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Using the Analytical Network Process (ANP) based on BOCR Model to select the most suitable region for forestation with almond species

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Abstract. *Mohammadi MF, Najafi A, Ahmadlo F. 2015. Using the Analytical Network Process (ANP) based on BOCR Model to select the most suitable region for forestation with almond species. Nusantara Bioscience 7: 118-127.* Forestation is the answer not only to the growing demand for timber and wood fiber, but also to the problem of deforestation. Forests in arid and semi-arid regions are in the specific conditions because of being in short of water and soil nutrition. Therefore, protection and rehabilitation of these forests is of very important due to its environmental condition as well as selecting suitable species for forestation. Considering all aspects of forestation in an effort to improve forest practices requires an approach that addresses multiple criteria and incorporates a wide range of data. After that, the approach should provide a framework to evaluate both quantitative and qualitative criteria. In this study, the Analytical Network Process (ANP) is utilized to evaluate four existing sites for forestation with Almond (*Amygdalus scoparia*) in Markazi province, central Iran. The ANP framework helps forest managers to prioritize all the alternatives and criteria with respect to each other and developing their corresponding preferences. This study is an analysis of the environmental, social-economic, and sustainability-genetic diversion context of forestation with the goal of making forest practices more sustainable. The results indicate that Risk and Cost priorities are more important in making decision (0.53, 0.47), compared to Benefits and Opportunities (0.29, 0.25). The final synthesis of the system shows that Sarabadan (B site) is the best choice among four potential regions which were evaluated for forest plantation based on judgment's comparisons.

Keywords: BOCR merits, decision support system, forest plantation, local priority, sensitivity analysis

INTRODUCTION

Forest plantation is generally intended for producing timber and pulpwood products in order to increase the total area of forest worldwide. Forest plantation may be important in the case of increasing biodiversity functions, maintaining soil structure and nutrient capital, as well as providing a sink for storing carbon in soil, specifically in arid and semi-arid areas. It may also play an important role in alleviating pressure on natural forested woodlands for timber, fuelwood production and windbreak protection (Sagheb-Talebi 1996). Forestation projects and enrichment of natural forest are the most important endeavors in Iran that are done in all provinces, especially in its central regions. Iran is considered as a low forest-covered region with percentage cover about seven percentage of the land area. However, this country has varied forest types with rich biological diversity. One of the most important species in these bare lands is Almond (*Amygdalus scoparia* Spach.) which covers a wide range of Iran. This species well establishes at hillsides of Zagros and Alborz Mountains and in Iran-Turanian regions (Alvani Nejad 1999). Noticeably, we can say that this species has much adaptation and resistance ability to different environmental condition in this area which is grown as clumps and almost utilizes for plantation and enrichment in these areas. Therefore, selecting the best site for plantation with this species is of very important and is an open avenue of most researches in field of ecology. In general, site selection is important decision-making in forest plantation activities (Moeinaddini et al. 2011).

There are different methods for site selection in forest plantation, and one of these methods is Algorithmic model. An algorithm is a specific set of obviously defined instructions aimed to do a task or process. Algorithmic model theory utilizes tools from mathematical logic to answer model-theoretic questions that arise from algorithmic issues in discrete mathematical structures and the modeling of data and computations. Algorithms for experimental modal analysis of linear dynamic systems can be categorized as to whether they use frequency or time domain data. Another categorization addresses the analytical representation of a response to which the measured data is fit. Even if the number of participatory modes was known, the presence of relatively large damping can give rise to identification difficulties for several reasons. Some algorithms implicitly assume that dissipation is viscous. Furthermore, if a system has a wide range of modal damping ratios, the more highly damped modes in any transient temporal responses are rapidly attenuated, thereby magnifying the contribution of noise to those modes (Allen and Ginsberg 2004).

Selecting the most suitable sites for forest plantation is a multidisciplinary decision problem because poor and ambiguous evaluation of forest plantations could lead to misleading assessments of links and subsequently poor policy; site selection plays a primary role in those assessments. On the other hand, it has different aspects such as socio-economic, environmental and sustainability-genetic diversion aspects. Accordingly, we need a flexible and comprehensive framework to simultaneously model and rank existing harvesting methods. To improve policy design and implementation, socio-economic and ecological evaluation of site selection should facilitate the comparison of the respective social, economic, and ecological benefits, costs, opportunities, and risks and allow assessment of tradeoffs and synergies. Therefore, this research develops a MCDM scheme to make the best decision. The concepts and methods of Multi-Criteria Decision Making (MCDM) present a framework that incorporates multiple, conflict criteria into planning (Komarov et al. 2002; Miettinen 2006). It is typically used for dealing with planning situations in which one needs to holistically evaluate different decision alternatives, and in which comprehensive evaluation is hindered, especially by the multiplicity of decision criteria that are difficult to compare, and by conflicting interests affecting the decision-making process. Thus, many of the challenges of today's multiple-criteria and complex forest management planning can be alleviated using MCDM methods (Tarp and Helles 1995; Martell et al. 1998; Mills and Clark 2001; Kangas and Kangas 2002). Problems with feedback structure and intangibles criteria and indexes can be addressed well by decision support tools such as the Analytic Network Process (ANP), specifically in natural resource management. Indeed, a few of mathematical models such as Linear Programming (LP), and multi-objective programming are one or more objective functions that including known quantitative variables. The objective function in these systems should be optimized in the given data space by taking into account the system constraints. Moreover, the qualitative (intangible) criteria could not be included in these models.

The ANP model has a good ability to capture and synthesize complex problem and allows for constructing a better interdependent relationship between elements and criteria. Developing such network models has a good potential in strengthening decisions, potentially can suggest some of the best places by involving and integrating criteria and indexes as well as alternatives, and feedback into the decision support system (Saaty 1999). Setting priorities and trade-offs among goals and criteria, measuring all tangible and intangible criteria (i.e. qualitative variables such as slash distribution) in the model (Momoh and Zhu 1998) and using the ratio scale of human judgment instead of arbitrary scales (Kim et al. 1997; Saaty 1999), makes ANP easy to use by managers and other decision makers.

A great deal of research has been carried out on characteristic of Almond species and its ecological demands in Iran (Irannejade Parizi 1995; Alvani Nejad 1999; Mirshamsi 1997). Most of them concentrated solely on ecological condition of its habitat, despite the fact that forest managers need a practical approach to determine priority scores of involved criteria in these areas, and finally get a good alternative in forest plantation endeavors. In fact, for making decisions regarding forest plantation, socio-economic and ecological factors should be simultaneously taken into consideration. There are a lot of tangible and intangible (i.e. quantitative and qualitative, respectively) criteria in terms of sustainable forest management that should be measured or estimated to get the best strategy for these activities (Spong 2007).

Selecting the appropriate site for forest plantation using decision-making tools can improve our vision and bring more success in this area in terms of sustainable forest management. Presented literature reviews show that a large number of publications reviewed the application of decision support systems in natural resources especially in forest areas (Wolfslehner et al. 2005; Yüksel and Dagdeviren 2007; Feurdean and Willis 2008; Wolfslehner and Vacik 2008, 2011; Chang et al. 2009; Ghajar and Najafi 2012). While in the case of site-selection for forestation using ANP we do not have a lot of publication, so far. Therefore, it is essential to optimize the strategic factors for selecting the best site for forestation. The main objective of this research is to quantity the preference of socio-economic and environmental attributes in forest plantation activities in terms of developing a tight decision model to select the best site (s) for forest plantation with Almond species in arid and semi-arid regions in Iran. The Analytic Network Process (ANP) (described by Saaty 1999) was applied to evaluate the overall preference of these four sites. By performing pairwise comparisons, we were able to prioritize the form in which this species is established in these four sites, which is an especially important factor for forestation. Incorporating all effective factors in this model is imperative in order to make a comprehensive decision and to achieve the strategic goals forestation.

MATERIALS AND METHODS

Study sites

This study carried out in Markazi province at central plateau of Iran. In general, the study site stretches from 48˚58´ to 51˚05´ E western and 33˚23´ to 35˚34´N northern latitude. It is located in the middle of two vegetative regions known as Irano-Turanian region and Zagros vegetative regions. There are many tree species in this province. The most important and abundant species in this region is Almond (*Amygdalus scoparia* Spach) which has a good potential ability in regeneration as a clump stand in this area. The companion species which have grown in this region including *Pistacia mutica*, *Pistacia khinjuk*, *Rhus coriaria*, *Celtis caucasica*, *Ulmus* sp., *Berberis integerrima*, *Quercus persica*, *Crataegus* sp., *Cerasus* sp., *Rhamnus pallasii*, *Amygdalus* sp., *Populus euphratica*, *Cotoneaster* sp., *Daphne mucronata*, *Lonicera nummulariifolia*, *Lycium* sp., *Nitraria schoberi*, *Fraxinus rotundifolia*, *Salix* sp., *Acer* sp., *Rosa* sp., *Ficus carica*, *Tamarix* sp. The other essential information of study sites is presented in Table 1.

Table 1. General characters of studied sites

Parameter	Sites			
	Sarabadan	**Chaftan**	**Nimor**	**Jalayer**
Longitude	50° 06 37	49° 43 24	50° 33 09	50° 06 47
Latitude	34° 46 37	34° 51 33	33° 49 12	34° 53 01
Area (ha.)	2920	239	2600	9824
Climate	Semi-dry with very cold winter	Semi-dry with very cold winter	Dry with cold winter	Dry with cold winter
Annual precipitation (mm)	387.49	304.50	275.80	212.30
Annual temperature (°C)	12.40	12.60	12.60	18.16
Altitude (m)	1900-2050	1400-1700	2000-2500	1240-1360
Slope gradient (%)	55	40 50		45

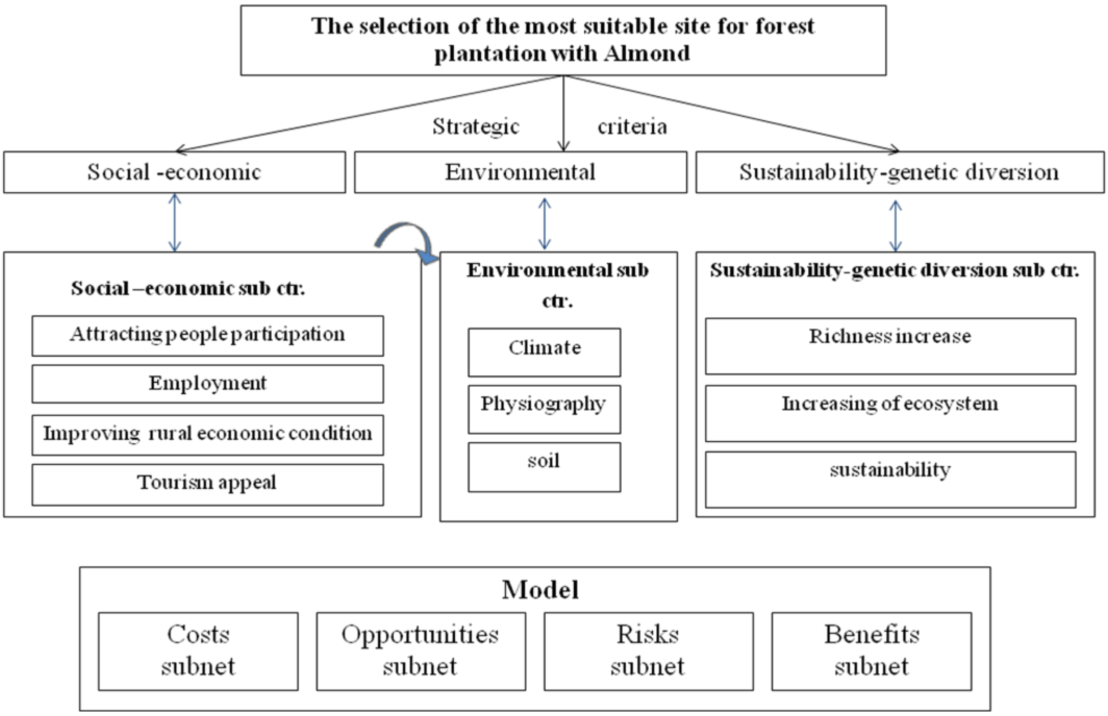

Figure 1. Top-levels of ANP for selecting the most suitable site for forestation with Almond

Building the model

The entire model of network for this study was designated into two levels of hierarchy with BOCR (Benefits, Opportunities, Costs, and Risks) merits. The BOCR subnets were composed of their respective clusters and elements. The purpose of the network model was selection of the best site (s) for forest plantation with Almond species through group decision-making scheme. The strategic criteria were created along with the goal of model. It included three main criteria; environmental, socio-economic and sustainability-genetic diversity at the first level. In addition, seven strategic sub-criteria, along with the strategic criteria, were developed to evaluate the priorities of the BOCR merits. The environmental sub-criterion was divided into three criteria include climate conditions, physiographic and soil parameters. The social economic criterion was split to attracting people's participation, creation of jobs and improving rural economic conditions. The sustainability-genetic diversity criterion was divided into tourism appeal, increase of richness and increasing of ecosystem sustainability criteria (Figure 1). In general, there were both quantitative and qualitative parameters in forestation. The first one could be calculated using scientific methods (tangible criteria), but making decisions about the second group (intangible criteria) was more variable in different conditions. In this case, local experts could compare alternatives in the model according to local realities and judge which alternative was the best. In our model, the pairwise comparisons, with respect to quantitative criteria, were performed by a group experienced experts based on findings of prior studies in mountainous forest. To solve the model, pairwise comparisons of criteria were completed by decision committee for all levels of network in order to elicit the local priorities. These comparisons were performed only for intangible parameters (Table 2).

Table 2. Final local weight of criteria in BOCR subnetworks

Strategic criteria	Normalized priorities	Sub criteria	Priorities	Subnet (Node)	Priorities
Environmental	**0.738**	Climate	0.240	Evaporation	0.031
				Precipitation	0.044
				Temperature	**0.924**
		Physiography	0.209	Geomorphology	**0.557**
				Land-form	0.442
		Soil		C/N	**0.402**
			0.549	EC	0.114
				Soil infiltration	0.282
				Soil texture	0.199
Social economic	0.060	Attracting people’s participation	0.075	-	-
		creation of jobs	**0.427**	-	-
		Improving rural economic condition	0.197	-	-
		Tourism appeal	0.298	-	-
Sustainability-genetic diversity	0.200	Increase of richness	0.200	-	-
		Increasing of ecosystem sustainability	**0.800**	-	-

Note: ** The local weights which are bold in table indicate the highest priority in their group

Any decision has several favorable and unfavorable factors to consider. Some of these are definite; the others are less certain but have a certain likelihood of materializing. The favorable definite factors are labeled Benefits and include items such as Soil improvement, Non-timber forest product and so on, while the unfavorable ones are labeled Costs and include items such as Cost price. The positive uncertain factors of a decision are the Opportunities that the selection of each alternative can create; for example, we have Created habitat for wildlife by forestation in this study. The fourth classification of general factors considered in all decisions is the Risks entailed in the decision. Each of these four concerns (BOCR) uses a separate structure for the decision, beginning with a Benefits control structure and the network of inter-dependencies that belong to it, and ending with risks that control structure. Also, each of these concerns contributes to the merit of a decision and must be evaluated (rated) individually on a set of (prioritized) criteria (Saaty et al. 2006). The BOCR factor and interaction is detailed in Table 2.

The purpose of the model is selected the best site for forestation with Almond designed based on BOCR models. Super Decisions software v.1.6.0 was used for the analysis due to the different variables that needed to be considered. The ANP model for evaluating the best site for forestation with Almond comprises several steps that will be discussed below.

Step 1: pairwise comparisons are performed based on presented top-level model (with the BOCR) (Figure 1). Here, we have a goal cluster with the best region for forestation with Almond, a strategic criteria cluster with the main criteria, and a cluster for each of the main criterion containing their strategic sub-criteria (Figure 1). The main criteria are compared with respect to the goal and the strategic sub-criteria are pairwise with respect to their strategic criterion (Table 2).

Step 2: The decision subnet for each BOCR is made. After linking the nodes and clusters suitably, the pairwise comparisons with respect to the parent clusters and nodes inside each of the BOCR are performed separately (Table 2). To obtain priorities of elements, firstly we prioritize the clusters constituting each of the BOCR. The importance of a cluster on the other clusters is shown in matrix form in Table 1. All of the comparisons are based on a scale of relative importance with the option to show preference between two elements on a ratio scale from equally important (i.e. equivalent to a numeric value of 1) to absolute preference (i.e. equivalent to a numeric value of 9) of one element over another (Saaty 1977). These influences are prioritized.

The matrix of priorities of all cluster comparisons under the Benefits sub-network is given in Table 3. Next, the elements of a cluster are prioritized with respect to the elements of the other clusters that have influenced on it. The obtained relative priorities of alternatives are inserted in the unweighted super-matrix that is given in Table 4. These priorities are then multiplied by the weight of the cluster alternatives in the cells (alternatives, advantages) from Table. 3. The results of it are shown in Tables 3 and 4. The values of Table 4 are used to obtain the limiting priorities of elements in the clusters under the Benefits sub-network (Table 5). Mathematically the limit of the super-matrix is processed by raising the entire super-matrix to powers until convergence in terms of a lime (i.e., a Cesaro sum) Eq. (1):

$$\lim_{n\to\infty}\left(\frac{1}{N}\right)\sum_{k-1}^{N} W^{k} \qquad \text{Eq. (1)}$$

Where W is the weighted super-matrix, N shows the sequence, and k is the exponent determined by iteration (Wolfslehner et al. 2005). After calculating the limit matrix, the priorities of alternatives are idealized by dividing by the largest priorities. Doing this for all merits (BOCR) and the overall synthesized priorities for alternatives under BOCR are also shown in this table (Table 6).

Table 3. Unweighted supermatrix of benefits (OK)

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	0.00000	0.00000	0.00000	0.00000	0.00000	**0.34541**	**0.38403**	**0.34388**	**0.41982**
A2	0.00000	0.00000	0.00000	0.00000	0.00000	**0.10172**	**0.11440**	**0.11822**	**0.10783**
A3	0.00000	0.00000	0.00000	0.00000	0.00000	**0.06717**	**0.06953**	**0.07386**	**0.07038**
A4	0.00000	0.00000	0.00000	0.00000	0.00000	**0.25740**	**0.24774**	**0.28241**	**0.25402**
A5	0.00000	0.00000	0.00000	0.00000	0.00000	**0.22831**	**0.18430**	**0.18164**	**0.14795**
A6	**0.33913**	**0.19322**	**0.28889**	**0.29947**	**0.21438**	0.00000	0.00000	0.00000	0.00000
A7	**0.34783**	**0.29576**	**0.29630**	**0.18811**	**0.39422**	0.00000	0.00000	0.00000	0.00000
A8	**0.16522**	**0.15085**	**0.11111**	**0.12355**	**0.19910**	0.00000	0.00000	0.00000	0.00000
A9	**0.14783**	**0.36017**	**0.30370**	**0.38887**	**0.19231**	0.00000	0.00000	0.00000	0.00000

Note: ** A1: assist to regeneration establishment; A2: non-timber production; A3: production cordwood; A4: protection of soil & water; A5: soil improvement; A6: Chaftan; A7: Jalayer; A8: Nimor; A9: Sarabadan

Table 4. Weighted supermatrix of benefits

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	0.00000	0.00000	0.00000	0.00000	0.00000	**0.34541**	**0.38403**	**0.34388**	**0.41982**
A2	0.00000	0.00000	0.00000	0.00000	0.00000	**0.10172**	**0.11440**	**0.11822**	**0.10783**
A3	0.00000	0.00000	0.00000	0.00000	0.00000	**0.06717**	**0.06953**	**0.07386**	**0.07038**
A4	0.00000	0.00000	0.00000	0.00000	0.00000	**0.25740**	**0.24774**	**0.28241**	**0.25402**
A5	0.00000	0.00000	0.00000	0.00000	0.00000	**0.22831**	**0.18430**	**0.18164**	**0.14795**
A6	**0.33913**	**0.19322**	**0.28889**	**0.29947**	**0.21438**	0.00000	0.00000	0.00000	0.00000
A7	**0.34783**	**0.29576**	**0.29630**	**0.18811**	**0.39422**	0.00000	0.00000	0.00000	0.00000
A8	**0.16522**	**0.15085**	**0.11111**	**0.12355**	**0.19910**	0.00000	0.00000	0.00000	0.00000
A9	**0.14783**	**0.36017**	**0.30370**	**0.38887**	**0.19231**	0.00000	0.00000	0.00000	0.00000

Table 5. Limited super matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	0.18789	0.18789	0.18789	0.18789	0.18789	**0.18789**	**0.18789**	**0.18789**	**0.18789**
A2	0.05485	0.05485	0.05485	0.05485	0.05485	**0.05485**	**0.05485**	**0.05485**	**0.05485**
A3	0.03487	0.03487	0.03487	0.03487	0.03487	**0.03487**	**0.03487**	**0.03487**	**0.03487**
A4	0.12874	0.12874	0.12874	0.12874	0.12874	**0.12874**	**0.12874**	**0.12874**	**0.12874**
A5	0.09365	0.09365	0.09365	0.09365	0.09365	**0.09365**	**0.09365**	**0.09365**	**0.09365**
A6	**0.14302**	**0.14302**	**0.14302**	**0.14302**	**0.14302**	0.14302	0.14302	0.14302	0.14302
A7	**0.15304**	**0.15304**	**0.15304**	**0.15304**	**0.15304**	0.15304	0.15304	0.15304	0.15304
A8	**0.07774**	**0.07774**	**0.07774**	**0.07774**	**0.07774**	0.07774	0.07774	0.07774	0.07774
A9	**0.12619**	**0.12619**	**0.12619**	**0.12619**	**0.12619**	0.12619	0.12619	0.12619	0.12619

Table 6. Criteria and their priorities with respect to BOCR structure

Merits	Priorities	Criteria	Normalized priorities	Alternatives	Priorities
Benefits	0.294597	Assist to regeneration	**0.37577**	Sarabadan	0.25239
		Non-timber forest product	0.10970	Chaftan	0.28604
		Soil & water protection	0.25748	Jalayer	**0.30609**
		Cordwood production	0.06974	Nimor	0.15548
		Soil improvement	0.18730	-	-
		Conservation	0.21778	-	-
Costs	**0.470373**	Cost price	0.17140	Sarabadan	0.17496
		Plantation	0.27715	Chaftan	**0.45560**
		Transportation	**0.33367**	Jalayer	0.25949
		Recreational values	0.18812	Nimor	0.19995
Opportunities	**0.259137**	Creating habitat for wildlife	**0.23638**	Sarabadan	0.19163
		C/N ratio Increases	0.18189	Chaftan	**0.29653**
		Percentages of nurse plants	0.22947	Jalayer	0.28719
		Social effects	0.16414	Nimor	0.22465
Risks	**0.535639**	Browsing	**0.39800**	Sarabadan	0.26716
		Decreasing of productivity	0.24366	Chaftan	0.22040
		Fire occurrence	0.14310	Jalayer	0.24016
		Pests and insects	0.21524	Nimor	**0.27228**

Table 7. Rating BOCR with respect to strategic criteria

Criteria	Environmental (0.738)			Socio- economic (0.060)				Sustainability-genetic diversity (0.200)			
Subcriteria	**Climate**	**Physiography**	**Soil**	**Attracting people's participation**	**Creation of jobs**	**Improving rural economic condition**	**Tourism appeal**	**Increase of richness**	**Increasing of ecosystem sustainability**	**Total**	**Priorities**
Weight	0.24	0.21	0.55	0.076	0.427	0.200	0.299	0.200	0.800		
Global weight	0.086	0.075	0.197	0.004	0.025	0.011	0.017	0.019	0.077		
Benefit	Medium	Low	Medium	Medium	Medium	Medium	High	High	High	0.294	0.188
Cost	Low	Medium	Very high	High	Medium	Medium	High	Low	Low	0.47	0.301
Opportunity	High	Medium	Very low	Low	Medium	Medium	High	Medium	High	0.259	0.166
Risk	High	High	High	Very high	High	High	Low	High	Very high	0.535	0.343

Note: Very high= 0.512; High=0.261; Medium=0.128; Low=0.063 and Very low= 0.033

Table 8. Priorities for alternatives under BOCR and final synthesized results from the ANP model based on ideal weights

Indexes/alternatives	Benefits	Opportunities	Costs	Risks	Final outcome using additive (norm)	Ranking
Chaftan (**A**)	0.93	1	1	0.80	0.76	3
Sarabadan (**B**)	0.82	0.64	0.38	0.98	1	1
Nimor-Mahalat (**C**)	0.50	0.75	0.24	1	0.80	2
Jalayer (**D**)	1	0.96	0.57	0.88	0.59	4

Step 3: After identifying the ideal alternative under each merit, the ratings of BOCR are done. Totally, for rating BOCR (or any alternative) correctly, they must be independent of another one. Otherwise, the presence or absence of an alternative must have no influence on how one rates any of the others; this kind of ranking with respect to an ideal is called absolute measurement or rating (Saaty et al. 2006). In order to rate BOCR with respect to an ideal, intensity levels are created (for example, very high, high, medium, low, and very low in our case). Then, in order to establish priorities, they are compared pairwise. The resulting priorities are normalized by dividing by the largest value among them, so that very high would have a value of 1.000 and others would be proportionately less (Table 7). The prioritized strategic sub-criteria are utilized to rate the BOCR by at first taking the ideal alternative for each merit obtained in Step 2 and then selecting the appropriate intensity from categories that we had created before, i.e. very high, high, medium, low, very low, (Table 7) for that ideal alternative, on each strategic sub-criterion. The selected intensity for each merit should describe it best on each sub-criterion.

For example, in order to select intensity for Benefits in relation to the sub-criterion 'employment,' the question is how much of the ideal alternative under Benefits can realize this goal? The answer is medium. Doing this for all sub-criteria yields the selected intensities of Benefits (Table 7). Likewise, the intensities of Opportunities, Costs, and Risks are chosen. The priorities of ratings of BOCR under each sub-criterion are given as the numbers in parentheses in Table 7. A score is computed for each merit by multiplying the priority of selected intensity times by the priority of the criterion (global weight in Table 8) and summing for all the sub-criteria (Table 7). The priorities of BOCR are obtained by normalizing the total score column by dividing by the sum of value in it (Table 7). The obtained normalized values are utilized for the priorities of the BOCR to do synthesis in the top-level network (Figure 1).

Step 4: Relative importance values for the alternatives are determined based on two formulas, the additive and the multiplicative. The additive and multiplicative formulas can be represented as bB+oO−cC−rR and $\{B^b\ O^o\ [(1/C)_{Normalized}]^c\ [(1/R)_{Normalized}]^r\}$, respectively, where B, O, C and R represent the overall synthesized priorities for alternatives under BOCR; whereas b, o, c, and r are BOCR rates. These subnets (sub-systems) are made up of components (clusters) and each component consists of elements.

In order to derive priorities for elements, pairwise comparisons are performed for weighting the criteria and alternatives and estimating the direction and importance of effects of one element on other both in the top-level network and BOCR sub-networks. Generally, there are three kinds of components (Saaty et al. 2006): (i) components which no arrow enters (source components), (ii) components from which no arrow leaves (sink components), and (iii) components which arrows both enter and exit (transient components). In this study, we just had the third component and most of components form a cycle of two components that feedback and forth into each other. Types of connection are different. Some components have loops that connect them to themselves (inner-dependent such as 'other' in the risks sub-network). All other connections represent dependence between components (outer-dependent). All analyses related to model processes are done in Super Decisions software v.1.6.0.

Synthesis

Comparison of each couple of nodes with respect to a parent node in the model showed that these elements influenced the parent node and also which of the children nodes (elements) was stronger than the other. In detail, preference values are calculated within three matrices: (i) the unweighted super-matrix is derived directly from pairwise comparison ratios; (ii) within the weighted super-matrix, the values are multiplied by cluster weights and normalized by column; and (iii) the limited super-matrix calculates the priorities of the alternatives by converging the super-matrix.

RESULTS AND DISCUSSION

Sensitivity analysis

The results of local weights of the top-levels of ANP model for selecting the most suitable site for forestation with Almond are shown in Table 2. Global priority of criteria is detailed in Table 2. As mentioned in this table the first part of conceptual model including three strategic criteria (environmental, social-economic and sustainability-genetic diversity), each cluster includes a group of criteria with their subnets in it. Environmental strategic criterion divides into three sub-criteria including climate, physiographic features, and soil. At the next step, an unweighted super-matrix was formed by inserting the local priorities of criteria vector on suitable columns. As an example, the unweighted super-matrix for the benefit sub-network is shown in Table 2. Following this step, a weighted super-matrix is computed by multiplying the values of the unweighted super-matrix in their related cluster weights. Further, we calculate a limit super-matrix by raising the entire super-matrix to powers enumerations, until matrix convergence is achieved. The final priorities of alternatives under each criterion can be seen in limited super-matrix. These matrixes can be used to assess the results of feedback structure in network model of decision. A simple example of the unweighted, weighted and limited super-matrix for the benefits sub-network is shown in Table 3, 4 and 5, respectively. As can be noticed in Table 2 the high and low priority levels of models are devoted to environmental conditions and the socio-economic factors (0.700 and 0.066) than the others, respectively. The soil sub-criterion has the most priority (0.55) than the others in this cluster.

The second part in network analyses is doing comparison between alternatives and criteria clusters. This network consists of four sub-networks that each represents the relationship of its own clusters and elements: Benefits, Opportunities, Costs, and Risks (BOCR). Within Benefit sub-network, five clusters are favorable for forestation activities. In mentioned cluster, each criterion influences on alternative clusters (candidate site) and will be affected by its criteria (Figure 1, Table 5). The results indicate that "assistant to regeneration" criterion has the most weight among them (0.37) and Jalayer (site D) (0.30) is the best site in this sub-network, accordingly (Table 5).

The results of BOCR shows that Cost sub-net that relates to seedling transportation had the most weight (0.330) among the others and the most suitable site in the case is Chaftan (0.45) (site A) (Table 7). In Opportunity sub-network, "creating habitat for wildlife" index has the most priority (0.23) among them, and in this sub-network, Chaftan (0.30) is superior (site A) to the others.

Finally, browsing index gets the most weight (0.39) within other criteria in Risk subnet under the BOCR structure (Table 7). This subnet consists of hazards and incidents that must be taken into account in forest plantation activities in these regions. Among all candidate sites, Nimor-Mahalat (0.27) is the critical site regarding our criteria in Risk sub-network (Table 5). Rating BOCR is performed with respects to an ideal mode. The normalized result is presented in (Table 7). A score is calculated for each merit through multiplying the priority of selected intensity times by the priority of the criterion (global weight in Table 7) and summing for all the sub-criteria (shown in Table 7, The priorities of BOCR are obtained by normalizing the total score column through dividing by the sum of value in it). The obtained normalized values are used for the priorities of the BOCR to do synthesis in the hierarchy of ANP network. Based on given results from each BOCR sub-network in the first four columns, we can synthesize the network to get the global ranking for every alternative (Table 8). The ranking shows that Sarabadan (site B) is the best and Jalayer (site D) is the worst site to forest plantation and enrichment with Almond species.

The results of sensitivity analysis of alternatives for each of the main controlling criteria identified as benefits, opportunities, costs, and risks associated with the goal of selecting the most suitable site for are shown in Figure 2. Ranking of alternatives varies when priority ratings are modified. Effects of this modification could be studied by performing sensitivity analysis.

Benefits

The benefit sensitivity analysis, illustrated in Figure 2.A, shows that the greatest benefit would always be achieved from the alternative Jalayer whereas the weight of benefits is less than 0.4; it is clear that the priority of Sarabadan increases and the priority of the other alternatives have no considerable changes.

Opportunity

The opportunity sensitivity analysis, illustrated in Figure 2.B, indicates that the highest opportunity is achieved through the alternative Chaftan whereas the weight of opportunity is less than 0.2; it is clear that the priority of Sarabadan will be more than Chaftan.

Cost

The cost sensitivity analysis, illustrated in Figure 2.C, indicates that the highest cost is achieved through the alternative Chaftan whereas the weight of cost is less than 0.3; it is clear that the priority of Sarabadan will be more than Chaftan.

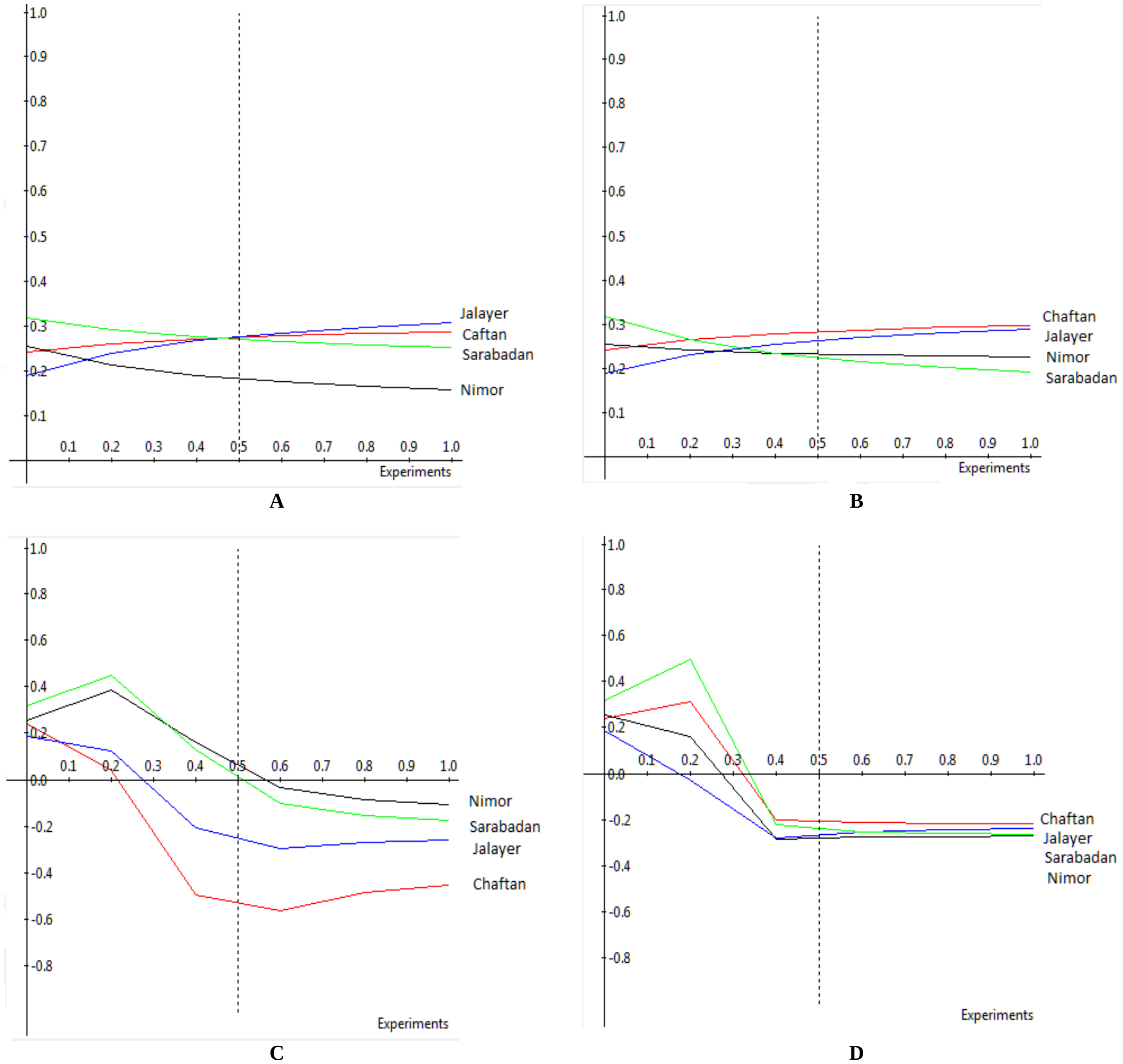

Figure 2. Sensitivity analysis of: A. Benefit, B. Opportunity, C. Cost, D. Risk

Risk

The risk sensitivity analysis, illustrated in Figure 2.D, indicates that the greatest risk is achieved through the alternative Nimor whereas the weight of risk is less than 0.4; it is clear that the priority of Jalayer will be more than Nimor.

Discussion

Forest plantations is one of the important activities in sustainable forest management (Tambe et al. 2011), especially in degraded forest areas or where it suffers from lack of natural regeneration like semi-arid vegetative region in central of Iran. Such activities may result in increasing of habitat diversity, richness and protection of soil and water in the large scale. The tree species that are used in forest plantation are also an important factor and extremely depends on its environmental conditions. Where non-native varieties or species are grown, few of the native fauna are adapted to exploit these and further biodiversity loss occurs with passing time. To establish forest plantation, several factors must be considered such as environmental, physiographic features and social-economic conditions, simultaneously. Some of these parameters are tangible and the others are intangible, so their comparison is impossible at the same time. Therefore, we must use conceptual techniques for making decision in such stochastic conditions. Our experiences show that the network model has a good potential to derive priorities for tangible and intangible criteria under stochastic conditions. In current study, we developed an ANP model to select the most suitable site for forestation with Almond. In ANP, separate evaluation of alternatives with respect to each merit in their respective subnet-work, and rating the BOCR based on strategic sub-criteria that are derived from three main strategic criteria (main goals), helps the manager or any decision maker arrive at the suitable conclusion, supported by the collected data.

This paper moves us one step closer to the usage of ANP in real-world situations and forestation. Evaluation of the strategic criteria shows that environmental condition is a reliable factor in forest plantation (0.73), mostly physical soil properties (0.54). These results are in line with the results of (Alvani Nejad 1999; Kathleen 2003) in arid and semi-arid plantations. The results indicate that Risk and Cost subnets at the BOCR model, are more important in making decision for forestation, compared to Benefits and Opportunity, respectively. Based on sensitive analyses it is clear that, if the cost of forestation increases by passing time, the risks of it may increase and implement of forestation plan won't be accurate, economically. According to sensitivity analysis of Benefit Jalayer (site D) is the most suitable site for forest plantation. This means that if forest management is based on the most benefits of plantation, this region will provide maximum benefits. There are several reasons for this selection such as minimum costs of seedlings transportation (Jalayer (site D) has minimum distance to nursery), the lower potential evapotranspiration rate and higher precipitation amount (Table 6). Physiographic features and topography parameters have an important role in relationship to plant and soil. Soil and water conservation may be difficult and sometimes impossible for plant growing in higher slope terrains. If slope gradient increases, the number of seedlings, floor cover and biodiversity index will decrease (Pakparvar et al. 2008). Also, two of the four candidate sites (B & C) have least biodiversity and lower canopy cover than others due to being close to timberline.

Sensitivity analysis of Risk merit indicates that Nimor (site C) has the most Risk among the other alternatives. The reasons for this issue may be associated with higher annual temperature, lower precipitation, steeper slope, and more fire occurrence, pests and insects invasion and overgrazing in this region. Our results indicate that Risk and Cost indices are more important in making decision, compared to Benefits and Opportunity indices in forest plantation, specifically in arid regions. The results of ranking alternatives according to Opportunity and Cost merits confirm that Sarabadan (site B) has a good potential ability to provide mentioned issues in plantation with Almond species. Our results show that ANP is a successful decision tool for making decisions strategy in forestation. However; the field experiment should be done to clarify the result in future researches. It is difficult to judge if a decision maker needs to be concerned about which alternative to choose, due to increasing the differences in cumulative priorities or different ranks when using different MCA approaches. The process of evaluation and decision-making may be more important in some cases than the ranking results. We may also have to accept that each method shapes the preferences of decision maker (s) in a particular way (Lootsma and Schuijt 1997).

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