Research Journal of Environmental and Earth Sciences 3(2): 167-176, 2011
ISSN: 2041-0492
© Maxwell Scientific Organization, 2011
Received: November 29, 2010 Accepted: December 25, 2010 Published: March 05, 2011

Multi-criteria Planning Approach for Ranking of Land Management Alternatives at Different Spatial Scales

[1]M. Reza Ghanbarpour and [2]Keith W. Hipel
[1]Center for Urban and Global Studies and Environmental Science Program, Trinity College, 70 Vernon Street, Hartford, 06106, Connecticut, USA
[2]Department of Systems Design Engineering, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

Abstract: Integrated land management decisions require comprehensive sets of criteria in order to properly account for all managerial alternatives. Economic criteria have been used to evaluate possible alternatives in most cases. However, it is important to consider the broadest possible range of social, economic and environmental criteria. This paper describes an integrated framework for land management planning at different spatial scales, comprising watershed, sub-watershed and land-unit levels. The structure includes four elements: (1) application of the strategic land management planning approach using the Delphi method and group decision analysis at sub-watershed scales, (2) identification of decision criteria at the land unit scale using socio-economic analysis and hydrologic modelling, (3) multi-criteria decision analysis of different alternatives, and (4) multi-stakeholder alternative prioritization. The Kan watershed north of Tehran, Iran, was selected as a case study. The major objective of this research is to integrate quantitative and qualitative decision criteria for planning purposes. This approach can be adapted to prioritize a wide variety of land and water resources management decisions in similar watersheds.

Key words: Decision making, Kan watershed, planning, stakeholder, TOPSIS

INTRODUCTION

The need to involve concerned stakeholders and related criteria in the planning of land management is universally recognized as a key element in obtaining balanced and sustainable watershed management (Koehler and Koontz, 2008). Watersheds include a variety of environmental and natural resources that provide basic goods and services to society and sustain a variety of ecosystem functions (Randhira *et al*., 2001). Environmental issues at watershed scale involve all stakeholders comprising the community, government and non-governmental agencies, and interest groups and non-governmental organizations (NGOs) (Ghanbarpour and Hipel, 2009). As Heathcote (1998) emphasised, stakeholders have conflicting interests and their objectives concerning land management may substantially differ. Many watershed development projects have performed poorly because they failed to take into account the needs, constraints, criteria, and practices of local stakeholders. In addition to the social and managerial aspects of different land use, making decisions requires the consideration of comprehensive sets of economical, technical and environmental criteria in order to properly account for all alternatives, especially in environmentally fragile regions. Sustainable development should be used as a conceptual paradigm to facilitate decision-making for suitable balance between development and environment (Ghanbarpour and Hipel, 2009).

Watershed management planning involves the interaction of objectives, existing constraints and available techniques to improve the effectiveness and efficiency of decision-making and implementation of choices made (Brooks *et al*., 1997). Oxley and Lemon (2003) presented an integrative modelling framework in the context of Mediterranean desertification to include stakeholders in the research, planning and implementation of policies and a willingness to step beyond disciplinary paradigms towards an integrative and transdisciplinary approach. Kepner *et al*. (2004) analyzed some future scenarios in the form of land-use/land-cover grids, relative to their impact on surface-water conditions. Their analysis has shown that the proposed tool can be used to evaluate the spatial impacts of urban growth patterns on surface-water hydrology. Ghanbarpour *et al*. (2005) proposed the SWMP (Strategic Watershed Management Planning) framework for finding long-term sustainable land management strategies at the watershed scale. Herrick *et al*. (2006) described an integrated framework for organizing,

Corresponding Author: M. Reza Ghanbarpour, Center for Urban and Global Studies and Environmental Science Program, Trinity College, 70 Vernon Street, Hartford, 06106, Connecticut, USA

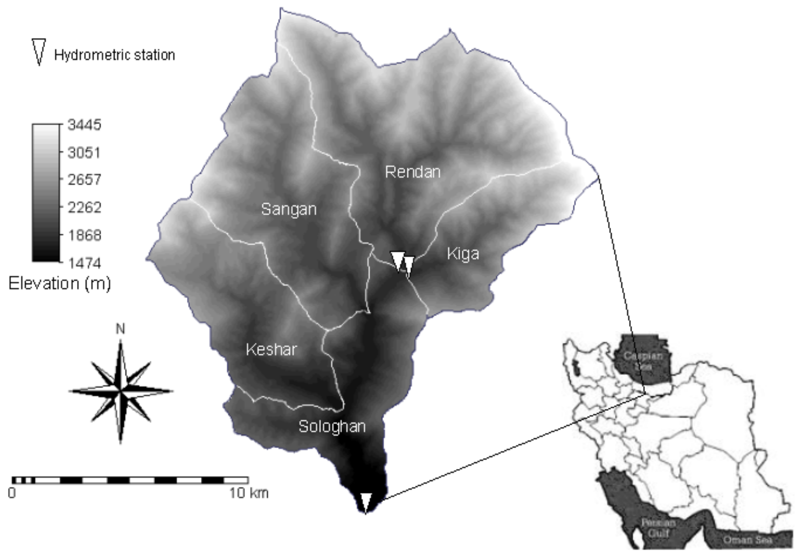

Fig. 1: Location of the Kan watershed and its sub-watersheds

synthesizing, and applying the growing knowledge of ecosystems to facilitate development of flexible, multi-objective assessment, monitoring, and management systems for arid and semi-arid ecosystems. Liu *et al*. (2007) have proposed an optimization method based on scenario analysis for handling watershed management under uncertainty. The method that they applied to the case of the Lake Qionghai watershed in southwestern China integrates system analysis, forecast methods, and scenario analysis, as well as the contributions of stakeholders and experts, into a comprehensive framework.

This paper develops a multi criteria framework to land prioritization for achieving multi-stakeholder and sustainable planning at different spatial scales comprising sub-watershed and land unit levels. However, this approach could be used to identify a cost effective mix of structural and non-structural management alternatives within an area. In this procedure, we apply decision analysis, hydrological simulation and scenario analysis to the selected watershed. The Kan watershed, located north of Tehran, Iran, is considered as a case study. The most important objective of this research is the integration of quantitative and qualitative decision criteria for multi-stakeholder land management decision making at different spatial scales.

MATERIALS AND METHODS

This study has conducted in Iran and in the Kan watershed located approximately 3 km northwest of Tehran, Iran. All questionnaires, interviews and field works conduced in 2004 and 2005.

Study area: This study focuses on the Kan watershed located approximately 3 km northwest of Tehran, Iran (Fig. 1). The Kan watershed has an area of 204 km^2. It is a mountainous semiarid region. Annual rainfall is around 350 mm as an aerial average. Average temperatures range between -10ºC in winter and 26ºC in summer. Altitude ranges between over 3875 m above sea level to around 1400 m at the outlet of the watershed. There is a distinct dry season during May to October. Land use in this semi-arid watershed is highly diversified, including a wide range of agricultural practices, mountain ranges, mining, natural areas, rocky and barren lands, settlements and industries. Rangelands are confined primarily to the mountains. Vegetation cover is 16 to 22% and many rangelands experience overgrazing. Agricultural lands dominate the narrow strips of land bordering streams and the valleys. There are very small natural forests with endangered species that dominate the narrow strips of land bordering upland streams. This area also offers diverse recreational opportunities and contains a number of attractive tourism sites in upland areas.

Watershed planning process: In this research, different land management strategies were evaluated. For this purpose, a methodology as a hierarchal policy-making process was proposed, which is shown schematically in Fig. 2.

Watershed and sub-watershed scale: The SWMP framework (Ghanbarpour *et al*., 2005) was applied to assess and analyse different stakeholders' preferences for various land management strategies and alternatives at

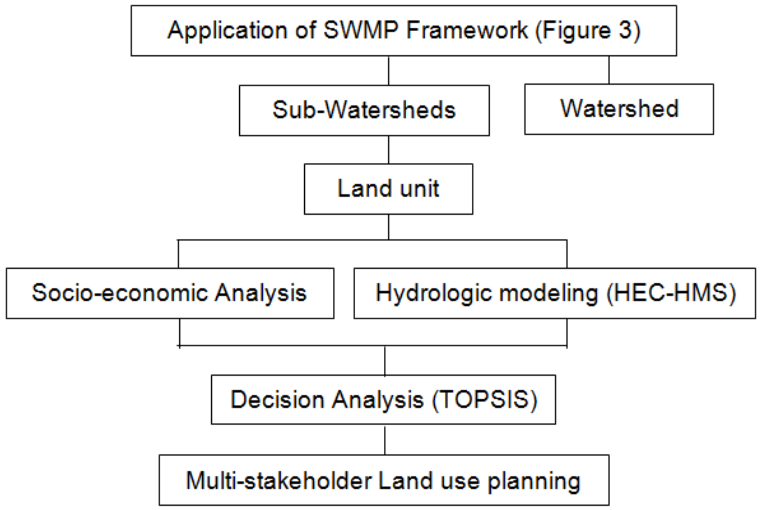

Fig. 2: Framework of the hierarchical land-use policy-making process at different spatial scales

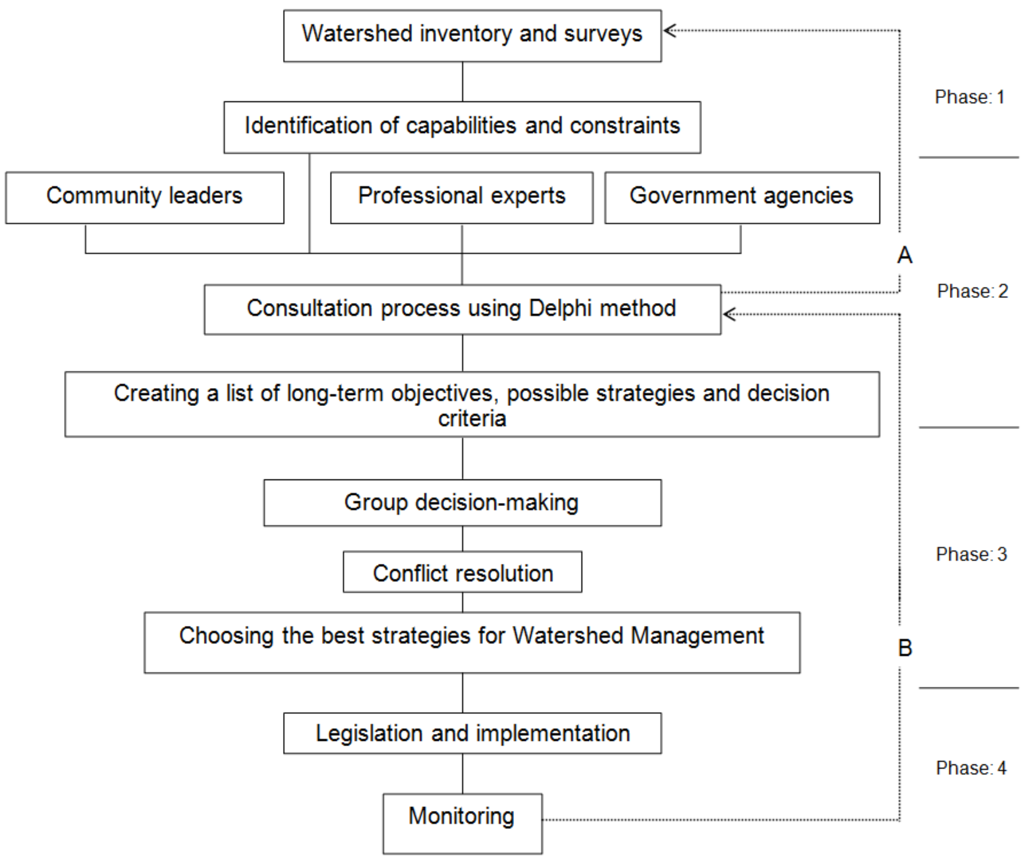

Fig. 3: The Strategic Watershed Management Planning (SWMP) framework (Ghanbarpour *et al*., 2005)

sub-watershed scales (Fig. 3). Professional experts, government agencies and community leaders constitute the different parties associated with the Kan watershed. The SWMP framework emphasizes the interaction of policy-makers at high levels of an organizational hierarchy, professional experts, and community and local leaders. It involves long-term, future-oriented and complex decision-making requiring top management actions (Ghanbarpour *et al*., 2005). The first phase of the SWMP framework emphasizes developing an understanding of watershed issues, problems, constraints and capabilities. This entails an initial investigation to clearly define the nature of the watershed under consideration, and the needs and opportunities facing the different stakeholders. The framework concentrates on a consultation process for planning by stakeholders to find a list of management strategies and alternatives.

In the Kan watershed, Sologhan, Keshar, Sangan, Rendan, Kiga and Emamzadeh constitute major residential areas. There are some community representatives who have been elected by an advisory committee in each area (JWWRC, 2000). Seven members of the local advisory committee participated in this research. The major part of governmental decisions for developmental plans in the study area have been made by four governmental sectors, including the watershed management division and the soil and water management division in the Ministry of Agriculture, the Environmental Protection Organization, and Tehran Municipality. Four representatives from these governmental agencies were invited to participate. Eight experts, including academic researchers and professors in the fields of environmental science, agriculture, water resources and integrated watershed management familiar with the Kan watershed, were asked to participate, and ultimately six people took part in this process. The criteria employed to choose members of the expert group were their having a high degree of knowledge about land resources and watershed management as well as familiarity with the Kan watershed.

The Delphi method, which offers a quick and cost effective method of assessing group preferences, was used to carry out the study. This method is a modification of the brainstorming and survey techniques conducted through several rounds of questioning (Hwang and Lin, 1987; Heathcote, 1998). All participants were asked to complete a questionnaire checking for the presence or absence of a list of long-term management strategies, alternatives and decision criteria. After the initial analysis of each individual's or group's replies using integration of opinion, each individual was encouraged to reconsider and, if appropriate, change his or her previous reply in light of the first results. After three rounds, the final list of options was determined. As a result, land management strategies and associated alternatives were identified at sub-watershed scales. Prioritizing of land management strategies and alternatives was carried out using the Analytical Hierarchy Process (AHP) group decision-making method (Saaty, 1990) and a Social Choice Function (SCF) method (Fishburn, 1974).

AHP is a multi criteria decision-making method that uses a hierarchical structure to decompose a complex problem into a hierarchy with a goal at the top, criteria and sub-criteria at the second and third levels, and alternatives at the bottom of the hierarchy. This method has been applied to a wide variety of decision problems, including participatory decision-making (Pykalainen *et al*., 1999), forest planning (Rauscher *et al*., 2000) and participatory strategic forest planning (Kangas, 1999). Three important components of AHP are: (1) the structuring of a problem into a hierarchy consisting of a goal and subordinate features, (2) pairwise comparisons between elements at each level and (3) propagation of level-specific, local priorities to global priorities. Strategies to be compared appear at the lowest level of the hierarchy. Pairwise comparisons are made between all strategies and the elements in the level above it. The intensity of preference between any two elements is assessed by integers ranging from 1 to 9 (Saaty, 1990). The AHP method was used to prioritize the watershed management strategies based on experts' preferences in the Kan watershed study.

The SCF technique involves mapping, which assigns a non-empty subset of the potential feasible subsets to each ordered pair consisting of a potential feasible subset of alternatives and a schedule or profile of voters' preferences (Fishburn, 1974). The SCF is based on pairwise comparisons of the number of voters between pairs of strategies. In other words, it assumes that all assertions of preference between two strategies carry equal weight. A final priority vector for the alternatives was obtained for the case study using the computation of a normalized pairwise comparison matrix and geometric mean. This method was used to prioritize long-term watershed management strategies from the community leaders and governmental agencies' point of view. The SWMP can be a more challenging process than may be apparent, partly because of differences in perception and priority among top-level policy-makers and other stakeholders. Through application of the SWMP framework, and with sufficient commitment by stakeholders, all priority strategies and alternatives can be identified.

Land unit scale: More detailed information including socio-economic, environmental and technical criteria needs to be considered at the land-unit scale. A brief description of the methodology used in this scale can be seen in Fig. 2. A list of different land-use classes was extracted using preference analysis of watershed stakeholders. In this paper, we focus only on agricultural and rangeland units. The list of land management strategies and alternatives for agricultural and rangelands in the study area are shown in Table 1. Social and economical decision criteria were determined using the Delphi method and an economic survey. Community and governmental organizations preferences, and maintenance and implementation cost are used as social and economic decision criteria.

Table 1: List of land management strategies and alternatives for agricultural and rangelands in the study area

Strategy	Alternatives	Code
Rangeland improvement	Seeding and planting	SP
	Pitting and furrowing	PF
	Seeding and planting and pitting and furrowing	SPPF
	Enclosure	E
	Enclosure and seeding and planting	ESP
	Enclosure and pitting and furrowing	EPF
	Enclosure and seeding and planting and pitting and furrowing	ESPPF
	Baseline	B
Agricultural land management	Horticulture and terracing	HT
	Horticulture and terracing and water basin	HTWB
	Horticulture and cement terracing	HCT
	Horticulture and cement terracing and water basin	HCTWB
	Cropping and terracing	CT
	Cropping and terracing and water basin	CTWB
	Cropping and cement terracing	CCT
	Cropping and cement terracing and water basin	CCTWB
	Timber harvesting and terracing	THT
	Timber harvesting and terracing and water basin	THTWB
	Timber harvesting and cement terracing	THCT
	Timber harvesting and cement terracing and water basin	THCTWB
	Agroforestry and terracing	AT
	Agroforestry and terracing and water basin	ATWB
	Agroforestry and cement terracing	ACT
	Agroforestry and cement terracing and water basin	ACTWB
	Baseline	B

Table 2: A part of the decision matrix and criteria for rangeland improvement alternatives

	Hydrologic criteria		Economical criteria		Social criteria	
Alternatives code	Peak flow 25 Yr	Peak flow 100 Yr	Maintenance cost	Implementation cost	Community preference	Gov. Org. preference
SP	0.390	0.388	0.251	0.251	0.286	0.228
PF	0.349	0.349	0.301	0.301	0.500	0.342
SPPF	0.330	0.332	0.552	0.552	0.714	0.456

An event-based hydrological model, Hydrologic Modeling System (HEC-HMS), was used to model the watershed response to different land management options and to determine environmental decision criteria. The HEC-HMS model was designed to simulate the rainfall-runoff processes of dendrite watershed systems at the Hydrologic Engineering Center of the US Army Corps of Engineers (HEC, 2000). The model includes a variety of mathematical models for simulating precipitation, evapotranspiration, infiltration, excess precipitation transformation, base flow and open channel routing. Data used for hydrologic modeling included the hydrograph data from three hydrometric gauges at the outlets of Kiga and Rendan and the outlet of the basin, and hourly rainfall data was used from two rain gauges at Kiga and Rendan. The locations of the hydrometric stations are shown in Fig. 1. For the sake of brevity, the data are not presented here. Simulated peak flows with 25 and 100 years return periods were considered as hydrologic decision criteria for each proposed strategy.

The TOPSIS method (Hwang and Lin, 1987) was used to find the best managerial alternatives according to all criteria based on the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution. Different stakeholders' preferences and economical and environmental criteria were integrated using TOPSIS, as a multi- criteria decision analysis method (Liu *et al*., 2006). A Multiple Criteria Decision Analysis (MCDA) problem can be expressed in a matrix format (Eq. 1). A part of the decision matrix of the agricultural land management alternatives and all criteria is shown in Table 2. As Chen and Hwang (1992) have shown, a decision matrix D is an (mxn) matrix for which element, , indicates the performance rating of alternative i,A_i , with respect to criterion j,x_j .

$$\begin{array}{c|ccccc} & x_1 & x_2 & . & . & . & x_n \\ \hline A_1 & x_{11} & x_{12} & . & . & . & x_{1n} \\ A_2 & x_{21} & x_{22} & . & . & . & x_{2n} \\ . & . & . & & & & . \\ . & . & . & & & & . \\ . & . & . & & & & . \\ A_m & x_{m1} & x_{m2} & . & . & . & x_{mn} \end{array} \quad (1)$$

Hence A_i , I = 1, 2…, m is denoted by $x_i = (x_{i1}, x_{i2}, ..., x_{in})$ and the column vector, n, shows the contrast of each alternative with respect to criterion x_j, as $x_j = (x_{j1}, x_{j2}, ..., x_{jn})^T$. The relative importance is usually given by a set of weights, which are normalized to sum to one. In the case of n criteria, a weight set is:

$$w^T = (w_1, w_2, ..., w_n) \text{ when } \sum_{j=1}^{n} w_j = 1 \qquad (2)$$

In this method the normalized value is calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1,2,.....,m; j = 1,2,....,n \qquad (3)$$

The weighted normalized value v_{ij} is calculated as:

$$v_{ij} = w_j, x_{ij}, \; i = 1,2,....,m; \; j = 1,2,....,n. \qquad (4)$$

where w_j is the weight of the jth criterion and $\sum_{j=1}^{n} w_j = 1$.

The ideal A* and negative ideal A$^-$ solution can be determined as:

$$A^* = \left\{ \left(\max_i v_{ij} \middle| j \in J\right), \left(\min_i v_{ij} \middle| j \in J'\right) \middle| i = 1,2,....,m \right\} = \left\{ v_1^*, v_2^*, ..., v_j^*, ..., v_n^* \right\} \qquad (5)$$

$$A^- = \left\{ \left(\min_i v_{ij} \middle| j \in J\right), \left(\max_i v_{ij} \middle| j \in J'\right) \middle| i = 1,2,....,m \right\} = \left\{ v_1^-, v_2^-, ..., v_j^-, ..., v_n^- \right\} \qquad (6)$$

where, $J = \{ j = 1,2,....,n | j \}$ associated with positive criteria

$J^- = \{ j = 1,2,....,n | j \}$ associated with negative criteria.

The separation between each alternative can be measured by the n-dimensional Euclidean distance. The separations of each alternative from the ideal and the negative-ideal solution are given as:

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2} \qquad i = 1, 2, ..., m \qquad (7)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \qquad i = 1, 2, ..., m \qquad (8)$$

At the final stage, the relative closeness of with respect to is defined as:

$$C_i^* = S_i^- / \left(S_i^* + S_i^-\right), \qquad 0 \langle C_i^* \langle 1, i = 1,2,.....,m \qquad (9)$$

Finally, a scenario analysis was conducted to show the importance of each criterion and to integrate them into the decision process. At this stage, the sensitivity to the criterion weightings was assessed by varying the weight assigned to each criterion and comparing the results with the original ones.

RESULTS AND DISCUSSION

Ranking of land management alternatives: Strategic planning of the land management alternatives at the sub-watershed scale was conducted using group decision analysis based on the SWMP framework proposed by Ghanbarpour *et al*. (2005). As can be seen in Table 3, there are some different land management alternative preferences regarding different sub-watersheds in the study area. The one exception is that water supply is the most preferred land-use strategy for all sub-watersheds. At the watershed scale, recreation enhancement could not be recognized as one of the best options (Ghanbarpour *et al*., 2005). As a result of the present study, sub-watershed scale analysis suggests that recreation and tourism could be considered in some areas, provided that the watershed offers diverse recreational opportunities and contains a number of attractive tourism sites in upland areas. Therefore, based on sub-watershed analysis it is concluded that the Kiga and Sangan sub-watersheds, for example, are suitable for recreation enhancement and tourism, considering water supply and horticulture as the competitive land-use alternatives. In the Kiga and Sologhan sub-watersheds, on the other hand, structural and non-structural flood control alternatives should also be considered as a priority (Table 3).

Historical flash floods threatening the Kan watershed have shown that flood control measures are urgently needed to protect natural resources, tourist sites and metropolitan areas. The area suffered from damage caused by floods in 1954, 1994, and 1995, in conjunction with other events. The worst case occurred in May 1995, when water from two sub-watersheds, Kiga and Rendan, gathered together and caused a very heavy flash flood on the lower and middle parts of the basin. Five people were killed in the disaster and there was significant damage to farms, gardens and roads, totalling more than 350 million rials (Hakimi Larijani, 1995; JWWRC, 2000).

Range management is an important management alternative that is only preferable in the Rendan and Sologhan sub-watersheds (Table 3). As reported by JWWRC (2000), land degradation due to over-grazing

Table 3: Ranking of long-term land-use systems at the sub-watershed level

Sub-watershed	Land management alternatives
Kiga	Water supply, tourism, structural and non-structural flood control, horticulture, soil conservation
Rendan	Water supply, range management, horticulture, non-structural flood control, soil conservation
Sangan	Water supply, horticulture, recreation and tourism development, soil conservation
Keshar	Water supply, horticulture, soil conservation, structural and non-structural flood control
Sologhan	Water supply, horticulture, structural and non-structural flood control, soil conservation, range management

Table 4: Ranking of land management alternatives at the land unit level using TOPSIS

Strategy	Land-use alternative	Priority	Strategy	Land-use alternative	Priority
	SP	0.39		CTWB	0.37
	PF	0.58		CCT	0.49
	SPPF	0.91		CCTWB	0.57
Rangeland improvement	E	0.19		THT	0.15
	ESP	0.41		THTWB	0.28
	EPF	0.49	Agricultural land management	THCT	0.44
	ESPPF	0.69		THCTWB	0.52
	B	0.09		AT	0.23
				ATWB	0.39
Agricultural Land Management	HT	0.54		ACT	0.50
	HTWB	0.62		ACTWB	0.60
	HCT	0.77			
	HCTWB	0.86		B	0.05
	CT	0.24			

and soil erosion is very serious in the study area and grazing should not be allowed in other sub-watersheds.

A critical factor in such an approach is the ability to prioritize land management alternatives and to target long-term policies to areas with maximum efficiency, considering stakeholders' preferences, along with hydrologic, social and technical criteria. It can be deduced that long-term land management strategies are based upon the nature of watershed resources and capabilities, but alternatives to achieve each strategy differ according to the objectives and interests of stakeholders.

In this research, the best management alternatives for each land-use class were prioritised using the TOPSIS method based on economic, social and hydrologic criteria at the land unit scale. The Delphi method was used to consult with the different parties, including community leaders and governmental organizations, to assign social decision criteria. Economic criteria were determined by means of an economic survey on different land management alternatives using field interviews and previous studies (JWWRC, 2000; Ghanbarpour *et al*., 2005). Community and governmental organizations preferences and maintenance and implementation costs were extracted as social and economic decision criteria.

The HEC-HMS hydrologic model was used to model the watershed response to different land management options and to determine environmental decision criteria. The model was calibrated using the six available rainfall-runoff observed data. Then, the model was validated based on the flood event of March 23, 2000. The differences between the observed and estimated peak flood discharges for the validation event in Kiga, Rendan and the outlet of the basin are 10, 1.48 and 11%, respectively. The estimated peak flows with 25 and 100 years return periods were considered as hydrologic decision criteria for each proposed strategy at the land unit scale.

The TOPSIS method was used for prioritizing the best management alternatives. Results of a decision analysis using the TOPSIS method are shown in Table 4 for agricultural and range land units in the study area. As can be seen in Table 4, for the case of rangeland units, SPPF is the most rated land management alternative, whereas baseline is the least preferred practice for the range improvement strategies. It is shown that enclosure is not a preferred alternative for range improvement in the study area. If any alternatives with enclosure should be chosen in the study area, the results of this study have shown that the ones that should be chosen in the order of most to least preferred are ESPPF, EPF and ESP. Without enclosure, SPPF, PF and SP can be utilized with respect to the ranking of land management alternatives according to Table 4.

As a result of the TOPSIS ranking of land management alternatives in agricultural land units, HCTWB is the most preferred practice, whereas the baseline is the least important agricultural land improvement alternative (Table 4). In this study, four land management strategies in agricultural land units including horticulture, cropping, timber harvesting and agroforestry were considered. The preferred horticultural alternatives in the order of most to least preferred are

Table 5: Best land management alternatives based on scenario analysis

No.	Scenario	Selected rangeland improvement alternative	Selected agricultural management alternative
1	Equal weight	SPPF	HCTWB
2	Hydrological-based	ESPPF	ACTWB
3	Economical-based	E	HT
4	Social-based	SPPF	HTWB
5	Community-based	SPPF	HTWB
6	Governmental-based	ESPPF	HCTWB

HCTWB, HCT, HTWB and HT (Table 4). As Ghanbarpour *et al*. (2005) have shown, horticulture development is one of the most important long-term land management strategies in the region. As can be seen in Table 4, all of the alternatives for horticulture are more preferred than any of the other practices for agricultural management in the study area. For cropping practices, CCTWB is the most important alternative. THCTWB is the most highly rated practice among the timber harvesting alternatives. Finally, ACTWB is the most preferred alternative for agroforestry land management (Table 4).

Scenario analysis: In the previous section, equal weight was assigned to each criterion into the decision making process using the TOPSIS method. In addition, a scenario analysis was conducted to show the importance of each criterion and how they are integrated in the decision process. The first scenario was based on the fact that the most important criterion in land-use planning is flood hazard mitigation in the study area. Therefore, in the first scenario of hydrologic decision criteria, peak flows at the outlet of the basin with 25 and 100 years return periods were assigned a ranking twice as high as the other criteria in the decision making process. In the second and third scenarios, higher weights were assigned to the economical and social criteria, respectively. In the fourth and fifth scenarios, equal weight was assigned to hydrologic, economic and social criteria, but different weights were assigned to community and governmental organization preferences.

The results of scenario analysis are shown in Table 5. This research has shown how integration of different stakeholders' preferences and economical and hydrological attributes can be conducted using a multi-attribute decision-making (MADM) method. This paper has shown that the integration of structural and biological land management practices (e.g., SPPF) for rangelands is the best option according to different points of view. Scenario analysis has demonstrated that enclosure is not a preferred alternative from the community point of view. However, horticulture development is the most important strategy in the study area. As a result, all land management alternatives for horticulture are more preferred to any other strategies for agricultural management in the region (Table 5). Scenario 1 is chosen as a benchmark, in which all criteria have equal weight in the decision making process. These four scenarios represent different management policies. The scenario approach offers a way to answer 'what if?' questions posed by considering different weights for the criteria, thereby reflecting different managerial viewpoints. Employing different scenarios, applying some restrictions and assumptions to the problem, and calculating the consequences, constitute a fast and low-cost source of information for strategic watershed planning and management at different scales.

CONCLUSION

In this paper, a methodology for land management planning to different spatial scales using social, managerial, economical and environmental criteria was proposed. Utilization of this methodology for prioritizing long-term preferred strategies at the watershed scale have been discussed by Ghanbarpour *et al*. (2005). This research targeted those areas at sub-watershed and land unit scales within the watershed that have the greatest impact on water supply, tourism, structural and non-structural flood control, horticulture, soil conservation, range management, agricultural management and rangeland improvements. Therefore, areas were targeted for adopting a specific alternative as a priority while using the balance of available resources to maintain current conditions.

This research has shown how the integration of different governmental and non-governmental stakeholders' preferences, and economical and environmental criteria can be conducted using a group and multi-criteria decision analysis method. Decision analysis at the land unit scale (tactical) needs more detailed information and analysis than at the watershed scale (strategic). Therefore, an event-based hydrological model and the Delphi method were used to extract values for the hydrologic and economical decision variables at the land unit scale. This paper has shown that integration of structural and non-structural land management practice (SPPF) for rangelands is the best option according to different points of view. Scenario analysis has shown that enclosure is not a preferred land management alternative in the study area, whereas horticulture development is the most important strategic and tactical land-use alternative in the study area.

Herrick *et al*. (2006) have described the limitations of an ecological site classification framework. Such drawbacks are inevitable when dealing with an integrated framework describing critical interactions among the social, economical, environmental and institutional processes. A limitation of our proposed framework is that it does not address linkages among site specific land unit alternatives that may affect the status of a particular location. This problem could be solved by using an improved framework under a GIS platform in future research programs. Prioritizing the strategies and alternative selections at the watershed and sub-watershed levels could be conducted more precisely (i.e., completely site specific) and conveniently.

As Oxley and Lemon (2003) emphasized, integrative planning and modelling is an iterative process which requires continual reassessment of both conceptual models and simulation models, and involvement of both scientists and local stakeholders. The proposed framework described here has the potential to significantly increase the extent to which ranking of land management alternatives is based on science, stakeholder participation and institutional collaboration, especially in regions with fragile environments.

Finally, it can be concluded that social, economical and environmental decision criteria can, and should, be included in the decision-making process for land-use planning at the different spatial scales. Scenario analysis in this research has shown that inclusion of a variety of criteria leads to a broadening of the decision-making process beyond the consideration of economic factors or managerial criteria alone. The set of managerial and social criteria in which the preferences of governmental and non-governmental organizations were considered, as outlined in this paper, reflect the need for a participatory and multidimensional process of land management planning and watershed development.

ACKNOWLEDGMENT

The authors wish to thank all participants who devoted their valuable time for filling in the questionnaires and taking part in interviews. The first author also is grateful for funding provided by the International Institute of Education and Scott M. Johnson Memorial Fund at Trinity College to complete this research. The first author also is grateful for the supports that received from the Center for Urban and Global Studies at Trinity College. The authors appreciate the excellent editing of their manuscript carried out by Mr. Conrad Hipel.

REFERENCES

Brooks, K.N., P.F. Efolliott, H.M. Gregersen and L.F. DeBano, 1997. Hydrology and the Management of Watersheds. Iowa State University Press, Ames, Iowa.

Chen, S.J. and C.L. Hwang, 1992. Fuzzy Multiple Attribute Decision Making, Methods and Applications. Springer-Verlag, Berlin, pp: 536.

Fishburn, P.C., 1974. Social choice functions. SIAM Review, 16: 63-90.

Ghanbarpour, M.R., K.W. Hipel and K.C. Abbaspour, 2005. Prioritizing long-term watershed management strategies using group decision analysis. Water Resour. Dev., 21(2): 297-309.

Ghanbarpour, M.R. and K.W. Hipel, 2009. Sustainable development conflict over freeway construction. Environ. Dev. Sustain., 11: 241-253.

Hakimi Larijani, P., 1995. Important historic floods in Tehran, water and development. Q. J. Water Aff. Devision Ministry Energ., 2: 70-77, (in Persian).

Heathcote, I.W., 1998. Integrated Watershed Management. Wiley, New York.

Herrick, J.E., B.T. Bestelmeyer, S. Archer, A.J. Tugel and J.R. Brown, 2006. An integrated framework for science-based arid land management. J. Arid Environ., 65: 319-335.

Hydrological Engineering Center (HEC), 2000. Hydrologic Modelling System HEC-HMS, Technical Reference Manual, US Army Corps of Engineers, Hydrologic Engineering Center, Davis, Calif, pp: 149.

Hwang, C. and M. Lin, 1987. Group Decision Making under Multiple Criteria. Springer, Berlin.

JWWRC, 2000. Integrated Watershed Surveys for Kan Watershed, Final Report. Jahad Water and Watershed research company (JWWRC), Tehran, Iran.

Kangas, J., 1999. The Analytic Hierarchy Process (AHP): Standard Version, Forestry Application and Advances. In: Helles, F., P. Holten-Andersen and L. Wichmann (Eds.), Multiple uses of Forests and other Natural Resources. Academic Publishers, Amsterdam, Kluwer.

Kepner, W.G., D.J. Semmens, S.D. Bassett, D.A. Mouat and D.C. Goodrich, 2004. Scenario analysis for the San Pedro River, analyzing hydrological consequences of a future environment. Environ. Monit. Assess., 94: 115-127.

Koehler, B. and T.M. Koontz, 2008. Citizen Participation in Collaborative Watershed Partnerships. Environ. Manage., 41: 143-154.

Liu, C., P. Frazier, L. Kumar, C. Macgregor and N. Blake, 2006. Catchment-wide wetland assessment and prioritization using the multi-criteria decision-making method TOPSIS. Environ. Manage., 38: 316-326.

Liu, Y., H. Guo, Z. Zhang, L. Wang, Y. Dai and Y. Fan, 2007. An optimization method based on scenario analysis for watershed management under uncertainty. Environ. Manage., 39: 678-690.

Oxley, T. and M. Lemon, 2003. From social-enquiry to decision support tools: Towards an integrative method in the mediterranean rural environment. J. Arid Environ., 54: 595-617.

Pykalainen, J., J. Kangas and T. Loikkanen, 1999. Interactive decision analysis in participatory strategic forest planning: Experiences from state-owned boreal forests. J. Forest Econ., 5: 341-364.

Randhira, T.O., R. O'Connor, P.R. Pennerc and D.W. Goodwin, 2001. A watershed-based land prioritization model for water supply protection. Forest Ecol. Manage., 143: 47-56.

Rauscher, H.M., F.T. Lloyd, D.L. Loftis and M.J. Twery, 2000. A practical decision-analysis process for forest ecosystem management. J. Comput. Electron. Agric., 27: 195-226.

Saaty, T.L., 1990. Multicriteria Decision Making: The Analytic Hierarchy Process. Pittsburgh, RWS.