

## 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.

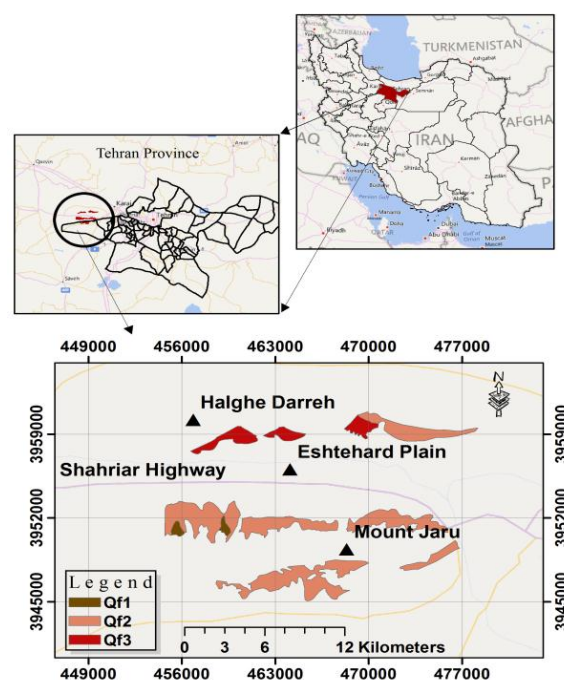
Application of MCDM techniques and kinds of attributes affecting land degradation is very important in investigation of desertification potential in alluvial fans that consist of susceptible geological formations to erosion. The AHP is a powerful tool to prioritize alternatives and criteria on the basis 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<sup>2</sup>, 42 and 58 percent of which are plain and highlands, respectively. This area, extending from 48° 30' to 51° 00' E and 35° 21' to 36° 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).

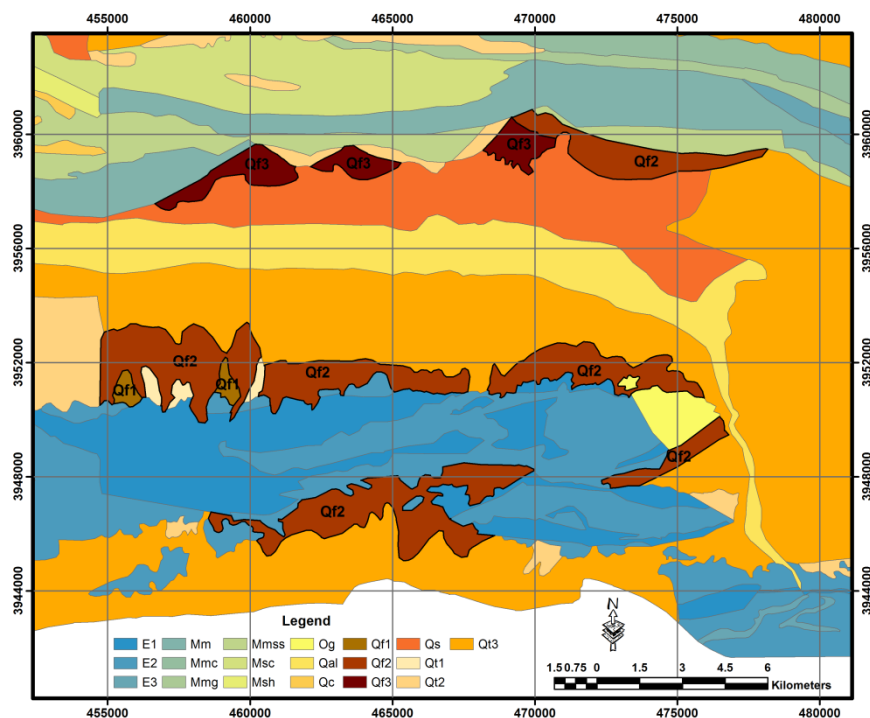


**Figure 1** Study area in southeast of Rude-shoor watershed area, Tehran province, IRAN

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

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

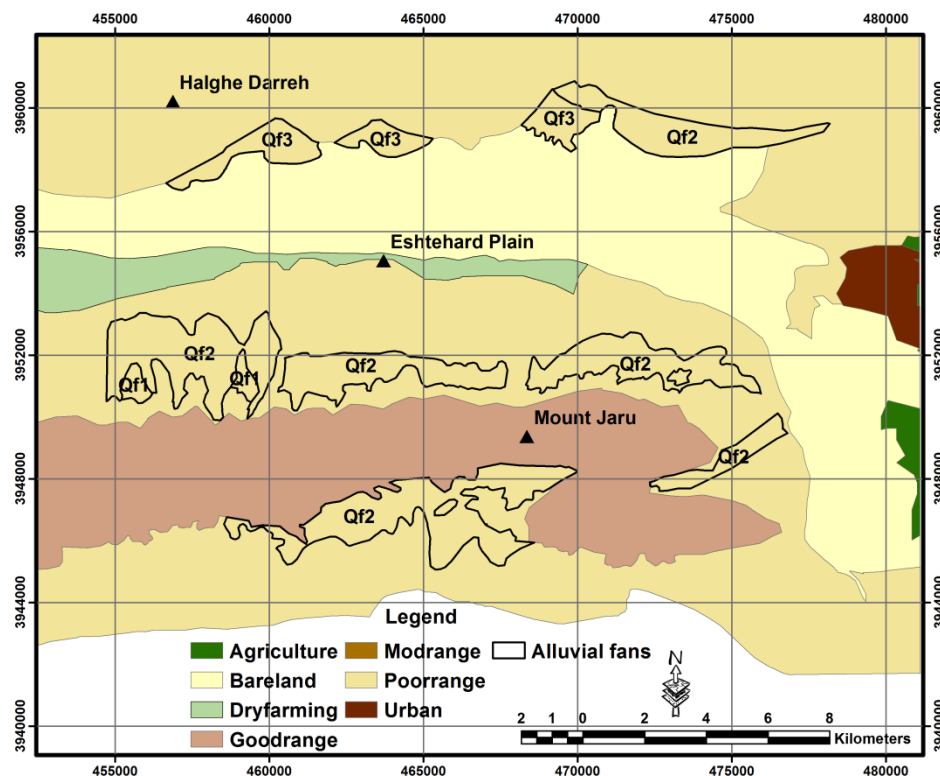
(Figure 2). The lithological characteristics of alluvial fans are illustrated in Table 1.



**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<br>(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                             | $Q_1^f$ | -     |            |          |



**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 × 1000 m<sup>2</sup> 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<sup>-1</sup>) of 159 saturated mud samples, based on which 4 classes of salinity (low (0 ≤ EC < 2), moderate (2 ≤ EC < 4), high (4 ≤ EC < 8), and very high (8 ≤ EC)) were differentiated (USSR, 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<sup>-1</sup>), low (0.069-1.388 cm min<sup>-1</sup>), moderate (1.388-6.944 cm min<sup>-1</sup>), and high (> 6.944 cm min<sup>-1</sup>).

## 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  $\lambda_{\max}$ :

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

Where, N is the number of alternatives in the decision matrix, and  $\lambda_{\max}$  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):

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

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

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

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

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

(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 ( $J = \{1, 2, \dots, m\}$ ) 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:

$$C_{kl} = \{j | v_{kj} \geq v_{lj}\} \quad (6)$$

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

$$D_{kl} = \{j | v_{kj} < v_{lj}\} = J - C_{kl} \quad (7)$$

(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:

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

(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:

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

The discordance interval matrix can be formulated as Equation 11:

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

(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  $\bar{c}$  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:

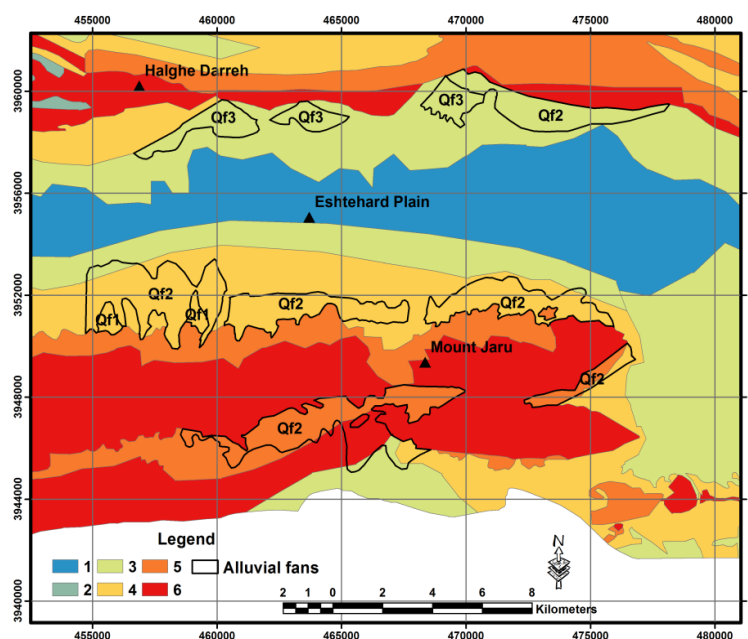
$$h_{kl} = f_{kl} \cdot g_{kl} \quad (18)$$

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

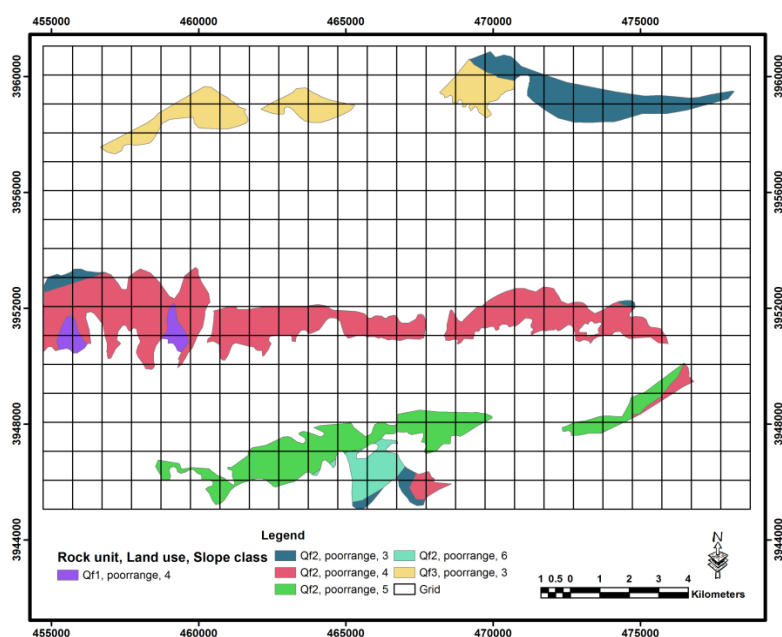
show the outranking relations between alternatives.

### 3 RESULTS

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



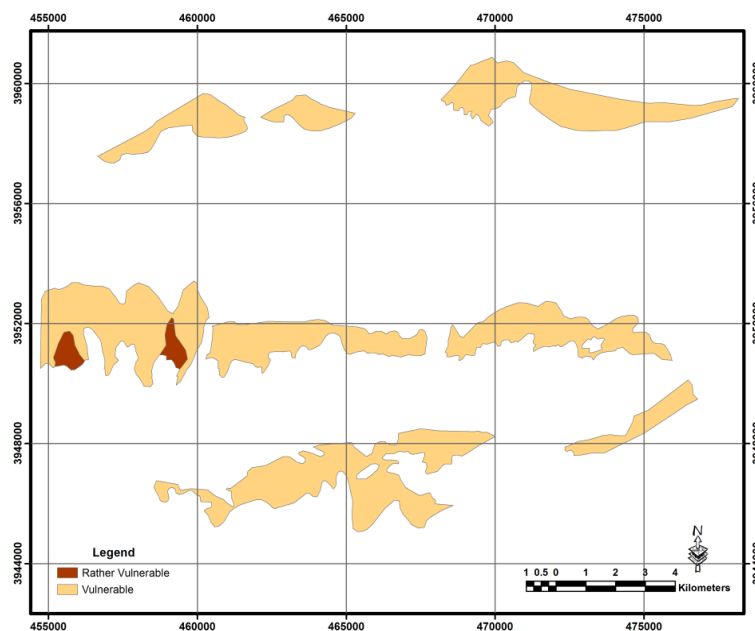
**Figure 4** Map of slope classes, southeast of Rude-shoor Watershed Area, Tehran Province, IRAN



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

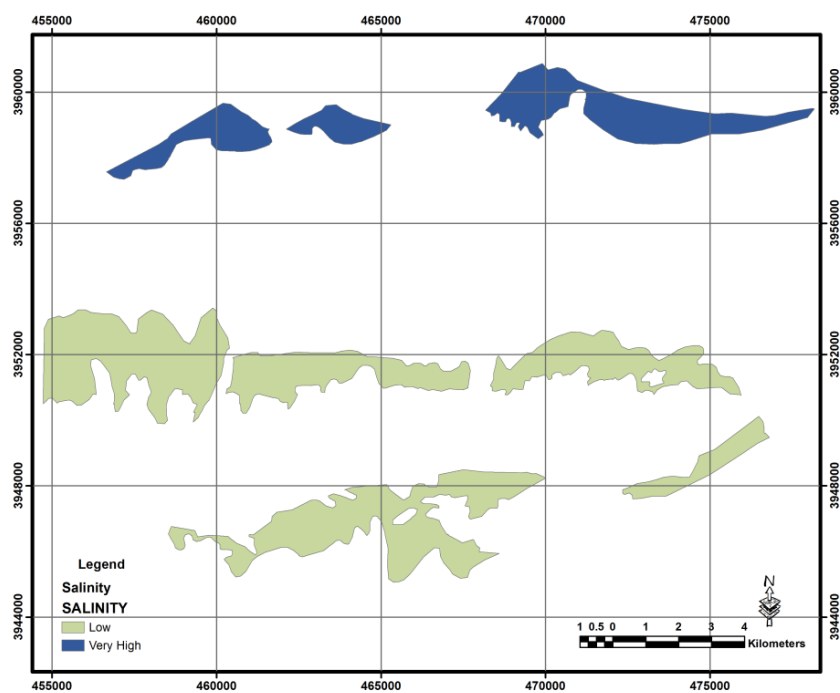
Zoning of the study area based on the indices of resistance to erosion, salinity, and permeability coefficient are illustrated in Figures 6 to 8,

respectively. Mean values of criteria in each unit were presented in Table 3.

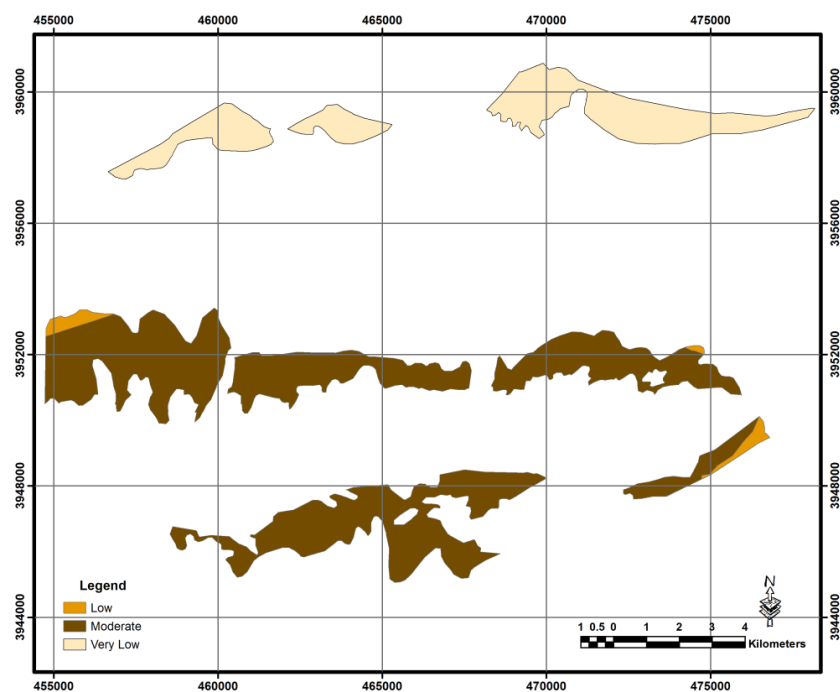


**Figure 6** Zonation map of resistance coefficient to erosion, southeast of Rude-shoor watershed area, Tehran province, IRAN





**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<br>(Dimensionless) | Qualitative class | Mmho.cm <sup>-1</sup> | Qualitative class | m.day <sup>-1</sup> | 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 ≤ 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.

**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   |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| <b>V1</b>  | *     | 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 |
| <b>V2</b>  | 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 |
| <b>V3</b>  | 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 |
| <b>V4</b>  | 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 |
| <b>V5</b>  | 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 |
| <b>V6</b>  | 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 |
| <b>V7</b>  | 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 |
| <b>V8</b>  | 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 |
| <b>V9</b>  | 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 |
| <b>V10</b> | 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 |
| <b>V11</b> | 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 |
| <b>V12</b> | 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 |
| <b>V13</b> | 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 |
| <b>V14</b> | 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 |
| <b>V15</b> | 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 |
| <b>V16</b> | 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 |
| <b>V17</b> | 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   |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| <b>V1</b>  | *     | 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 |
| <b>V2</b>  | 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 |
| <b>V3</b>  | 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 |
| <b>V4</b>  | 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 |
| <b>V5</b>  | 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 |
| <b>V6</b>  | 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 |
| <b>V7</b>  | 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 |
| <b>V8</b>  | 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 |
| <b>V9</b>  | 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 |
| <b>V10</b> | 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 |
| <b>V11</b> | 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 |

|            |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| <b>V12</b> | 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 |
| <b>V13</b> | 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 |
| <b>V14</b> | 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 |
| <b>V15</b> | 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 |
| <b>V16</b> | 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 |
| <b>V17</b> | 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

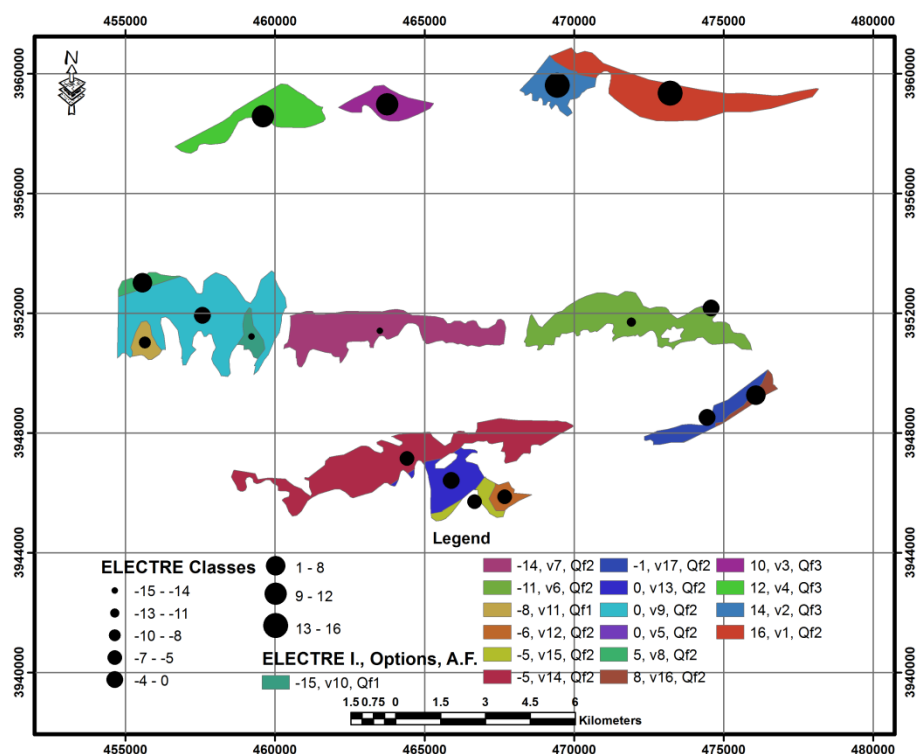
| Options    | V1    | V2    | V3    | V4    | V5    | V6    | V7    | V8    | V9    | V10   | V11   | V12   | V13   | V14   | V15   | V16   | V17   |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| <b>V1</b>  | *     | 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 |
| <b>V2</b>  | 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 |
| <b>V3</b>  | 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 |
| <b>V4</b>  | 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 |
| <b>V5</b>  | 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 |
| <b>V6</b>  | 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 |
| <b>V7</b>  | 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 |
| <b>V8</b>  | 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 |
| <b>V9</b>  | 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 |
| <b>V10</b> | 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 |
| <b>V11</b> | 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 |
| <b>V12</b> | 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 |
| <b>V13</b> | 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 |
| <b>V14</b> | 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 |
| <b>V15</b> | 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 |
| <b>V16</b> | 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 |
| <b>V17</b> | 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).

**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   |
| <b>Resistance coefficient to erosion</b> | 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 |
| <b>Salinity</b>                          | 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 |
| <b>Permeability Coefficient</b>          | 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 |
| <b>Dominance</b>                         | 16      | 15    | 13    | 14    | 6     | 2     | 0     | 10    | 6     | 0     | 1     | 3     | 5     | 3     | 3     | 12    | 5     |
| <b>Defeat</b>                            | 0       | 1     | 3     | 2     | 6     | 13    | 14    | 5     | 6     | 15    | 9     | 9     | 5     | 8     | 8     | 4     | 6     |
| <b>Difference</b>                        | 16      | 14    | 10    | 12    | 0     | -11   | -14   | 5     | 0     | -15   | -8    | -6    | 0     | -5    | -5    | 8     | -1    |



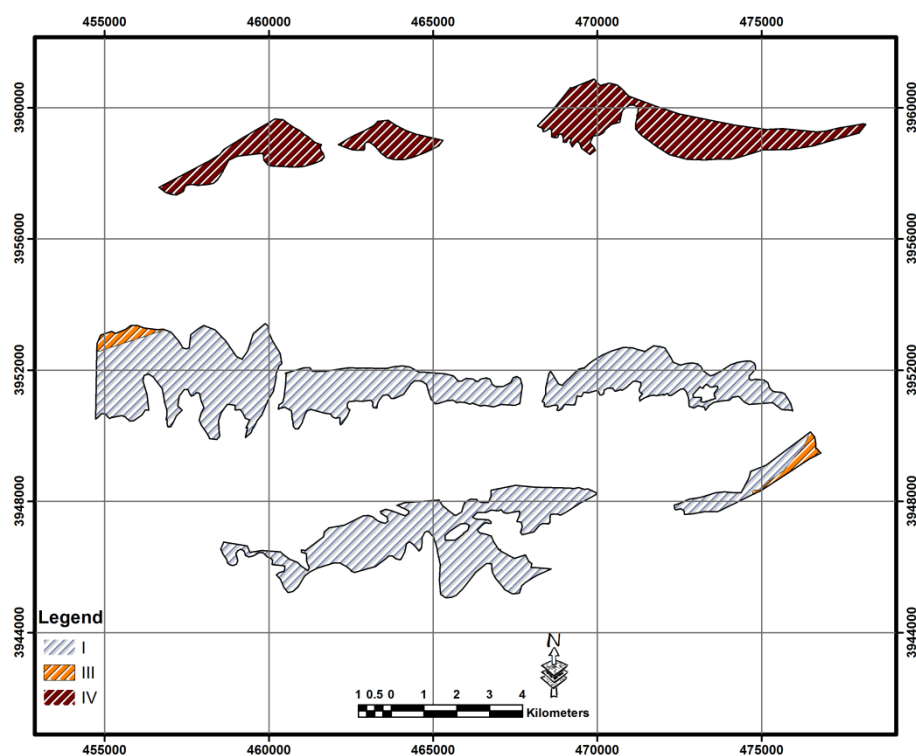
**Figure 9** Map of different values in research area, southeast of Rude-shoor watershed area, Tehran province, IRAN

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                   |



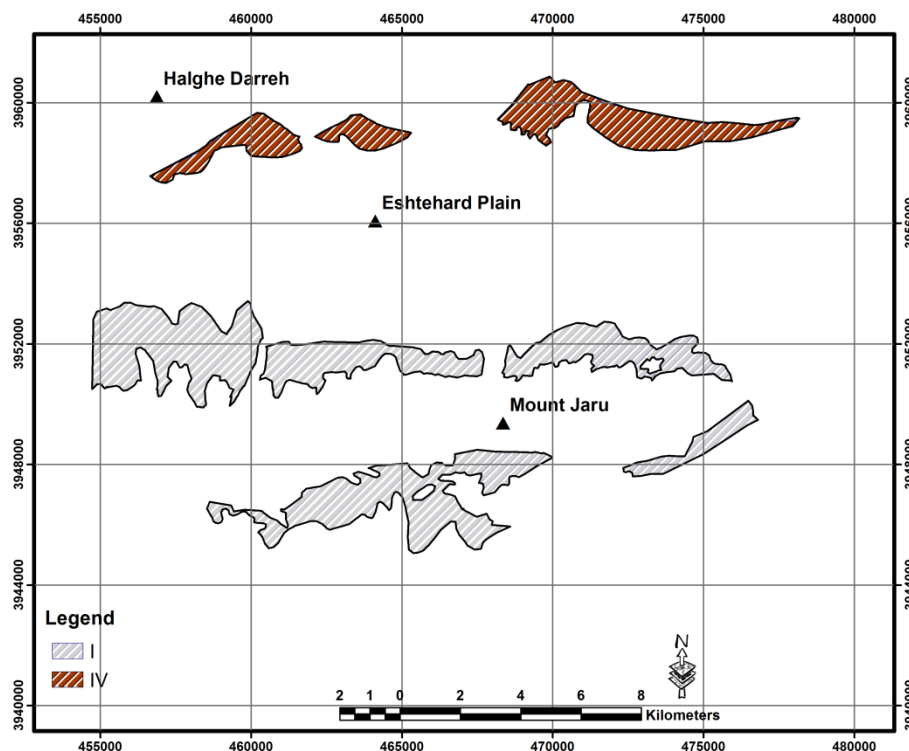
**Figure 10** Map of desertification potential by AHP-ELECTRE technique in research area, southeast of Rude-shoor watershed area, Tehran province, IRAN Province, IRAN

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

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<br>(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).

**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,

#### 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

and 2.2% and 25.8 % were in the high and very high desertification potential, respectively.

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



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 حوزه 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، زمین‌شناسی، 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 به‌منظور 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:** فرسایش‌پذیری، شوری، نفوذپذیری، اولویت‌بندی، تصمیم‌گیری چندمعیاره