrapolations of erosion-factor weights, Eq. (3) is applied. This equation evaluates the relationship between the rate of sediment yield in each catchment area unit in m^3/km^2/year (Qs), and the total weights of causal factors (R). $QS = 0.253\ e^{0.0353\ R}$

Landslide

The sediment volumes from landslide areas were cited from the planning report of “The Fourth Integrated Management Planning of Karun Reservoir” and tabulated as follow (Yavari, 2007):

Table 2: **Sediment Volumes and Areas of Landslide for Joneqan Watershed**

No. of Sub-watershed	Landslide Area_ m2	Sediment Volume(*10^6 m^3)
1(A)	10.255	0.5
2(B)	54.256	2.42
Total	64.511	2.92

Controlled Volume of Sediment

From the same source as landslide data, the controlled volume of sediment for each sub-watershed of Joneqan Watershed is estimated by dividing the total volume by the number of sub-watersheds with the assumption of equal controlled sediment volume. Therefore, the value was 431374.21 m^3/year for each sub-watershed.

Completeness Ratio

With zero allowable soil loss, the estimated values of surface erosion, landslide volume, and controlled volume were then substituted into Equation (1) and concluded the completeness ratio of soil erosion control for A and B sub-watershed are 22/70 and 20/44, respectively.

Water Resources Conservation

This criterion is utilized to evaluate the condition of water resources maintained by the watershed and it is highly related to soil type, vegetation, and slope of watershed. Besides, land cover condition also indicates the status of human activities and needs for watershed management projects. In this paper, water resources conservation of sub-watershed is judged by its geology through the aid of GIS and RS techniques and a research for water reserving capacity (i.e., Table 3) of different formation and lithology. Hence, the performance of each sub-watershed on water resources conservation is listed in Table 3.

Table 3: **Estimated Water Reserving Capacity under Different formation (Unit: Tone/Hectare)**

Effective formation	Asmari, Sarvak (limestone)	Quaternary (sediment)	Kashkan, Bakhteary (sandstone, conglomerate)
Groundwater levels	10	60.2	40
city	Soreshjan	Farsan	Joneqan

Water Quality

Water quality of these sub-watersheds will directly affect the function of Joneqan Reservoir which is the main water supply of central Iran. However, some of these sub-watersheds are also the main production area of high-elevation fruits and vegetables such that agriculture activities and application of fertilizer, herbicide, and pesticide will degrade the water quality. To represent the condition of water quality and these non-point source pollutions, total phosphorus loading is utilized in the planning report of "The Fourth Integrated Management Planning of Joneqan Reservoir." With the estimated total phosphorus loading for two sub-watersheds were calculated as 300 and 450 tone/ year, respectively (Yavari, 2007).

Land Use Regulation

To appropriately zoning the slope land in Iran, a classification standard of land use limitation was first legal started in 1976 based on the criteria of slope, effective soil depth, soil erosion condition, and property of bedrock (Solaimani, 2010). Six levels of slope land were then defined with three different landuse and management strategies: agricultural/grazing land (A/G), forest land (F), and conservation land (C). In general, the higher degree of the slope land, the more conservative strategy may be applied to it. However, improper land use is still one of the major problems in Joneqan Watershed for the attraction from high-elevation fruits and vegetables. As mention above, both water resources conversation and water quality will be affected by these so called "over-limitation" land use. Consequently, higher percentage of improper land use in a sub-watershed, higher priority of watershed management should be distributed to it. In this paper, average slope of sub-watershed and effective soil depth were used to analysis the classification of land use for incomplete detail data in erosion condition and bedrock property. With help from GIS, land use classification for A and B sub-watersheds was defined as C/A and A/G/C, respectively.

Ecology Conservation

As one of the top priority tasks for sustainable development in Iran, enhancement on the conservation of ecology species and habitants is also the main task for natural resources which covers Joneqan watershed. However, it is difficult to evaluate the "value" of species living in each sub-watershed without detail information on their activities area and habitant condition. To emphasize the methodology proposed herein the paper, the number of kinds of species (both animals and plants) this criterion for A and B sub-watershed 41 and 10, respectively.

Assessment of Preference Weight and Priority

To explore the viability of this integrated model, the preference weights and priorities of the Joneqan Reservoir Management do not really be analyzed on these criteria. After assigning specific weight to testing criterion, the relative weights of the rest of criteria are then evenly distributed.

Multiple Criteria Evaluation by AHP method

As mention above, the main purpose is to illustrate this integrated model. Therefore, the preference function of each criterion was assumed as followed (Hua et al.,2010; Suling et al.,2010; Mingwu et al.,2010; Qilin et al.,2011; Ge and Jun-yan,2011; Zhang et al.,2012)(AHP): 1. State the overall objective of the problem and identify the criteria that influence the overall objective. 2. Structure the problem as a hierarchy of goal, criteria, sub-criteria, and alternatives. 3. Start by the second level of the hierarchy (Do pair-wise comparisons of all elements in the second level and enter the judgments in an n*n matrix? Calculate priorities by normalizing the vector in each column of the matrix of judgments, average over the rows of the resulting matrix and thus obtain the priority vector. Compute the consistency ratio of the matrix of judgments to make sure that the judgments are consistent). 4. Repeat step 3 for all elements in a succeeding level but with respect to each criterion in the preceding level. 5. Synthesize the local priorities over the hierarchy to obtain an overall result for each alternative.

In this case study, the purpose of evaluation is to distribute higher priority to the sub-watershed with lower achievement in these five criteria. Therefore, intensity of preference on an alternative over another can be defined from previous five assumed functions once all the comparison between two alternatives (sub-watersheds) on all the criteria is made. With same weights on all the criteria, result of multiple criteria evaluation through AHP was preceded and listed in Table 4. The results of comparison of Criterion Values and final analysis of AHP were presented in 5 and 6 tables.

Table 4. **Net Outranking Flows of Sub-watersheds with Relative on Different Criterion**

No. of Sub-watershed	A	B
Completeness Ratio	0.66	0.33
Water Resources Conservation	0.87	0.12
Water Quality	0.75	0.24
Land Use Regulation	0.66	0.33
Ecology Conservation	0.83	0.16
Priority Level	Medium	Low

Table 5. Comparison of Criterion Values

Completeness Ratio	Water Resources Conservation	Water Quality	Land Use Regulation	Ecology Conservation
0.121	0.418	0.196	0.110	0.210

Table 6: **Final Analysis Result of AHP**

No. of Sub-watershed	1(A)	2(B)
Outranking	.835	0.205

Influence of Changing Weights for Focusing Criterion

Let the ratio of the relative weight of one focusing criterion and that of the other criteria be defined as importance rate in this study, then the influence of changing weights for the focusing criterion can be observed. In general, the net outranking flows for all sub-watersheds will change in different directions and paces depending on their performances on all the criteria (Hua et al.,2010; Suling et al.,2010; Mingwu et al.,2010; Qilin et al.,2011; Ge and Jun-yan,2011; Zhang et al.,2012). For example, Table.7 represents the results of net outranking flows for two sub-watersheds when water quality is selected as focusing criterion and the importance rate is changed from 1, 2 and 5.

Table 7: **Influence of Changing Weights of Water Quality**

No. of Sub-watershed	1A	2B
W1	0.147	0.047
W2	0.294	0.094
W5	0.735	0.235

The change has this means that the management priority for sub-watershed #1 is in the medium level for its fare conditions on all criteria, but its priority will increase very faster than any other watershed when the concern about water quality is increasing.

Conclusion

With increasing emphasis on sustainable development and natural resources conservation, traditional planning methods are no longer good enough to solve the complexity and conflicts of multi-objective watershed management, no mention to provide the list of priority of potential alternatives. In this paper, an integrated model of GIS, RS, and MCDM for the planning of reservoir watershed management is explained first by conceptual graph to illustrate the structure, relationships among all components, and its operation paths of the model. Demonstration of operation procedures then is clearly conducted in the case study after five criteria being selected for the evaluation of alternatives In this case study, sub-watershed A is the top priority area in Joneqan Watershed to practice watershed management projects either equally considering all criteria or partially emphasizing on each criterion. The functions of GIS and RS techniques are essential and valuable for this study because both the criteria and alternatives of this reservoir watershed management project have to rely on the watershed spatial database. With traditional data collection methods, this procedure itself may last for months. With their aid, analysis can be proceeded easily once updated image of studying area being received. As one of pair-comparison method, AHP shows its ability on multiple criteria evaluation to provide priority list of alternatives under given relative weights or preference on the criteria. The analysis results also indicate that this method can give decision maker the idea about the impact of changing weights in one specific criterion to the ranks of alternatives. However, assumptions on some basic information of spatial database and preference functions of evaluation criteria are made under limitations of research time and budget. Further research can focus on the interview of decision maker for true preference functions and comparison between MCDM methods budget.

References

1. Bolloju N. Aggregation of analytic hierarchy process models based on similarities in decision maker preferences. E J O Res. 2001; 128: 499-508.

2. Creek C. Integrated watershed management plan. Mc-Graw Hill. 2004.

3. Darghouth S . Watershed Management Approaches, Policies, and Operations: Lessons for Scaling Up The World Bank, Washington, DCPaPerno.11. 2008.

4. Daroussin J, King D . Mapping erosion risk for cultivated soil in France, Catena.2001;46: 207-220

5. Dolnicar S, Hurlimann A, Grün B. Water conservation behavior in Australia, Journal of Environmental Management. 2012; 105(30): 44-52.

6. Garcia-Cascales M S, Lamata M T. Selection of a cleaning system for engine maintenance based on the analytic hierarchy process. Computers and Industrial Engineering. 2009; 56: 1442–1451.

7. Ge Yu, Jun-yan Zh. Analysis of the impact on ecosystem and environment of marine reclamation-A case study in Jiaozhou Bay, Energy Procedia. 2011;5:105–111.

8. Gumiere S, Bissonnais Y, Raclot D. Soil resistance to inter rill erosion: Model parameterization and sensitivity, Catena. 2009; 77:274–284.

9. Hsu T H, Pan F F C. Application of Monte Carlo AHP in ranking dental quality attributes. Expert Systems with Applications.2009; 36: 2310–2316.

10. Hua B, Zhai HJ, Zhang PC, Liu XL, Liu HH. Study on the integrated process analysis system of runoff regulation and control technology and strategy of slope farmland, Procedia Environmental Sciences. 2010, 2:496–506.

11. Jabbra J, Jabbra N. Challenging environmental issues: Middle Eastern perspective. 1997.

12. Johnson C W, Gembhart AC. Predicting sediment yield from Sagebrush range lands. USDA SEAARM Western Series. 1982; 26: 145-156.

13. Kablan M M. Decision support for energy conservation promotion: An analytic hierarchy process approach. Energy Policy. 2004; 32, 1151–1158.

14. Lipovetsky S, Conklin W M. Decision aiding, robust estimation of priorities in the AHP. E J O Res. 2002;137, 110–122.

15. Lufafa A, Tenywa MM, Isabirye M, Majaliwa MJG, Woomer PL. Prediction of soil erosion in Alakevictoria basin catchment using a GIS- based universal soil loss model. Agricultural Systems. 2003; 76, 883-894.

16. Mendoza GA, Martins H. Multi-criteria decision analysis in natural resource management: A critical review of methods and new modeling paradigms, Forest Ecology and Management. 2006; 230, 1–22.

17. Mingwu ZH, Haijiang C, Desuo J, Chunbo L. The comparative study on the ecological sensitivity analysis in Huixian karst wetland, China, Procedia Environmental Sciences. 2010; 2, 386–398.

18. Nijkamp P, Rietveld P, Voogd H. Multicriteria Evaluation in Physical Planning, North-Holland. 1990.

19. PSIAC. Report of the Water Management Subcommittee on Factors Affecting Sediment Yield in the Pacific Southwest Area and Selection and Evaluation of Measures for Reduction of Erosion and Sediment Yield. ASCE. 1968; 98, Report No. HY12.

20. Qilin Y, Jiarong G, Yue W, Bintian Q. Debris Flow Characteristics and Risk Degree Assessment in Changyuan Gully, Huairou District, Beijing, Procedia Earth and Planetary Science. 2011;2 : 262 -271.

21. Saaty T L. The analytic hierarchy process. Mc-Graw Hill.1980.

22. Saaty T L. Group decision making and the AHP. New York: Springer.1989.

23. Sadeghi SHR. Comparison of some erosion potential and sediment yield assessment models in Ozon-Dareh sub-catchment. Proceedings of the National Conference on Land Use Planning, Tehran, Iran, 1993.

24. Sadeghi SHR, Jalili Kh, Nikkami D. Land use optimization in watershed scale , Land Use Policy. 2009; 26 (2):186-193.

25. Solaimani K. Land use/cover change detection based on remote sensing data (a case study Neka basin) Agric.Biol,J.N.Am. 2010;1(6):1148-1157.

26. Steiguer JE. Multi-criteria Decision models for forestry Natural resources management. Published by: USDA. 2003.

27. Steiguer J E, Liberti L, Schuler A, Hansen B. Multi-Criteria Decision Models for Forestry and Natural Resources Management: An Annotated Bibliography, USDA FOREST SERVICE. 2003. http://www.fs.fed.us/ne

28. Steuer R E. Multiple criteria decision making combined with finance: A categorized bibliographic study. European Journal of Operational Research. 2003; 150,496–515.

29. Suling L, Yan L, Guobao S, Yu Ch, Shushen Zh, Jingwen Ch, Youbin W, Dong S, Zhipeng T. Study on the Eco-Compatibility between Port Construction and Wetland Nature Reserve, Procedia Environmental Sciences. 2010; 2:486-495.
30. Tabucanon M. Multiple Criteria Decision Making in Industry, Elsevier Science Publishers, New York, US. 1992.
31. Takashikoi N. Prolonged impact of earthquake-induced land slide on sediment yield in a mountain watershed: the Tanzawa region. japan. Geomorphology. 2008; 101:692-702.
32. Tian Y, Huang Zh, Xiao W. Reductions in non-point source pollution through different management practices for an agricultural watershed in the Three Gorges Reservoir Area, Journal of Environmental Sciences. 2010; 22(2):184-191.
33. Webb NP, Strong CL. Soil erodibility dynamics and its representation for wind erosion and dust emission models, Aeolian Research.2011; 3:165-179.
34. Yavari Sh. Soil erosion assessment using MCDM and MPSIAC models in Joneqan catchment, MSc thesis, Bou Ali University, Hamadan, Iran (in Persian). 2007.
35. Zhang YJ, Li AJ, Fung T. Using GIS and Multi-criteria Decision Analysis for Conflict Resolution in Land Use Planning, Procedia Environmental Sciences. 2012; 13:2264 – 2273.