Int. J. Hum. Capital Urban Manage., 2(3): 189-202, Summer 2017
DOI: 10.22034/ijhcum.2017.02.03.003

ORIGINAL RESEARCH PAPER

Application of multi-criteria decision making to estimate the potential of flooding

*M. Eshghizadeh**

Department of Agricultural and Natural Resources, Faculty of Science, University of Gonabad, Gonabad, Iran

Received 4 April 2017; revised 9 May 2017; accepted 26 June 2017; available online 1 July 2017

ABSTRACT: Integrating a geographic information system and multi-criteria decision making methods have been lead to provide spatial multi-criteria decision making methods. In this study, the spatial potential of flooding was determined based on analytic network process and analytic hierarchy process. At first, six factors of flooding were determined as criteria. The criteria were the slope, hill-slope aspect, curve number, snow, and rainfall on snow and land use. Also, 25 sub-criteria were determined for them. Then, the criteria and their sub-criteria were weighted based on the analytic network process and the analytic hierarchy process methods. In the next stage, were integrated the weights of the criteria and sub-criteria on their layers in the IlWIS 3 and were calculated the relative weighted average of flooding as the spatial potential of flooding. The results showed that analytic network process and the analytic hierarchy process methods have a high capability to estimate the potential of flooding. The analytic hierarchy process method had calculated the relative weighted average of flooding in the control and sample sub-catchments 26 and 23 percent, respectively. Also, the analytic network process method had calculated it 25 and 21 percent. Based on the results, the both methods have the same capability to estimate the potential of flooding, but for comparison of sub-catchments, the analytic hierarchy process method is recommended, whereas the analytic network process method is recommended for studying one sub-catchment and spatial variations of flooding. Moreover, the analytic hierarchy process method is simpler than analytic network process method to estimate the potential of flooding.

KEYWORDS: *Analytic hierarchy process (AHP); Analytic network process (ANP); Flooding; Geographic information system (GIS); Spatial multi-criteria decision making (SMCDM)*

INTRODUCTION

There are few places on the earth where people need not be concerned about flooding. Any place where rain falls is vulnerable, although rain is not the only impetus for the flood. The flood is a natural occurrence where an area that is usually dry, suddenly or slowly gets submerged under water. Floods occur in all types of river and stream channels in humid to arid climates.

Flooding is one of the main problems in many countries. Determining the potential of the flooding is necessary for prevention, control, and flood inhibiting projects. One of the newest approaches is using the spatial multi-criteria decision making (SMCDM) methods to estimate the spatial potential of flooding. Integrating the

---

*Corresponding Author Email: *m.eshghizadeh@gonabad.ac.ir*
Tel.: +98 515 722 9802; Fax:+98 515 725 2969

geographical information systems (GIS) and multi-criteria decision making (MCDM) methods can lead to the SMCDM methods (Malczewski, 1999).

The analytic hierarchy process (AHP) and analytic network process (ANP) are two methods of the MCDM. The AHP is a mathematical model which was developed for solving the multi-criteria decision making by Saaty in 1977. This method can consider both quantitative and qualitative criteria (Taslicali and Ercan, 2006).

In general, the AHP model is composed of goal, criteria, sub-criteria, and alternatives (Buyukyazc and Sucu, 2003). Saaty developed the AHP and introduced the ANP. In this method, the term of the cluster was replaced by levels (Saaty, 1999). The ANP is a network of criteria, sub-criteria, and alternatives that called elements and gathered in the clusters. The elements and clusters can have to be linked together (Buyukyazc and Sucu, 2003; Garcia-Melon *et al.*, 2008). The ANP is composed of two basic parts: the first control hierarchy that consists relationship between goal, criteria, and sub-criteria. These are effective on the internal communication network. The second is network connections that include dependencies between the elements and clusters (Saaty, 1999). Recently, many types of research have been done in the field of environmental management based on the MCDM methods.

In one study in Iran, AHP was used for sediment yield problems, in watershed management and was prioritized and determined the most important factors on sediment yield in a semi-arid region of Iran (Eshghizadeh *et al.*, 2015). Recently, the AHP-Fuzzy method was used to evaluate range suitability of Bagheran Birjand watershed. The results showed that AHP method is one of the most methods to prioritizing and weighting the criteria (Rouhi-Moghaddam *et al.*, 2017). The ANP was used to estimate the potential of flooding in Kakhk paired catchment in Iran (Eshghizadeh and Talebi, 2014).

The results showed that the ANP can be used to estimate the potential of flooding and it is able to display the variations of the potential of flooding in the area. Moreover, the GIS and AHP were integrated to determine the most suitable site for constructing the underground dam on qanat (Eshghizadeh and Noura, 2013). The ANP method was used to evaluate the landslide hazard susceptibility in Eastern Nepal (Neaupane and Piantanakulchai, 2006). The potential of the ANP method was shown for modeling a complex physical process like soil erosion (Nekhay *et al.*, 2009). The groundwater artificial recharge suitable area was determined by use of the GIS and AHP method in the Silakhor, Borujerd of Iran rangelands and was used of the AHP to determine the weights of layers (Mehrabi *et al.*, 2012).

The flood is the main challenge for areas, developing at various spatial scales. Therefore, the creation of flooding maps is the main key to flood risk management. In areas where there are not enough data for analyzing the potential of flooding, using multi-criteria decision making methods can be useful. The main purpose of the study was determining the best method of ANP and AHP to estimate the spatial potential of flooding in sub-catchment scale.

MATERIALS AND METHODS

Study area

The research implemented in Kakhk Shahid Noori watershed in Gonabad County of the Khorasan-e Razavi Province, the northeast of Iran (coordinates 34°4’34", N; 58°35’37", E). It included control and sample sub-catchments. The sub-catchments were almost similar in physiography, climate, geology, geomorphology, soil and land cover. Measurements of flooding, runoff, and erosion in two sub-catchments have carried out since 1998.

The area of the sample sub-catchment is 106.5 hectares and watershed operations have been implemented on it. The area of the control sub-catchment is 110.6 hectares and no types of watershed operations were performed on it (Eshghizadeh *et al.*, 2016). Table 1 shows the physical characteristics of the control and sample sub-catchments. Fig. 1 shows the study area.

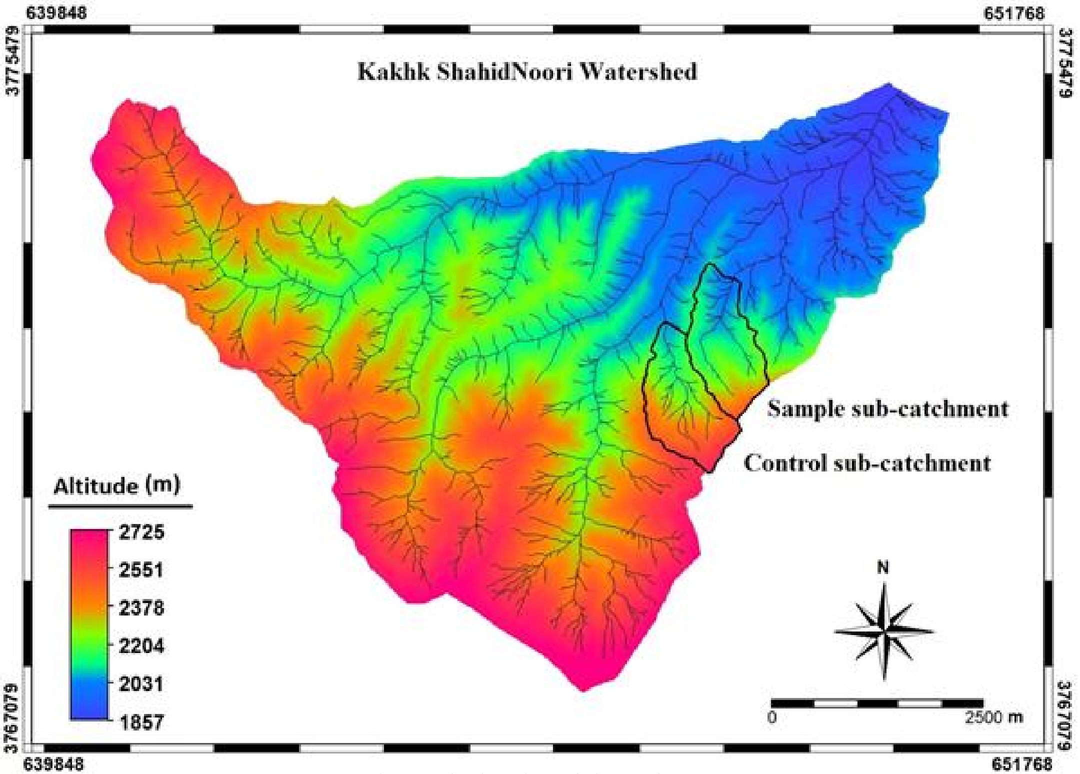

Fig. 1: The location of the study area

Table 1: Physical characteristic of the control and sample sub-catchments (Eshghizadeh *et al*., 2016)

Characteristic	sub-catchments	
	Sample	Control
Area (km^2)	1.065	1.106
Perimeter (km)	4.600	4.800
Maximum altitude (m.a.s.l)	2521	2623
Minimum altitude (m.a.s.l)	1997	2048
Mean altitude (m m.a.s.l)	2171	2325
Weighted average slope (%)	52.90	55.40
Main channel length (km)	1.800	1.800
Average annual precipitation (mm)	243	
Distribution of rainfall	October, November, December, January, February, March, April, May, June	
Mean annual temperature (ºc)	14.2	
Dominant geological formations	Shemshak Js, Js vb	
Annual evaporation (mm)	1645	
Climate	Semi-arid	
Soil Texture	Loamy sand, loamy	
Dominant vegetation	Lactoca orientalis, Poa bulbosa, Seratulla orientalis, Ferula ovina- Gundelia tourneforti, Artemesia sp, Astragalus sp	

Determining the criteria and sub-criteria

The main criteria and sub-criteria on flooding in the study area were determined by Eshghizadeh and Talebi (2014). The criteria were included slope, hill-slope aspect, curve number (CN), snow, rainfall on snow and land use factors. Also, the determined sub-criteria was shown in Fig. 2.

Weighting the criteria and sub-criteria based on the AHP

The following steps were performed to determine the weight of the criteria and sub-criteria to estimate the potential of flooding based on the AHP.

Step 1: Building the hierarchical model

Fig. 2 shows the hierarchical structure to estimate the spatial potential of flooding based on the AHP.

Step 2: Making the pairwise comparison matrices

At first, the elements were compared two by two and were formed pairwise comparison matrix. In comparative judgment phase, the elements of one level of the hierarchy are compared to the strength of their influence on an element of the next higher level. A scale was developed to make a comparison by Thomas Saaty that was shown in Table 2 (Saaty and Vargas, 2006). Then, the matrices were formed.

In the next stage, the relative weights of the elements were calculated. The relationship between the criteria and sub-criteria was shown in Fig. 3. The primary unweighted matrix according to Fig. 3 was presented in Table 3.

Table 2: Saaty's fundamental scale (Saaty and Vargas, 2006)

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Table 3: Structure of the primary unweighted matrix in the hierarchical model to estimate the spatial potential of flooding based on the AHP

	Goal	Criteria	Sub-criteria
Goal	0	0	0
Criteria	W_{21}	0	0
Sub-criteria	0	W_{32}	0

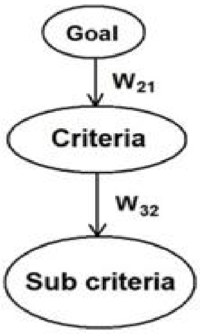

Fig. 3: The relationship between criteria and sub-criteria based on the AHP

Step 3: Calculating the importance of criteria and sub-criteria

The importance of the criteria and sub-criteria were calculated by the pairwise comparisons according to the scale of Table 2. For this purpose, the pairwise comparisons were performed by 30 academic experts and specialists in watershed management.

Then, the matrices of the pairwise comparisons were entered into the Expert choice (EC) program. The EC program presents a graph of the weights (W_{21}, W_{32}) and shows their inconsistency. In general, if the inconsistency rate is less than 0.1, the inconsistency is acceptable. If more than 0.1 should be revised in the judgments (Saaty and Vargas, 2006).

Finally, the relative importance of the criteria ($W_{criteria}$) and sub-criteria ($W_{sub\text{-}criteria}$) were calculated by determining the W_{21} and W_{32} vectors.

Weighting the criteria and sub-criteria based on the ANP

The following steps were performed to determine the weight of the criteria and sub-criteria to estimate the spatial potential of flooding based on the analytic network process.

Step 1: Building the model and convert subject to the network structure

A network structure of the subject was created in the Superdicision program. The network was created of the criteria and sub-criteria. The criteria and sub-criteria are called elements in the ANP. The elements are gathered in clusters and each cluster is called a node. The elements within a cluster are associated with one or more elements of the other clusters. The communications are called outer dependence and are displayed by an arrow. It is also possible that the

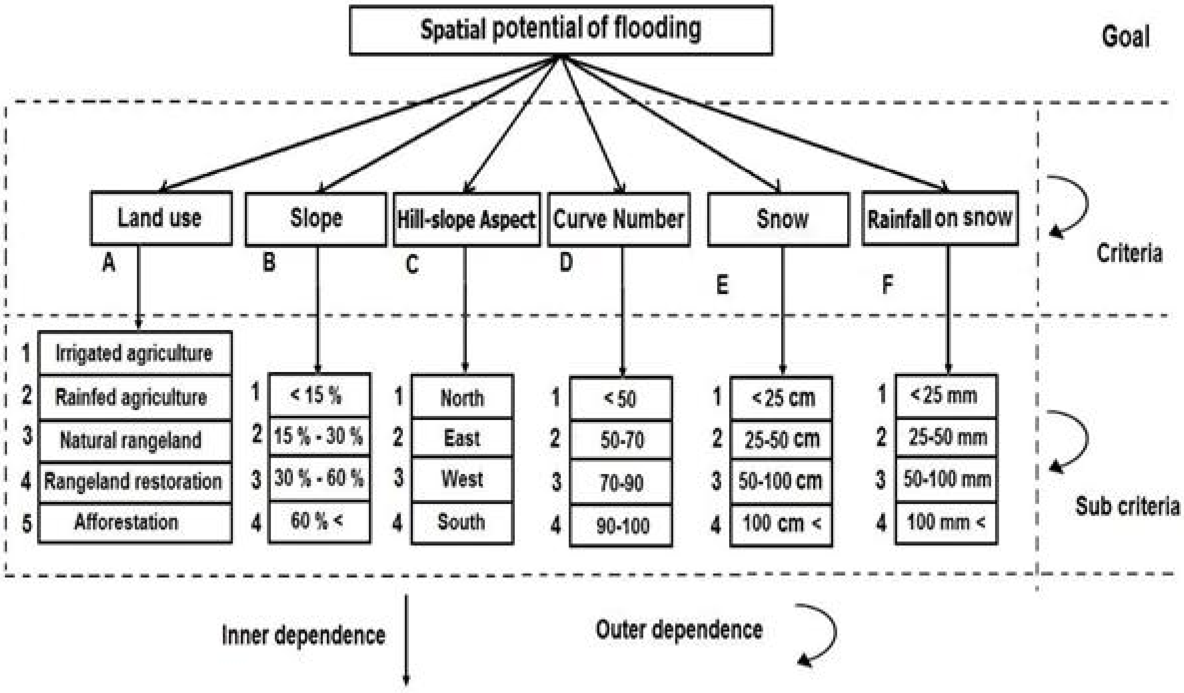

Fig. 4: The network models of the criteria and sub-criteria to estimate the spatial potential of flooding based on the ANP

Table 4: Structure of the primary unweighted matrix in the network model to estimate the spatial potential of flooding based on the ANP

	Goal	Criteria	Sub-criteria
Goal	0	0	0
Criteria	W_{21}	W_{22}	0
Sub-criteria	0	W_{32}	W_{33}

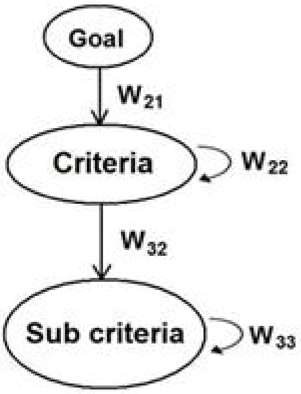

Fig. 5: The relationship between criteria and sub-criteria based on the ANP

elements within a cluster have an internal interaction between themselves. The internal interaction with the network structure are known as inner dependence and are displayed by an arc connected to the cluster (Buyukyazc and Sucu, 2003). The network model was shown in Fig. 4. Also, the relationship between the criteria was shown in Fig. 5. The overall structure of the primary unweighted supermatrix, according to Fig. 5 was summarized in Table 4.

Step 2: Making the pairwise comparison matrices

At this stage, the comparative matrices were formed for the criteria and sub-criteria and their dependence. For this purpose, the pairwise comparisons were performed by 30 academic experts and specialists in watershed management.

Pairwise comparisons of the criteria (W_{21} matrix)

The pairwise comparisons of the criteria were performed based on Table 2. Then, the matrix of W_{21} was formed.

Pairwise comparisons of the inner dependences for criteria (W_{22} matrix)

Interdependencies between the criteria have been shown in Table 5. The interdependencies created based on the opinions of experts and specialists in watershed management. Then, the pairwise comparisons of the inner dependences were performed for the criteria based on the scale of Table 2. The matrix of W_{22} was formed based on the rating obtained through the questionnaire.

Pairwise comparisons of the sub-criteria (W_{32} matrix)

The pairwise comparisons of the sub-criteria were performed based on Table 2 and the matrix of W_{32} was formed.

Pairwise comparisons of the inner dependences for the sub-criteria (W_{33} matrix)

Interdependencies were created based on the opinions of experts and specialists in watershed management. Then, the pairwise comparisons of the inner dependences for the sub-criteria were performed based on Table 2. Based on the rating obtained through the questionnaire, the matrix of W_{33} was formed.

Step 3: Calculating the importance of the criteria and sub-criteria

After calculating the matrices of the pairwise comparisons (W_{21}, W_{22}, W_{32}, W_{33}), the matrices entered into the Superdicision program and controlled their inconsistency. Then, the unweighted supermatrix was created by replacement the matrices in the primary unweighted supermatrix (Table 4). In the next stage, the weighted supermatrix was calculated by multiplying

Table 5: Inner dependences for criteria in the network model to estimate the spatial potential of flooding based on the ANP

Criteria	Land use	Slope	Hill-slope Aspect	Curve Number	Snow	Rainfall on snow
Land use				*	*	
Slope	*			*	*	
Hill-slope Aspect					*	
Curve number						
Snow						
Rainfall on snow	*			*		

the unweighted supermatrix by the cluster matrix. Therefore, the matrix was randomized (Saaty, 1996). The relative importance of the criteria ($W_{criteria}$) and sub-criteria ($W_{sub\text{-}criteria}$) was calculated of the normalized matrix.

Integrating the weighted layers

The final weights of the sub-criteria in the AHP and ANP methods were calculated via multiplying the relative importance of criteria ($W_{criteria}$) by the relative importance of their sub-criteria ($W_{sub\text{-}criteria}$). Then, the final weights of sub-criteria were imported on the raster layers of sub-criteria in the ILWIS 3. Finally, the weighted layers were summed and were created a map that shows the potential of flooding for each sub-catchment.

RESULTS AND DISCUSSION

Weighting of the criteria and sub-criteria based on the AHP

The results showed that the criterion of the rainfall on snow had been the most relative importance (0.364) for the flooding, whereas the hill-slope aspect had been the least (0.024). Table 6 shows the special vector of W_{21} and the relative importance of the criteria ($W_{criteria}$) based on the AHP method. This result showed that the main factor for flooding is the amount of rainfall on snow. Rainfall for start a flood is a trigger factor. Therefore, that is a dominant factor for it. In runoff generation, a dominant factor determines the quantity of the effect of land cover on runoff (Eshghizadeh *et al*., 2016).

The weight of each sub-criteria were calculated in the EC program. Table 7 shows W_{32} matrix and the relative importance of the sub-criteria ($W_{sub\text{-}criteria}$) based on the AHP.

Weighting of the criteria and sub-criteria based on the ANP

The pairwise comparisons of the criteria showed that the curve number had been the most relative importance (0.342), whereas the hill-slope aspect had been the least (0.018). Table 8 shows the outer dependence matrix (W_{21}), the inner dependence matrix (W_{22}) and the relative importance of the criteria ($W_{criteria}$) based on the ANP. The results of the outer dependences matrix showed that the curve numbers between 90 and 100 are the most important sub-criteria for the flooding (0.612), but the irrigated agriculture is the least. In the inner dependences matrix (W_{33}) showed that the curve numbers between 90 and 100 on land use with rain-fed agriculture have the highest relative importance (0.800) for the flooding. Table 9 shows the outer dependences matrix (W_{32}) and the relative importance of the sub-criteria ($W_{sub\text{-}criteria}$) based on the ANP. Table 10 shows the inner dependences matrix (W_{33}) and the relative importance of the sub-criteria ($W_{sub\text{-}criteria}$) based on the ANP.

The final weights of the sub-criteria based on the AHP method showed that the rainfall more than 100 mm is the most important sub-criterion (0.215), whereas the north hill-slope aspect is the least (0.002). Based on the ANP method the curve numbers between 90 and 100 are the most important sub-criteria (0.209), but the north hill-slope aspect is the least sub-criterion (0.001). Table 11 shows the final weights of the sub-criteria based on the AHP and ANP methods.

Based on the results, the ANP method showed that the curve number is a dominant factor in the potential of flooding. The result of Eshghizadeh *et al.* (2015) showed that hydrology is the most important factor in runoff generation. The curve number is a sub-criteria of the hydrology. Also, they obtained the same result for the hill-slope aspect. Because of the inner dependences, in ANP the relation between criteria is more complicated than AHP (Wolfslehner *et al*., 2005).

Therefore, the curve number affected by the rainfall and is a dominant factor for flooding. The results showed that ANP has a more compatibility with natural resources studies.

Table 6: The special vector of W_{21} and relative importance of criteria ($W_{criteria}$) based on the AHP

	Criteria	Special vector of W_{21}	Relative importance of criteria ($W_{criteria}$)
A	Land use	0.062	0.062
B	Slope	0.210	0.210
C	Hill-slope aspect	0.024	0.024
D	Curve number	0.239	0.239
E	Snow	0.100	0.100
F	Rainfall on snow	0.364	0.364

Table 7: The W_{32} matrix and relative importance of the sub-criteria ($W_{sub-criteria}$) in AHP

Sub-criteria		Land use	Slope	Hill-slope aspect	Curve Number	Snow	Rainfall on snow	$W_{sub-criteria}$
		A	B	C	D	E	F	
A1	Irrigated agriculture	0.064	0.000	0.000	0.000	0.000	0.000	0.064
A2	Rainfed agriculture	0.510	0.000	0.000	0.000	0.000	0.000	0.510
A3	Natural rangeland	0.243	0.000	0.000	0.000	0.000	0.000	0.243
A4	Rangeland restoration	0.079	0.000	0.000	0.000	0.000	0.000	0.079
A5	Afforestation	0.104	0.000	0.000	0.000	0.000	0.000	0.104
B1	<15%	0.000	0.047	0.000	0.000	0.000	0.000	0.047
B2	15-30%	0.000	0.105	0.000	0.000	0.000	0.000	0.105
B3	30-60%	0.000	0.257	0.000	0.000	0.000	0.000	0.257
B4	60%<	0.000	0.591	0.000	0.000	0.000	0.000	0.591
C1	North	0.000	0.000	0.078	0.000	0.000	0.000	0.078
C2	East	0.000	0.000	0.125	0.000	0.000	0.000	0.125
C3	West	0.000	0.000	0.492	0.000	0.000	0.000	0.492
C4	South	0.000	0.000	0.306	0.000	0.000	0.000	0.306
D1	CN<50	0.000	0.000	0.000	0.047	0.000	0.000	0.047
D2	CN 50-70	0.000	0.000	0.000	0.105	0.000	0.000	0.105
D3	CN 70-90	0.000	0.000	0.000	0.257	0.000	0.000	0.257
D4	CN 90-100	0.000	0.000	0.000	0.591	0.000	0.000	0.591
E1	Snow <25 cm	0.000	0.000	0.000	0.000	0.047	0.000	0.047
E2	Snow 25-50 cm	0.000	0.000	0.000	0.000	0.105	0.000	0.105
E3	Snow 50-100 cm	0.000	0.000	0.000	0.000	0.257	0.000	0.257
E4	Snow >100 cm	0.000	0.000	0.000	0.000	0.591	0.000	0.591
F1	Rainfall on snow<25 mm	0.000	0.000	0.000	0.000	0.000	0.047	0.047
F2	Rainfall on snow 25-50 mm	0.000	0.000	0.000	0.000	0.000	0.105	0.105
F3	Rainfall on snow 50-100 mm	0.000	0.000	0.000	0.000	0.000	0.257	0.257
F4	Rainfall on snow >100 mm	0.000	0.000	0.000	0.000	0.000	0.591	0.591

Table 8: The outer dependences matrix (W_{21}), the inner dependences matrix (W_{22}) and the relative importance of the criteria ($W_{criteria}$) based on the ANP

	Criteria	W_{21}	W_{22}						$W_{criteria}$
			Land use	Slope	Hill-slope aspect	Curve Number	Snow	Rainfall on snow	
			A	B	C	D	E	F	
A	Land use	0.062	0.000	0.308	0.000	0.000	0.000	0.250	0.102
B	Slope	0.210	0.000	0.000	0.000	0.000	0.000	0.000	0.153
C	Hill-slope aspect	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.018
D	Curve number	0.239	0.857	0.312	0.000	0.000	0.000	0.750	0.342
E	Snow	0.100	0.143	0.380	1.000	0.000	0.000	0.000	0.119
F	Rainfall on snow	0.364	0.000	0.000	0.000	0.000	0.000	0.000	0.266

Table 9: The outer dependences matrix (W_{32}) and the relative importance of the sub-criteria ($W_{sub\text{-}criteria}$) based on the ANP

	Sub-criteria	Land use	Slope	Hill-slope aspect	Curve Number	Snow	Rainfall on snow	$W_{sub\text{-}criteria}$
		A	B	C	D	E	F	
A1	Irrigated agriculture	0.064	0.000	0.000	0.000	0.000	0.000	0.031
A2	Rainfed agriculture	0.510	0.000	0.000	0.000	0.000	0.000	0.504
A3	Natural rangeland	0.243	0.000	0.000	0.000	0.000	0.000	0.258
A4	Rangeland restoration	0.079	0.000	0.000	0.000	0.000	0.000	0.110
A5	Afforestation	0.104	0.000	0.000	0.000	0.000	0.000	0.097
B1	<15%	0.000	0.047	0.000	0.000	0.000	0.000	0.047
B2	15-30%	0.000	0.105	0.000	0.000	0.000	0.000	0.105
B3	30-60%	0.000	0.257	0.000	0.000	0.000	0.000	0.257
B4	60%<	0.000	0.591	0.000	0.000	0.000	0.000	0.591
C1	North	0.000	0.000	0.078	0.000	0.000	0.000	0.078
C2	East	0.000	0.000	0.125	0.000	0.000	0.000	0.125
C3	West	0.000	0.000	0.492	0.000	0.000	0.000	0.492
C4	South	0.000	0.000	0.305	0.000	0.000	0.000	0.305
D1	CN<50	0.000	0.000	0.000	0.047	0.000	0.000	0.037
D2	CN 50-70	0.000	0.000	0.000	0.105	0.000	0.000	0.096
D3	CN 70-90	0.000	0.000	0.000	0.257	0.000	0.000	0.255
D4	CN 90-100	0.000	0.000	0.000	0.591	0.000	0.000	0.612
E1	Snow <25 cm	0.000	0.000	0.000	0.000	0.047	0.000	0.042
E2	Snow 25-50 cm	0.000	0.000	0.000	0.000	0.105	0.000	0.131
E3	Snow 50-100 cm	0.000	0.000	0.000	0.000	0.257	0.000	0.261
E4	Snow >100 cm	0.000	0.000	0.000	0.000	0.591	0.000	0.566
F1	Rainfall on snow <25 mm	0.000	0.000	0.000	0.000	0.000	0.047	0.047
F2	Rainfall on snow 25-50 mm	0.000	0.000	0.000	0.000	0.000	0.105	0.105
F3	Rainfall on snow 50-100 mm	0.000	0.000	0.000	0.000	0.000	0.257	0.257
F4	Rainfall on snow >100 mm	0.000	0.000	0.000	0.000	0.000	0.591	0.591

Table 10: The inner dependences matrix of the sub-criteria (W_{33}) based on the ANP

	A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	F2
A1	0	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	0	0	0	0	0	0.35	0.29	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18	0.18
A3	0	0	0	0	0	0	0.15	0.04	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.10
A4	0	0	0	0	0	0	0.07	0.03	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05
A5	0	0	0	0	0	0	0.07	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05
B1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D1	0.33	0	0	0	0	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.03
D2	0.67	0	0.09	0.07	0.04	0.43	0.10	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.06
D3	0	0.2	0.25	0.18	0.10	0	0.31	0.09	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.17
D4	0	0.8	0.65	0.43	0.30	0	0	0.21	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0.36	0.36
E1	0	0	0	0.09	0	0	0	0	0	0.05	0.05	0.05	0.05	0	0	0	0	0	0	0	0	0	0
E2	0	0	0	0.22	0.11	0	0	0.08	0.07	0.10	0.10	0.10	0.10	0	0	0	0	0	0	0	0	0	0
E3	0	0	0	0	0.18	0	0	0.15	0.15	0.26	0.26	0.26	0.26	0	0	0	0	0	0	0	0	0	0
E4	0	0	0	0	0.27	0	0	0.26	0.29	0.59	0.59	0.59	0.59	0	0	0	0	0	0	0	0	0	0
F1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 11: The final weights of the sub-criteria based on the AHP and ANP methods to estimate the potential of flooding

Criteria	sub-criteria	AHP			ANP		
		$W_{criteria}$	$W_{sub\text{-}criteria}$	W_{AHP}	$W_{criteria}$	$W_{sub\text{-}criteria}$	W_{ANP}
(A) Land use	Irrigated agriculture	0.062	0.064	0.004	0.102	0.031	0.003
	Rainfed agriculture		0.510	0.032		0.504	0.051
	Natural rangeland		0.243	0.015		0.258	0.026
	Rangeland restoration		0.079	0.005		0.110	0.011
	Afforestation		0.104	0.006		0.097	0.010
(B) Slope	<15%	0.210	0.047	0.010	0.153	0.047	0.007
	15-30%		0.105	0.022		0.105	0.016
	30-60%		0.257	0.054		0.257	0.039
	60%<		0.591	0.124		0.591	0.090
(C) Hill-slope Aspect	North	0.024	0.078	0.002	0.018	0.078	0.001
	East		0.125	0.003		0.125	0.002
	West		0.492	0.012		0.492	0.009
	South		0.305	0.007		0.305	0.005
(D) Curve Number	CN<50	0.239	0.047	0.011	0.342	0.037	0.013
	CN 50-70		0.105	0.025		0.096	0.033
	CN 70-90		0.257	0.062		0.255	0.087
	CN 90-100		0.591	0.141		0.612	0.209
(E) Snow	Snow <25 cm	0.100	0.047	0.005	0.119	0.042	0.005
	Snow 25-50 cm		0.105	0.011		0.131	0.016
	Snow 50-100 cm		0.257	0.026		0.261	0.031
	Snow >100 cm		0.591	0.059		0.566	0.067
(F) Rainfall on snow	Rainfall on snow <25 mm	0.364	0.047	0.017	0.266	0.047	0.012
	Rainfall on snow 25-50 mm		0.105	0.038		0.105	0.028
	Rainfall on snow 50-100 mm		0.257	0.094		0.257	0.068
	Rainfall on snow >100 mm		0.591	0.215		0.591	0.157

The spatial potential of flooding based on the AHP and ANP methods

The results showed that both methods can show the potential of flooding variations in catchment scale. The relative weight of flooding potential shows the maximum and minimum danger of flooding in the area. Therefore, the relative weighted average of flooding can be used for camper and rank the flooding of the area. The AHP method calculated the relative weighted average of flooding in the Control and Sample sub-catchments 26 and 23 percent, respectively. Also, the ANP method calculated it 25 and 21 percent. Table 12 shows the potential of flooding in the Control and Sample sub-catchments based on the AHP and ANP methods. In both methods, the potential of flooding in the Control sub-catchment is more than Sample sub-catchment. Recorded data in hydrometric stations in the Control and Sample sub-catchments confirmed it. During 2008 to 2016 years, only 6 floods were recorded in the Sample sub-catchment, while in the Control sub-catchment 12 floods have been recorded. The both methods can account a minimum and maximum amount potential of flooding in the Control and Sample sub-catchments. Figs. 6a and 6b show the potential of flooding in the Control and Sample sub-catchments based on the AHP and ANP methods. The AHP method shows a higher potential for flooding in the both sub-catchments than ANP method.

Based on the results, the AHP and ANP methods have the same ability to estimate the potential of flooding. The result of Eshghizadeh *et al*. (2015) and Eshghizadeh and Talebi (2014) showed that AHP and ANP can use in the natural resources studies. Also, in the other studies were shown that both methods were suitable to selecting the best sites, but the ANP method is better than AHP (Hossenali *et al*., 2010). Wolfslehner (2005) has stated that ANP is closer to the real world. In the real world the relationships are usually more complex than hierarchical mode and there are plenty of internal dependencies. But, that is a more complex method than AHP. In addition, ANP is more powerful than AHP in the decision environment with uncertainty and dynamics (Taslicali and Ercan, 2006).

In comparing the two methods, it can be concluded that the ANP method is a more comprehensive method than AHP method. Furthermore, the inventor of them is the same person and the ANP method has been suggested after the AHP method. Of course, this does not mean that the AHP method is outdated or ANP can be replaced in all cases (Saaty, 2001).

Table 12: The potential of flooding in the Control and Sample sub-catchments based on the AHP and ANP methods

	AHP		ANP	
	Control Sub-catchment	Sample Sub-catchment	Control Sub-catchment	Sample Sub-catchment
Mean potential of flooding	0.260	0.230	0.250	0.210
Maximum potential of flooding	0.366	0.356	0.347	0.332
Minimum potential of flooding	0.119	0.064	0.091	0.058

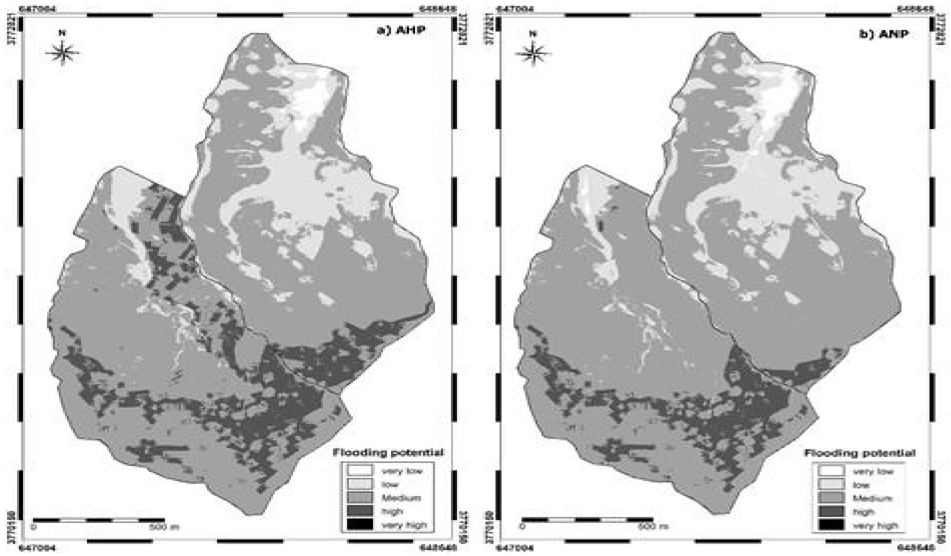

Fig. 6: The potential of flooding in the Control and Sample sub-catchments based on a)AHP b)ANP

CONCLUSION

This research showed that the AHP and ANP methods are capable to estimate the potential of flooding. These methods can use to the natural resources and environmental studies. Descriptive studies in the natural resources and watershed management had used in many models such as pacific southwest inter-agency committee (PSIAC), Modified PSIAC (MPSIAC), Erosion potential method (EPM), FAO, Bureau of land management (BLM). Therefore, the AHP and ANP methods can use as new models for flooding studies.

A weighted map of flooding potential shows the maximum and minimum danger of flooding in the area. Also, the relative weighted average of flooding can be calculated to compare and ranking sub-catchments, catchments, basins, and watersheds. The research showed that the ability of the AHP and ANP methods to estimate the potential of flooding is equal in catchment scale. The difference between ANP and AHP in the research is to consider outer and inner dependences by the ANP method, whereas the final result is the same. Therefore, for comparison of sub-catchments the AHP method is recommended, but for studying one sub-catchment and spatial variations on it the ANP method is recommended. Because the ANP method considers the interconnections and interactions of criteria and sub-criteria, this more compatible with the nature of watershed and results can be more reliable. However, complex relationships in the watershed and natural resources make it difficult.

ACKNOWLEDGEMENT

The authors would like to thank Forests, Range and Watershed Management Organization of Iran and experts of General Department of Natural Resources and Watershed Management in Khorasan-e Razave Province and Gonabad County.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript.

REFERENCES

Buyukyazc, M.; Sucu, M., (2003). The analytic hierarchy process and analytic network process. Hacet J. Math. Stat., 32: 65-73 **(9 pages)**.

Eshghizadeh, M.; Fazelpoor, M.R.; Ekhtesasi. M.R., (2015). Analysis of Analytical Hierarchy Process Method to Prioritize and Determine the Most Important Factors Influencing Sediment Yield in Semi-arid Region of Iran. Int. J. Farm Alli. Sci, 4(1): 37-49 **(13 pages)**.

Eshghizadeh, M.; Noura, N., (2013). Determine the suitable site to build underground dams for the recharge and discharge control of Qanats by using Analytical Hierarchy Process (AHP). J. Water Soil Conserv., 17(3): 45-64 **(20 pages)**. (In Persian)

Eshghizadeh, M.; Talebi, A., (2014). The efficiency of Analytic Network Process to estimate the flooding potential watershed (Case study: Kakhk Paired Watershed of Gonabad). Watershed Manage. Res., 103: 61-73 **(13 pages)**. (In Persian)

Eshghizadeh, M.; Talebi, A.; Dastorani, M.T.; Azimzadeh, H.R., (2016). Effect of natural land covers on runoff and soil loss at the hill-slope scale. Global J. Environ. Sci. Manage., 2(2): 125-134 **(10 pages)**.

Garcia-Melon, M.; Ferris-Onate, J.; Aznar-Bellver, J.; Aragones-Beltran, P.; Poveda-Bautista, R., (2008). Farmland appraisal based on the analytic network process. J. Global Optim., 42(2): 143-155 **(13 pages)**.

Hossenali, F.; Malek, M.R.; Silavi, T., (2010). Analysis of multi-criteria decision-making methods AHP and ANP to determine the suitable sites for pedestrian bridge construction. Eng. J. Geospatial Inf. Technol., 1(1): 31-41 **(11 pages)**. (In Persian)

Malczewski, J., (1999). GIS and multicriteria decision analysis. John Wiley & Sons.

Mehrabi, H.R.; Zienivand, H.; Hadidi, M., (2012). Site Selection for Groundwater Artificial Recharge in Silakhor Rangelands Using GIS Technique. J. Rangeland Sci., 2(4): 687-695 **(9 pages)**.

Neaupane, K.M.; Piantanakulchai, M., (2006). Analytic network process model for landslide hazard zonation. Eng. Geol., 85(3): 281–294 **(14 pages)**.

Nekhay, O.; Arriaza, M.; Boerboom, L., (2009). Evaluation of soil erosion risk using Analytic Network Process and GIS: A case study from Spanish mountain olive plantations. J. Environ. Manage., 90(10): 3091–3104 **(14 pages)**.

Rouhi-Moghaddam, E.; Joloro, H.; Memarian, H., (2017). Determining Range Suitability Using Fuzzy and Hierarchical Method (Case Study: Bagheran Birjand Watershed, South Khorasan Province, Iran). J. Rangeland Sci., 7(3): 232-241 **(10 pages)**.

Saaty, T.L., (1996). Decision making with dependence and feedback: The analytic network process (Vol. 4922). RWS publications, Pittsburgh.

Saaty, T.L., (1999). Fundamentals of the analytic network process. Paper presented at the ISAHP, Kobe, Japan. 1-14 (**14 pages**).

Saaty, T.L., (2001). The analytic network process: decision making with dependence and feedback. RWS Publications, Pittsburgh, USA.

Saaty, T.L.; Vargas, L.G., (2006). Decision making with the analytic network process: economic, political, social and technological applications with benefits, opportunities, costs and risks. Springer, US.

Taslicali, A. K.; Ercan, S., (2006). The analytic hierarchy and the analytic network processes in multicriteria decision making: A comparative study. Aeronaut. Space Technol,. 2(4): 55-65 **(11 pages)**.

Wolfslehner, B.; Vacik, H.; Lexer, M. J., (2005). Application of the analytic network process in the multi-criteria analysis of sustainable forest management. For. Ecol. Manage., 207(1): 157-170 **(24 pages)**.