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Pedological Criterion Affecting Desertification in Alluvial Fans Using AHP-ELECTRE I Technique (Case Study: Southeast of Rude-Shoor Watershed Area)

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ABSTRACT Pedological criterion affecting desertification in alluvial fans was investigated, for which the map of units was prepared by crossing maps of land use, geology, slope classes and grid layer created by the extension of ET Geo-Wizards in ArcGIS 10.3. Three indices of salinity, erodibility, and permeability of soil were considered and classified. Weights of criteria and consistency ratio were calculated by the AHP method and ELECTRE I method was used to prioritize the options. After creating the weighted super matrix and calculating the concordance and discordance matrix, the difference between dominance and defeat values were calculated. The results showed that the difference in values obtained from AHP-ELECTRE I technique varied from -15 to 16. The alluvial fans were classified into three classes of I, III, and IV from the viewpoint of pedological criterion affecting desertification by using AHP-ELECTRE I technique. Results showed that 71.99% of the area was in the low desertification potential, while 2.19% and 25.82% were in the high and very high desertification potential, respectively.

Keywords: *Erodibility, MCDM, Permeability, Priority, Salinity*

1 INTRODUCTION

Land degradation is defined as desertification and its management is a common measure in watershed management. Various factors, including climatic variations and human activities can lead to the land degradation (UNCCD, 2012). Vegetation is an effective way to prevent soil erosion that besides playing an important role in soil and water conservation (Lieskovský and Kenderessy, 2014), it can increase hydraulic roughness on the slopes and leads to the most resistance in comparing with other surface roughness (Zhao *et al.*, 2015). Sheikh *et al.* (2016) also indicated the role of aspects and slopes on runoff generation and soil erosion.

Land degradation and desertification has been studied from different viewpoints (Feiznia, 1995 and 1997; Kashki, 1997; Tahmasebi, 1998; Rajabi Aleni, 2001; Sarabian, 2002; Metternicht *et al.*, 1996; Esenov *et al.*, 1999; Sadeghiravesh *et al.*, 2014; Xu *et al.*, 2015; Eskandari *et al.*, 2016). Vieira *et al.* (2015) prioritized areas from the viewpoint of

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desertification potential based on various effective factors. Salehpour Jam (2006) investigated desertification potential of kinds of rock units in the Rude-shoor watershed area using the fuzzy logic method, based on which the function of 0.8 introduced. Salehpour Jam and Karimpour Reihan (2016) prioritized desertification potential in the south east of Rude-shoor watershed area into three classes using AHP-TOPSIS technique. Symeonakis *et al.* (2014) estimated the environmental sensitivity through a modified model of ESAI, considering 10 parameters of groundwater quality, soil erosion, demographic and grazing pressure.

Application of MCDM techniques and kinds of attributes affecting land degradation is very important in investigation of desertification potential in alluvial fans that consist of susceptible geological formations to erosion. The AHP is a powerful tool to prioritize alternatives and criteria on the basis of the pairwise comparison of both. The elimination and choice translating reality (ELECTRE) method plays the main role in decision making, as it uses concordance and discordance indices to prioritize alternatives. MCDM techniques have been used to determine desertification potential (Grau *et al.*, 2010; Sepehr *et al.*, 2011; Sepehr and Zucca, 2012; Sadeghiravesh *et al.*, 2014). For instance, Grau *et al.* (2010) used the three models of AHP, ELECTRE, and PROMETHEE to prioritize alternatives in order to manage desertification; Sadeghiravesh *et al.* (2011, 2014) used the analytical hierarchy process to prioritize alternatives and also assessed de-desertification options using AHP-ELECTRE.

The aim of this research was prioritization of desertification potential of alluvial fans from the viewpoint of effects of pedological criterion on desertification potential using AHP-ELECTRE I technique.

2 MATERIALS AND METHODS

2.1 Research area

The Rude-shoor watershed area covers 17000 km^2, 42 and 58 percent of which are plain and highlands, respectively. This area, extending from 48º 30′ to 51º 00′ E and 35º 21′ to 36º 30′ N, is located between two different geological structures of the central Iran and south Alborz that consists of different susceptible geological formations to erosion. The prioritization of desertification potential of the alluvial fans located in the southeast of this area was investigated from the viewpoint of pedological criterion by using AHP-ELECTRE technique (Figure 1).

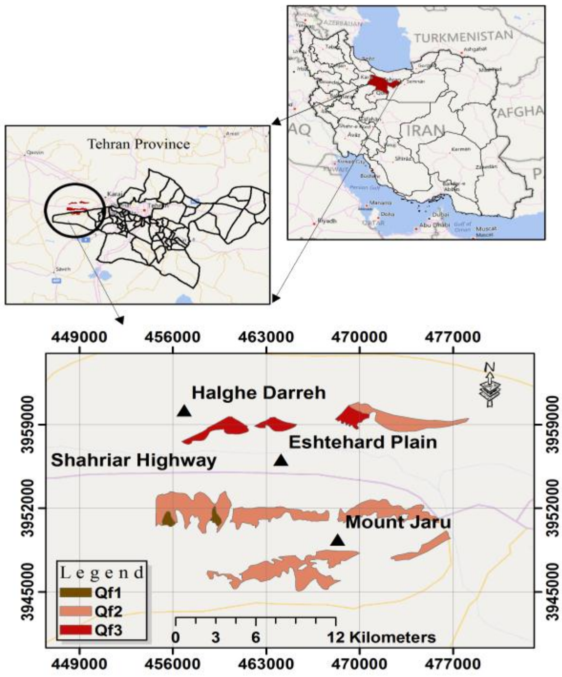

Figure 1 Study area in southeast of Rude-shoor watershed area, Tehran province, IRAN

The map of units was initially prepared by crossing maps of land use, geology, slope classes and grid layer created by the extension of ET Geo-Wizards in ArcGIS 10.3. To create the geological map, sheets of Karaj and Eshtehard were merged and georeferenced

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using ArcGIS 10.3. According to different names of rock units on the Karaj and Eshtehrd sheets, the Karaj sheet was considered as a base map where the denomination of units was done (Figure 2). The lithological characteristics of alluvial fans are illustrated in Table 1.

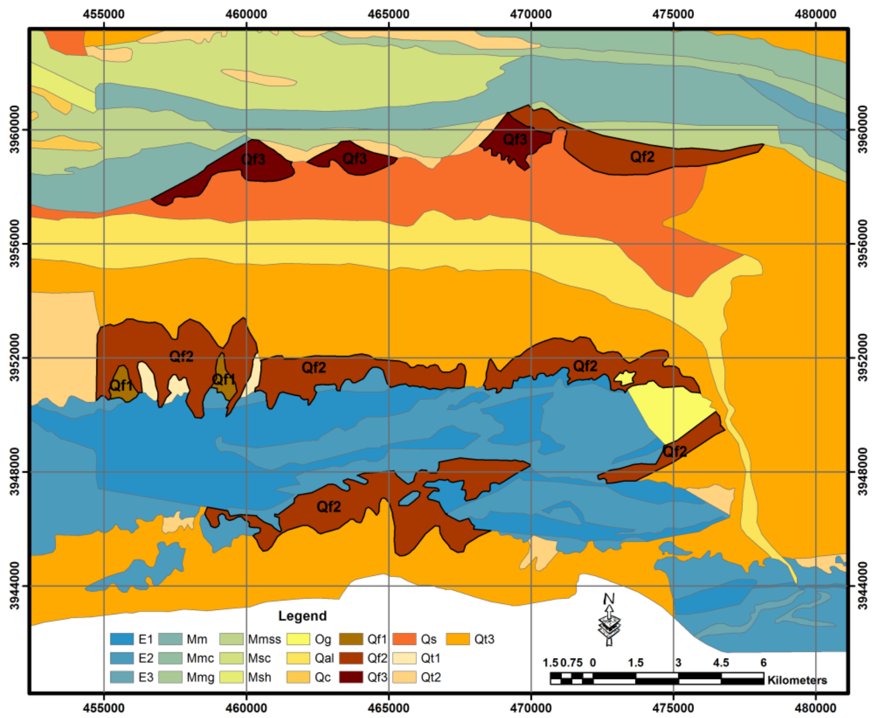

Figure 2 Geological map of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Table 1 Alluvial fan characteristics of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Area (ha)	Lithological characteristics of search area	Sig.	Age		
			epoch	period	era
798.7	Youngest gravel fans	Q_3^f	-	Quaternary	Cenozoic
4773.1	Young gravel fans	Q_2^f	-		
152.2	Old gravel fans	Q_1^f	-		

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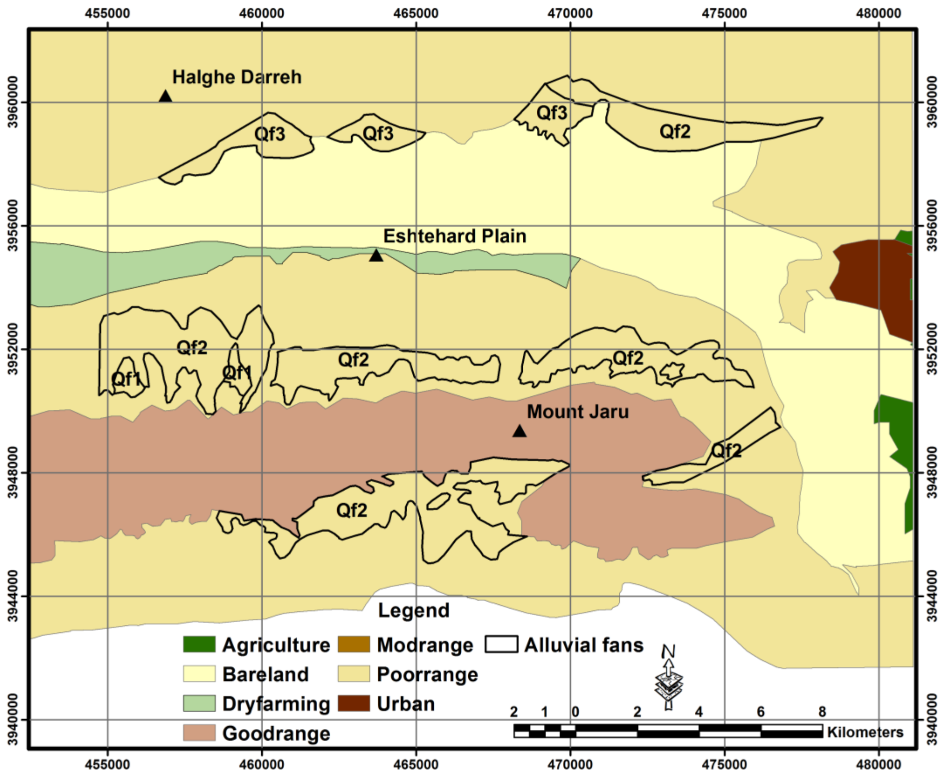

Figure 3 Map of land use of research area, southeast of Rude-shoor watershed, Tehran province, IRAN

After creating the digital elevation model, the map of slope classes was prepared using ArcGIS 10.3. It was classified using slope classes of 1 (0-1%), 2 (1-2%), 3 (2-4%), 4 (4-8%), 5 (8-15%), and 6 (>15%). The land use map of the area, obtained from "Watershed Atlas" (SCWMRI, 2008), was used by monitoring it using Landsat 8, Google Earth, and field studies (Figure 3). After preparing three maps of the slope classes, rock units, and land uses, the map of work units was created using ArcGIS by crossing them. After creating units, grids of 1000 x 1000 m^2 in the research area were created using an extension of ET GeoWizards in ArcGIS to create final units.

The study area was classified into two classes from the viewpoint of resistance coefficient to erosion, according to the soil texture samples, the limits of resistance coefficient to erosion (Feiznia, 1995), and coefficient of erodibility (Morgan, 1986). Classification from the salinity viewpoint was conducted by using the electrical conductivity ($mmho.cm^{-1}$) of 159 saturated mud samples, based on which 4 classes of salinity (low ($0 \leq EC < 2$), moderate ($2 \leq EC < 4$), high ($4 \leq EC < 8$), and very high ($8 \leq EC$) were differentiated (USSL, 1954).

The permeability of the area was based on the coefficients measured according to the Darcy′ s law (Bouwer, 1978) from 174 samples by brazen rings, based on which 4 classes were differentiated: very low (<0.069 cm min^{-1}), low (0.069-1.388 cm min^{-1}), moderate (1.388-6.944 cm min^{-1}), and high (> 6.944 cm min^{-1}).

2.2 Computing weights and prioritization

In order to compute the weights for the different attributes, the following steps were taken using the AHP technique:

(1) Creating a pairwise comparison matrix, in which the comparisons between each

criterion was done based on Satty's scale (giving the preference of criteria depending on the relative importance of them based on the numerical values between 1 and 9). In this research, the questionnaires of the analytical hierarchy process were filled by 24 experts.

(2) Creating the normalized pairwise comparison matrix

(3) Calculating the weights of criteria

(4) Calculating the Consistency Ratio (CR) (Equation 1).

$$CR = \frac{CI}{RI} \quad (1)$$

Where, RI is the Random Inconsistency Index, obtained from Table 2. CI is the Consistency Index, calculated by the Equation 2, after calculating the λ_{max}:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (2)$$

Where, N is the number of alternatives in the decision matrix, and λ_{max} is the maximum eigenvalue calculated by averaging the values of the consistency vector.

In this research, ELECTRE method was used to prioritize the options, the main idea of which was based on concordance and discordance concepts (Roy and Vanderpooten, 1997). The following steps were set for priorities:

Table 2 Random inconsistency indices (Satty, 1980).

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1. 46	1. 49

(1) Creating decision matrix (A):

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{bmatrix} \quad (3)$$

Where, A_{ij} is a pairwise comparison of each alternative in each criteria.

(2) Calculating the normalized value n_{ij} :

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}, \text{ for } i \in I = \{1,2,\cdots,m\} \quad (4)$$

and $j \in J = \{1,2,\cdots,n\}$

(3) Calculating the weighted super matrix v_{ij} :

$$v_{ij} = w_j n_{ij}, \ \forall i \in I, \forall j \in J. \quad (5)$$

Where, w_j is the weight value of the j^{th} criterion, and $\sum_{j=1}^{n} w_j = 1$.

(4) Making sure of the interval sets of concordance and discordance, since the reliability design scheme decision is a multiple-attribute decision with preference information (Pang *et al.*, 2011). For each pair of k and l options, set of criteria (J= {1, 2, …, m}) was classified into two concordance and discordance subsets. In the following formulation, the attribute sets were divided into two different sets of concordance interval set (C_{kl}) and discordance interval set (D_{kl}). The concordance interval set is applied to describe the dominance query if the following condition is satisfied:

$$C_{kl} = \left\{ j \middle| \nu_{kj} \geq \nu_{lj} \right\} \quad (6)$$

On completion of C_{kl}, we obtain the discordance interval set (D_{kl}) using Equation 7.

$$D_{kl} = \left\{ j \middle| \nu_{kj} < \nu_{lj} \right\} = J - C_{kl} \quad (7)$$

(5) Creating concordance matrix. According to the deciders' preference for alternatives, the concordance interval index (C_{kl}) can be obtained using Equation 8:

$$c_{kl} = \sum_{j \in C_{kl}} w_j \quad (8)$$

The concordance index explains the preference of k option to l option and alters from 0 to 1. The concordance interval matrix can be formulated as Equation 9:

$$C = \begin{bmatrix} - & c_{12} & c_{13} & \dots & c_{1m} \\ c_{21} & - & c_{23} & \dots & c_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ c_{m1} & c_{m2} & c_{m3} & \dots & - \end{bmatrix} \quad (9)$$

(6) Creating the discordance matrix. The preference of discontent in a decision of scheme k rather than scheme l. The discordance index can be calculated using Equation 10:

$$d_{kl} = \frac{\max_{j \in D_{kl}} \left| \nu_{kj} - \nu_{lj} \right|}{\max_{j \in J} \left| \nu_{kj} - \nu_{lj} \right|} \quad (10)$$

The discordance interval matrix can be formulated as Equation 11:

$$D = \begin{bmatrix} - & d_{12} & d_{13} & \dots & d_{1m} \\ d_{21} & - & d_{23} & \dots & d_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ d_{m1} & d_{m2} & d_{m3} & \dots & - \end{bmatrix} \quad (11)$$

(7) Determining the concordance index matrix. The concordance index matrix for satisfaction measurement problem can be written as follows:

$$\bar{c} = \sum_{k=1}^{m} \sum_{l=1}^{m} \frac{c_{kl}}{m(m-1)} \quad (12)$$

Where c is the critical value, which can be determined by the average dominance index. Thus, a Boolean matrix (f) is given by Equations 13 and 14:

$$f_{kl} = 1, \text{ if } c_{kl} \geq \bar{c} \quad (13)$$

$$f_{kl} = 0, \text{ if } c_{kl} < \bar{c} \quad (14)$$

(8) Determining the discordance index matrix. On the contrary, the preference of dissatisfaction can be measured by discordance index:

$$\bar{d} = \sum_{k=1}^{m} \sum_{l=1}^{m} \frac{d_{kl}}{m(m-1)} \quad (15)$$

Based on the discordance index mentioned above, the discordance index matrix (g) is given by Equations 16 and 17:

$$g_{kl} = 1, \text{ if } d_{kl} \leq \bar{d} \quad (16)$$

$$g_{kl} = 0, \text{ if } d_{kl} > \bar{d} \quad (17)$$

(9) Determining the aggregate dominance matrix. Now we calculate the intersection of the matrix F and G. The elements of this matrix are defined by Equation 18:

$$h_{kl} = f_{kl} . g_{kl} \quad (18)$$

(10) Eliminating the less favorable alternatives and ranking. The aggregate matrix H's elements show the outranking relations between alternatives.

3 RESULTS

The maps of slope classes and work units of research area are illustrated in Figures 4 and 5.

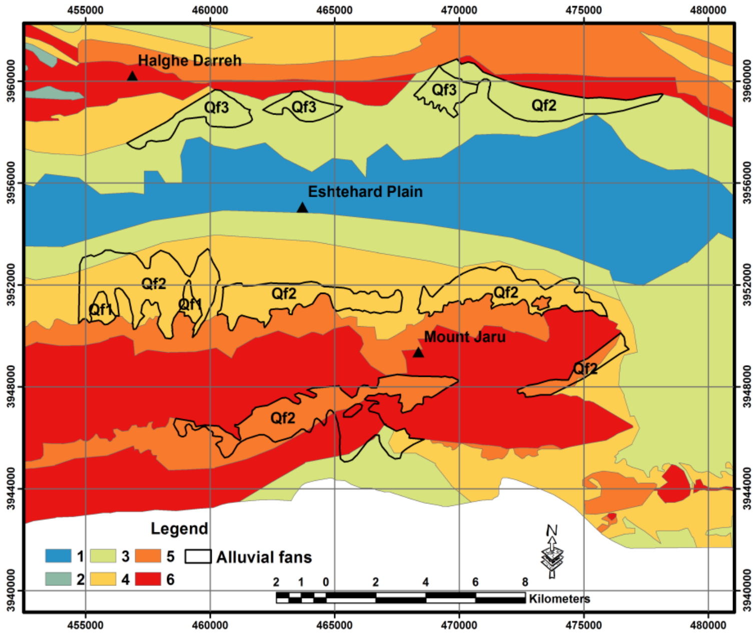

Figure 4 Map of slope classes, southeast of Rude-shoor Watershed Area, Tehran Province, IRAN

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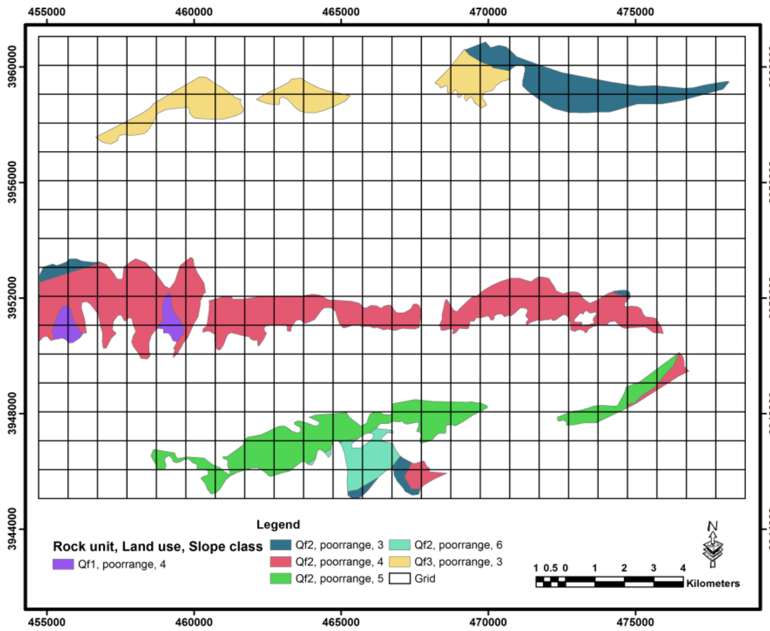

Figure 5 Map of work units, southeast of Rude-shoor watershed area, Tehran province, IRAN

Zoning of the study area based on the indices of resistance to erosion, salinity, and permeability coefficient are illustrated in Figures 6 to 8, respectively. Mean values of criteria in each unit were presented in Table 3.

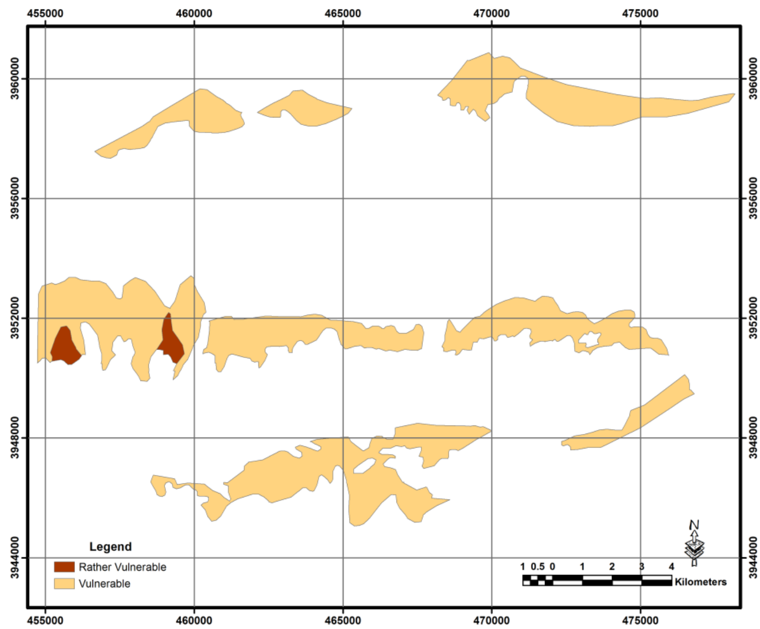

Figure 6 Zonation map of resistance coefficient to erosion, southeast of Rude-shoor watershed area, Tehran province, IRAN

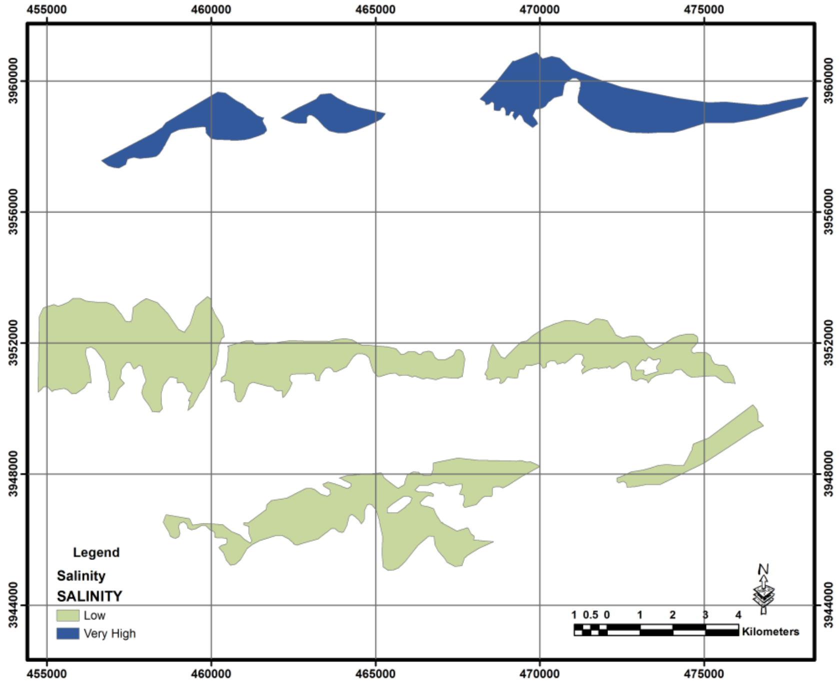

Figure 7 Zonation map of salinity, southeast of Rude-shoor watershed area, Tehran province, IRAN

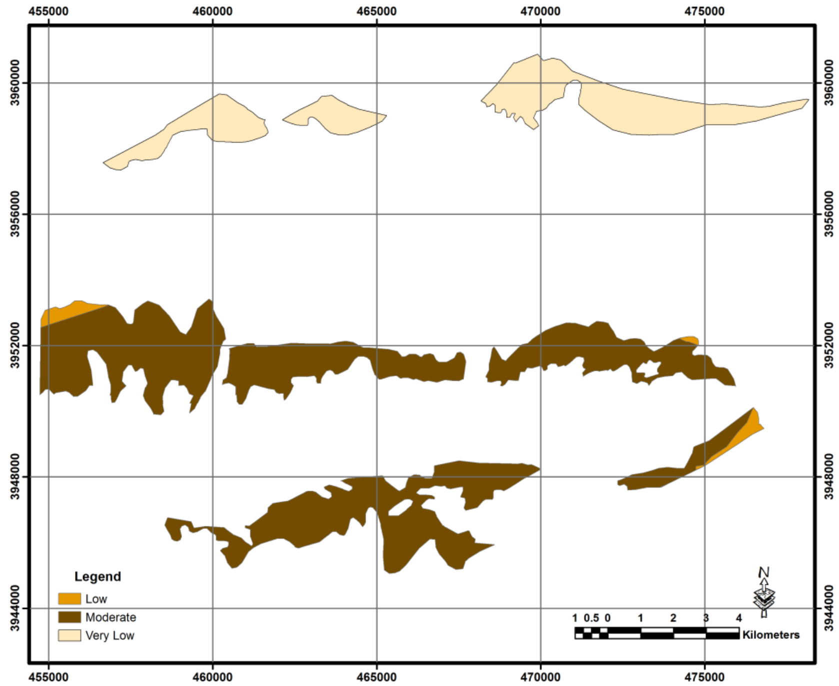

Figure 8 Zonation map of permeability coefficient, southeast of Rude-shoor watershed area, Tehran province, IRAN.

Table 3 Mean values of criteria in each unit of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Resistance Coefficient To Erosion		Salinity		Permeability		Area (ha)	Unit number
Quantitative amounts (Dimensionless)	**Qualitative class**	**Mmho.cm^{-1}**	**Qualitative class**	**m.day^{-1}**	**Qualitative class**		
3	Vulnerable	12.430	Very High	0.614	Very Low	679	**1**
3	Vulnerable	11.270	Very High	0.718	Very Low	239	**2**
3	Vulnerable	9.480	Very High	0.671	Very Low	193	**3**
3	Vulnerable	9.640	Very High	0.620	Very Low	367	**4**
4	Vulnerable	0.905	Low	19.230	Low	9	**5**
4	Vulnerable	0.746	Low	59.444	Moderate	708	**6**
4	Vulnerable	0.680	Low	68.114	Moderate	682	**7**
4	Vulnerable	1.002	Low	17.215	Low	69	**8**
4	Vulnerable	0.918	Low	51.825	Moderate	1047	**9**
5	Rather Vulnerable	0.730	Low	71.019	Moderate	73	**10**
5	Rather Vulnerable	0.881	Low	68.225	Moderate	80	**11**
4	Vulnerable	0.802	Low	53.030	Moderate	70	**12**
4	Vulnerable	1.030	Low	63.791	Moderate	249	**13**
4	Vulnerable	0.783	Low	12.201	Low	943	**14**
4	Vulnerable	0.880	Low	59.701	High	75	**15**
4	Vulnerable	1.096	Low	13.613	Low	57	**16**
4	Vulnerable	0.817	Low	11.822	Low	185	**17**

Weights of criteria and consistency ratio derived from AHP are presented in Table 4. Because of the consistency ratio is less than 0.1 ($CR \leq 0.1$), the values of subjective judgment are considered acceptable.

Table 4 Weights of criteria and consistency ratio derived from AHP

Criterion	Weight	Consistency Index (CI)	Random Inconsistency Index (RI)	Consistency Ratio (CR)
Resistance coefficient to erosion	0.221			
Salinity	0.685	0.027	0.580	0.047
Coefficient of permeability	0.093			

The concordance and discordance matrix and the aggregate dominance matrix are presented in Tables 5 to 7.

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Table 5 The concordance matrix of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Options	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
V1	*	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
V2	0.314	*	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
V3	0.314	0.314	*	0.314	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
V4	0.314	0.314	0.999	*	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
V5	0.000	0.000	0.000	0.000	*	0.999	0.999	0.221	0.314	0.999	0.999	0.999	0.314	0.906	0.999	0.221	0.906
V6	0.000	0.000	0.000	0.000	0.221	*	0.999	0.221	0.221	0.999	0.314	0.221	0.314	0.221	0.314	0.221	0.221
V7	0.000	0.000	0.000	0.000	0.221	0.221	*	0.221	0.221	0.314	0.314	0.221	0.221	0.221	0.221	0.221	0.221
V8	0.000	0.000	0.000	0.000	0.999	0.999	0.999	*	0.999	0.999	0.999	0.999	0.314	0.906	0.999	0.221	0.906
V9	0.000	0.000	0.000	0.000	0.906	0.999	0.999	0.221	*	0.999	0.999	0.999	0.314	0.906	0.999	0.221	0.906
V10	0.000	0.000	0.000	0.000	0.000	0.000	0.685	0.000	0.000	*	0.221	0.000	0.000	0.000	0.000	0.000	0.000
V11	0.000	0.000	0.000	0.000	0.000	0.685	0.685	0.000	0.000	0.999	*	0.685	0.000	0.685	0.685	0.000	0.685
V12	0.000	0.000	0.000	0.000	0.221	0.999	0.999	0.221	0.221	0.999	0.314	*	0.314	0.906	0.314	0.221	0.221
V13	0.000	0.000	0.000	0.000	0.906	0.906	0.999	0.906	0.906	0.999	0.999	0.906	*	0.906	0.906	0.221	0.906
V14	0.000	0.000	0.000	0.000	0.314	0.999	0.999	0.314	0.314	0.999	0.314	0.314	0.314	*	0.314	0.314	0.221
V15	0.000	0.000	0.000	0.000	0.221	0.906	0.999	0.221	0.221	0.999	0.314	0.906	0.314	0.906	*	0.221	0.906
V16	0.000	0.000	0.000	0.000	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.906	0.999	*	0.906
V17	0.000	0.000	0.000	0.000	0.314	0.999	0.999	0.314	0.314	0.999	0.314	0.999	0.314	0.999	0.314	0.314	*

Table 6 The discordance matrix of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Options	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
V1	*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V2	1.000	*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V3	1.000	1.000	*	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V4	1.000	1.000	0.000	*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V5	1.000	1.000	1.000	1.000	*	0.000	0.000	1.000	0.024	0.000	0.000	0.000	0.170	0.950	0.000	1.000	1.000
V6	1.000	1.000	1.000	1.000	1.000	*	0.000	1.000	1.000	0.000	0.311	1.000	1.000	1.000	1.000	1.000	1.000
V7	1.000	1.000	1.000	1.000	1.000	1.000	*	1.000	1.000	0.115	0.463	1.000	1.000	1.000	1.000	1.000	1.000
V8	1.000	1.000	1.000	1.000	0.000	0.000	0.000	*	0.000	0.000	0.000	0.000	0.036	0.378	0.000	1.000	0.481
V9	1.000	1.000	1.000	1.000	1.000	0.000	0.000	1.000	*	0.000	0.000	0.000	0.568	1.000	0.000	1.000	1.000
V10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	*	1.000	1.000	1.000	1.000	1.000	1.000

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V12	1.000	1.000	1.000	1.000	1.000	0.000	0.000	1.000	1.000	0.000	0.182	*	1.000	1.000	0.709	1.000	1.000
V13	1.000	1.000	1.000	1.000	1.000	0.252	0.000	1.000	1.000	0.000	0.000	0.778	*	0.097	0.551	1.000	1.000
V14	1.000	1.000	1.000	1.000	1.000	0.000	0.000	1.000	0.207	0.000	0.106	0.028	0.290	*	0.124	1.000	1.000
V15	1.000	1.000	1.000	1.000	1.000	0.032	0.000	1.000	1.000	0.000	0.002	1.000	1.000	1.000	*	1.000	1.000
V16	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.074	0.000	*	0.106
V17	1.000	1.000	1.000	1.000	0.720	0.000	0.000	1.000	0.153	0.000	0.069	0.000	0.249	0.000	0.080	1.000	*

Table 7 The aggregate dominance matrix of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Options	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
V1	*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V2	0.000	*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V3	0.000	0.000	*	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V4	0.000	0.000	1.000	*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
V5	0.000	0.000	0.000	0.000	*	1.000	1.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000	1.000	0.000	0.000
V6	0.000	0.000	0.000	0.000	0.000	*	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V7	0.000	0.000	0.000	0.000	0.000	0.000	*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V8	0.000	0.000	0.000	0.000	1.000	1.000	1.000	*	1.000	1.000	1.000	1.000	0.000	1.000	1.000	0.000	1.000
V9	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	*	1.000	1.000	1.000	0.000	0.000	1.000	0.000	0.000
V10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	*	0.000	0.000	0.000	0.000	0.000	0.000
V12	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	*	0.000	0.000	0.000	0.000	0.000
V13	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	1.000	0.000	*	1.000	0.000	0.000	0.000
V14	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	0.000	0.000	*	0.000	0.000	0.000
V15	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	*	0.000	0.000
V16	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*	1.000
V17	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000	0.000	*

The difference between dominance and defeat values ranges from -15 to 16. Weighted super matrix and the difference between dominance and defeat values are presented in Table 8. According to the results, units v1 and v10 had, respectively, the highest and the least potential of desertification with values of 16 and -15, respectively (Figure 9).

[DOR: 20.1001.1.23222700.2017.5.1.6.4]

Table 8 Weighted super matrix and difference between dominance and defeat values of research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

Criterion	Options																
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**
Resistance coefficient to erosion	0.041	0.041	0.041	0.041	0.055	0.055	0.055	0.055	0.055	0.068	0.068	0.055	0.055	0.055	0.055	0.055	0.055
Salinity	0.391	0.354	0.298	0.303	0.028	0.023	0.021	0.032	0.029	0.023	0.028	0.025	0.032	0.025	0.028	0.034	0.026
Permeability Coefficient	0.000	0.000	0.000	0.000	0.010	0.031	0.035	0.009	0.027	0.037	0.035	0.028	0.033	0.006	0.031	0.007	0.006
Dominance	16	15	13	14	6	2	0	10	6	0	1	3	5	3	3	12	5
Defeat	0	1	3	2	6	13	14	5	6	15	9	9	5	8	8	4	6
Difference	16	14	10	12	0	-11	-14	5	0	-15	-8	-6	0	-5	-5	8	-1

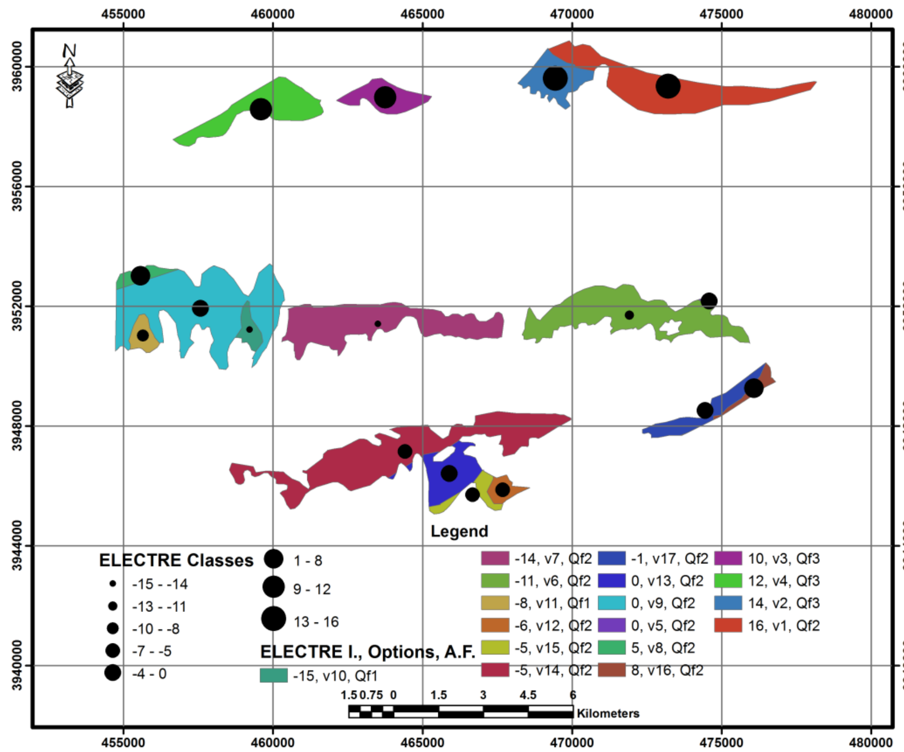

Figure 9 Map of different values in research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

[DOR: 20.1001.1.23222700.2017.5.1.6.4]

Then, potential classification of desertification in alluvial fans was done using Arc GIS 10.3 and different values (D) after joining the values to attribute limits presented in Table 9 (Figure 10).

Table 9 Conspectus of integrative results of desertification potential, southeast of Rude-shoor watershed area, Tehran province, IRAN

Class	Desertification Qualitative Potential	Desertification Quantitative Potential	Mean Of D Values	Limits Of D Value Changes
I	low	$D \leq 0$	- 5.91	-15 - 0
II	moderate	$0 < D < 5$	-	-
III	high	$5 < D < 10$	6.50	5 - 8
IV	Very high	$D \geq 10$	13.00	10 - 16

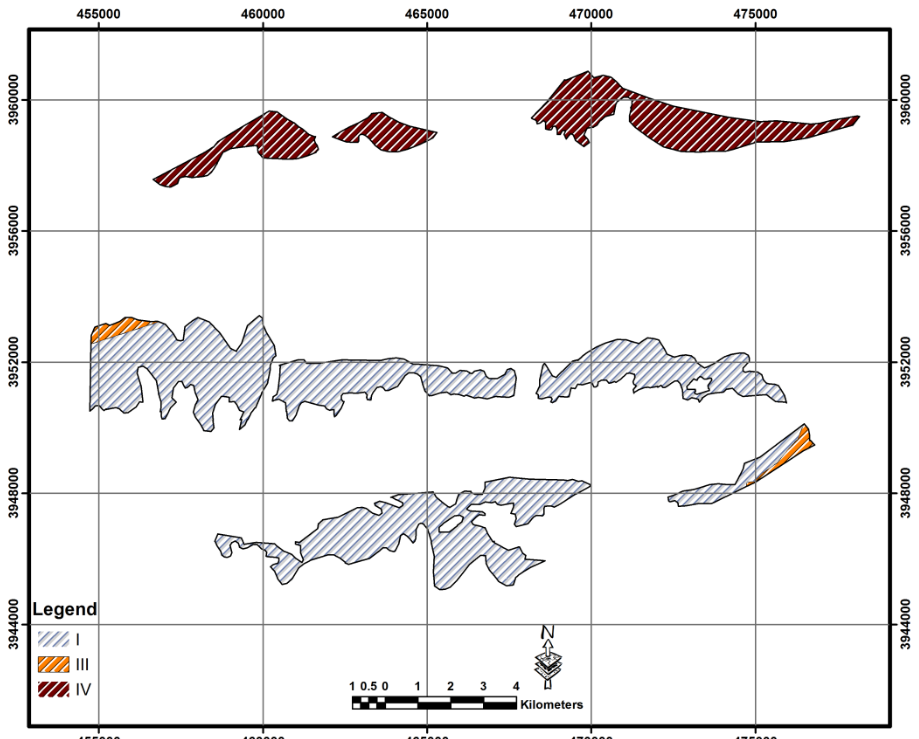

Figure 10 Map of desertification potential by AHP-ELECTRE technique in research area, southeast of Rude-shoor watershed area, Tehran province, IRAN Province, IRAN

After determining desertification potential in alluvial fans by using AHP-ELECTRE I Technique, the control map was created according to the field measurements in each unit based on plant covers and soil degradation. This map has two classes of maximum and minimum desertification potential in the research area (Figure 11). The I and IV classes

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have a maximum and minimum desertification intensity, respectively. Overlaying and crossing the map using AHP-ELECTRE I with the control map indicated that there was the overlapped area of 97.8% between equal desertification potentials in the research area and the AHP-ELECTRE I technique was a suitable model (Table 10).

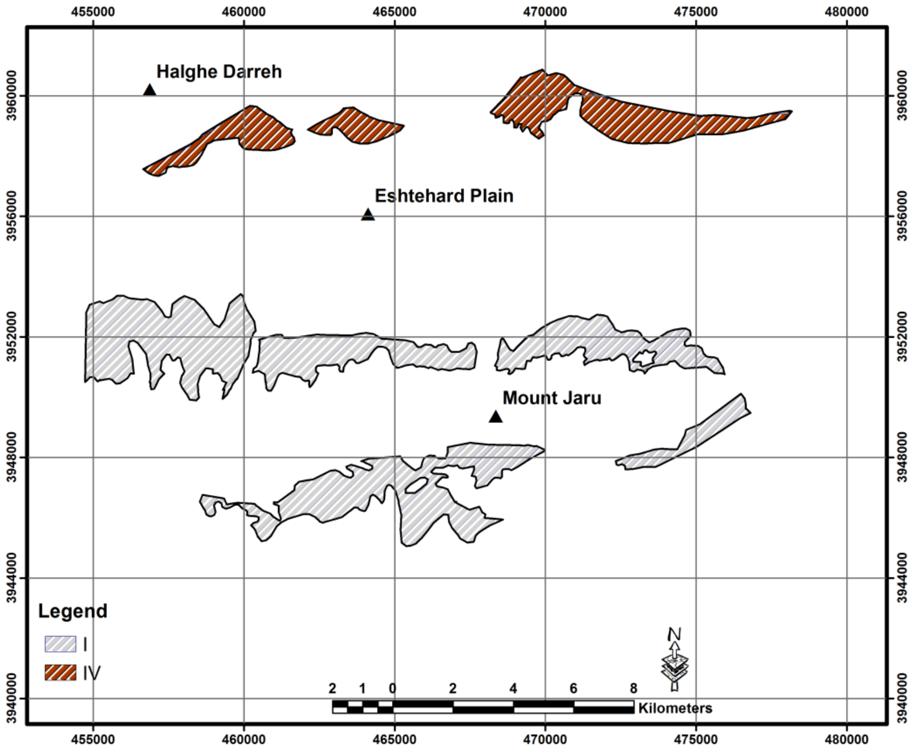

Figure 11 Control map of desertification potential in research area, southeast of Rude-shoor watershed area, Tehran province, IRAN Province, IRAN

Table 10 Overlapped area between the control and obtained map in the southeast of Rude-shoor watershed area, Tehran province, IRAN

Units (Obtained map – Control map)	Overlapped Area (ha)	Overlapped Area (%)
I - I	4120.40	71.99
III - I	125.36	2.19
IV - IV	1477.67	25.82

Also, the overlaying and crossing the ranked map of desertification potential (based on the pedological criterion) with the geological map determined the soil desertification potential (Table 11).

[DOR: 20.1001.1.23222700.2017.5.1.6.4]

Table 11 Soil desertification potential of alluvial fans in southeast of Rude-shoor watershed area, Tehran province, IRAN

Class	Desertification Qualitative Potential	Rock Unit	Rock Unit Area (%)	Rock Unit Area (Ha)	Area (Ha)	Area (%)
I	Low	Qf1	1.27	72.57	4120.40	71.99
		Qf2	11.92	682.28		
		Qf2	12.37	707.86		
		Qf1	1.39	79.65		
		Qf2	1.22	69.98		
		Qf2	16.48	943.01		
		Qf2	1.31	75.15		
		Qf2	3.24	185.41		
		Qf2	0.15	8.63		
		Qf2	18.29	1046.57		
		Qf2	4.36	249.29		
III	High	Qf2	1.20	68.62	125.36	2.19
		Qf2	0.99	56.74		
IV	Very high	Qf3	3.37	192.71	1477.67	25.82
		Qf3	6.41	366.82		
		Qf3	4.18	239.22		
		Qf2	11.86	678.92		

The results showed that almost 72% of the area was in the low desertification potential, and 2.2% and 25.8 % were in the high and very high desertification potential, respectively.

4 DISCUSSION AND CONCLUSION

In this research, prioritization of desertification potential using AHP-ELECTRE I technique was introduced to watershed management. The results of this research showed that the alluvial fans in research area were classified into three classes of I, III, and IV from the viewpoint of pedological criterion affecting desertification. The alluvial fans in the study area, originated from different susceptible geological units to erosion, were classified into the very high desertification potential, which was similar to result of Salehpour Jam (2006) who investigated the role of geological criterion on land degradation. He found the function of 0.8 from the fuzzy logic method to prioritize desertification potential of rock units, which indicated that the youngest and young gravel fans located in the south of Halgheh-Darreh had the maximum desertification potential in the Rude-shoor watershed area. Karimpour Reihan *et al.* (2007) found that alluvial fans had different classes of desertification potential in the south of the Rude-shoor watershed area. Feiznia and Nosrati (2007) showed that the erodibility of rock units increased when lithology of geological units shifted from basalt to alluvial deposits and finally gypsum.

The results from the AHP method also showed that salinity was the most important factor affecting land degradation and desertification, while the other factors, such as resistance coefficient to erosion and the permeability coefficient, had less importance.

Finally, it is important to note that the multiple criteria decision making techniques can be also used to prioritize de-desertification

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alternatives (Sadeghiravesh *et al.*, 2014). The authors suggest that the other methods of MCDM, such as VIKOR, TOPSIS, etc., to be applied to show the effects of the pedological criterion on land degradation and desertification.

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بررسی اثر معیار خاک‌شناسی بر پتانسیل بیابانزایی مخروط افکنه‌ها با کاربرد روش AHP-ELECTRE I (مطالعه موردی: بخش جنوبی حوزه‌ی آبخیز رودخانه‌ی شور)

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چکیده به‌منظور بررسی اثر معیار خاک‌شناسی بر پتانسیل بیابانزایی مخروط افکنه‌ها، نخست اقدام به تهیه‌ی نقشه‌ی واحدهای کاری از طریق تقاطع نقشه‌های کاربری اراضی، زمین شناسی، طبقات شیب و نیز نقشه شبکه ایجاد شده به‌وسیله برنامه جانبی ET GeoWizards در نرم‌افزار ArcGIS 10.3 گردید. در این بررسی سه شاخص حساسیت‌پذیری نسبت به فرسایش، شوری و نفوذپذیری خاک در نظر گرفته شد که در نهایت هر یک به‌صورت نقشه‌ای طبقه‌بندی شده، ارائه شدند. سپس اقدام به محاسبه وزن معیارها و نیز نسبت سازگاری با کاربرد روش فرآیند تحلیل سلسله مراتبی (AHP) شد. در این تحقیق از روش ELECTRE I به منظور تعیین پتانسیل بیابانزایی و اولویت‌بندی گزینه‌ها استفاده شد. پس از محاسبه ماتریس استاندارد شده موزون، ماتریس سازگاری و ناسازگاری، تفاوت میان مقادیر تسلط و شکست محاسبه گردید. بر اساس نتایج به‌دست آمده، دامنه مقادیر تفاوت حاصل از ماتریس تسلط مبتنی بر روش AHP-ELECTRE I از -۱۵ (واحد V10) تا ۱۶ (واحد V1) متغیر بوده که به‌ترتیب گویای کمینه و بیشینه پتانسیل بیابانزایی در منطقه تحقیق است. نتایج حاصل از پهنه‌بندی منطقه تحقیق نشاندهنده حضور سه طبقه کم (I)، زیاد (III) و خیلی زیاد (IV) در پهنه‌بندی شدت یا پتانسیل بیابانزایی مخروط افکنه‌ها است، به‌طوری که ۷۱/۹۹ درصد منطقه دارای پتانسیل بیابانزایی کم، ۲/۱۹ درصد منطقه دارای پتانسیل بیابانزایی زیاد و ۲۵/۸۲ درصد منطقه دارای پتانسیل بیابانزایی خیلی زیاد است.

کلمات کلیدی: فرسایش پذیری، شوری، نفوذپذیری، اولویت بندی، تصمیم‌گیری چندمعیاره