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Comparison and evaluation of three methods of multi attribute decision making methods in choosing the best plant species for environmental management (Case study: Chah Jam Erg)

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Abstract
Today, environmental crisis and loss of natural resources are the principle causes of the creation of environmental management systems. The optimal management of natural resources requires the assessment and classification of ecological and environmental potentials. Using this method, the abilities and restrictions of resources can be recognized, and their future trends can be predicted. Nebka landscape is the natural reaction of ecosystem against the stress of wind erosion and ecosystem tries to adjust wind stress by creating this landscape. Therefore, the development of Nebka is the best and most suitable method for quicksand stabilization in the study area, and the most adaptable type of Nebka species must be identified and selected for the development of the ecosystem. This important aim will not be achieved except through careful and scientific investigation of Nebka phenomenon. According to the present environmental conditions, a suitable method with high accuracy is required in order to evaluate and manage natural resources and environment for achieving sustainable development. The aim of this study was to select the best Nebka species for quicksand stabilization using their morphometric parameters analysis by multi attribute decision making (MADM) methods. The results of this study show that in three models, *Haloxylon* obtained the highest point. Therefore, it has the highest effect in stabilization of quicksand. For implementation of stabilization projects of mobile sands in the study area, development of *Haloxylon* Nebka systems have the highest importance and efficiency. The results of this study will be beneficial in systemic management of desert regions and stabilization projects of quicksand.

Keywords
Chah Jam Erg, multi attribute decision making (MADM) models, Nebka, plant species.

1. Introduction
Million hectares of Iran's areas are recently affected by wind erosion processes, due to special environmental conditions, such as rainfalls being less than 150 mm, lack of vegetation and fast and strong winds. These factors have caused the influx of quicksand into infrastructures, settlements, communication ways and industrial and agricultural installations. This problem is considered as one of the most important environmental issues in some parts of Iran. Wind erosion and running sand influx pose in the event of a serious indicator of desertification and serious threat for arid areas. The running sand influx makes the much damage to towns and villages, streets, roads, and also the loss of soil fertility (Refahi, 2004). Therefore, in order to

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revive desert to stabilize the running sand began in Iran, in 1959. Research on methods to stabilize running sand was started in Ahvaz, in 1969 (Ahmadi, 1998). However, these activities have been needed in basic programming to harness and control wind erosion. Over the past half century, various methods have been used to stabilize running sand.

One of the ways to expand Nebkazar is in prone areas in order to stabilize the running and prevent the spread of desertification. The purpose of this study was to select the best plant species to develop Nebkazar using multiple attribute decision-making (MADM). Nebka are one of desert and semi-desert current landscapes. Community ecological landscape is shaped Nabaka. Infact, Nabaka, is a natural reflection of life in the desert. Thus, the role of vegetation in the creation and development of the Nebka has importance and special place. Multi criteria decision making (MCDM) is a branch of known operations research, that is, the studied criteria decision making problems under a number of criteria in decision making. In the decision to place a measure of optimality, several criteria were used for the measurement (Pradhan, 2011). In general, MCDM models are divided into two major categories, including MADM and Multi Objective Decision Making (MODM) (Tavakoli, 2005). The objective of the decision issues of MODM is the optimization of multiple objective functions under a set of constraints. In general, MODM model is used for problems of design and optimization; however, MCDM are used to select the best option or options among the available options according to several criteria to decide. This model is used to select the best option (Asgharpoor, 2012). In general, it can be said that in the MCDM process, the efficient solution is obtained by using MODM, and then the most preferred option among the available options is selected using MCDM method. In conjunction with the morphological characteristics of the plant species Nebka and their impact on the consolidated sand properties, many studies have been done, including Bishop et al. (2002) who modeled desert dune fields based on discrete dynamics. Hesp (2002) described foredunes and blowouts: initiation, geomorphology and dynamics. Douseri (1995) researched on sedimentological and morphological characteristics of some Nebkha deposits in the northern coastal plain of Kuwait. Wasson and Hyde (1983) discussed about factors determining desert dune type. Werner (1995) carried out a research on Eolian dunes: computer simulation and attractor interpretation. Danin (1996) reported plants of desert dunes. Dougill and Thomas (2002) described Nebkha dunes in the Molopo Basin, South Africa and Botswana. Khalaf et al. (1995) described sedimentological and morphological characteristics of some Nebkha deposits in the Northern Coastal Plain of Kuwait. Nickling and Wolfe (1994) analysed the morphology and origin of Nebkhas, region of Mopti, Mali, West Africa. Tengberg (1994) carried out a research on Nebkhas, their spatial distribution morphometry, composition and age in the SidiBouzid area, Central Tunisia. Tengberg (1995) described Nebkha dunes as indicators of wind erosion and land degradation in the Sahel zone of Burkina Faso. Wanga et al. (2006) did a research on Nebka development and its significance to wind erosion and land degradation in semi-arid Northern China. Tengberg and Chen (1998) did a comparative analysis of Nebkha in Centeral Tunisia and Northern Burkina Faso. Vali and Poorgsrvani (2008) did a comparison analysis on Nebka morphometric relationships between components and morphology of plant species: *Tamarix mascatensis, Reaumuria turkestanica*, *Alhagi mannifera* in Khairabad Sirjan. Poorgsrvani et al. (2009) grouped a comparative Nebkas type Sedliziavloreda, Romarlatorkestenica and *A. mannifera* on the basis of the righteousness of performance of plants in the vegetative forms in Kheirabadi Sirjan. Poorgsrvani et al. (2008) worked on the relationship of plant morphology and morphometric characteristics of Nebkas Romaryaturkstanika.

The main purpose of this study was to compare and evaluate three methods of MADM methods in choosing the best plant species for environmental management. The purpose of this research is selecting the best choice among the available options to select the best type of species Nebka using MCDM and results evaluation of each of the methods. Hence, in the following, a detailed background of MCDM and algorithm background was proposed for decision making. The next section briefly describes the various methods of MCDM and each feature is explained. Then, the best option was chosen to choose the best varieties taken using the mentioned Nebka and the results of the different approaches were compared.

2. Study area

The studied field is located in South of Haj Ali Gholi playa, in central part of Semnan province (Fig. 1). Haj Ali Gholi playa is the most important playa of Semnan province, that is situated in southwestern of Shahroud to south of Damghan. This playa is a tectonic and sediment hole, which at present is influenced by different geomorphic and climatic process. Shortage of vegetation cover and moisture are caused by windy geomorphic process which has been dominated upon other processes around the playa. Hence, some kinds of windy features erosion in this region were observed. Chah Jam Erg, with coverage of about 25260 hectares, is one of the most important Ergs of Haj Ali Gholi playa that is located regularly along northeastern to southwestern edge of playa with 10 to 12 km length (Ahmadi, 2007). The studied field (Chah Jam Erg) is bounded between latitudes 350, 45 and 350, 50 N and longitudes 540, 40 and 550, 10 E (Fig. 1).

The typical geographical position of the studied area is caused by opposite climatic conditions in different seasons of the year. Furthermore, human and natural intensified factors of desertification are the other reasons of opposite climatic conditions in this area. Position of field in the south of Alborz chain mountain, vicinity with dry plains of Central Iran, and remote from moisture masses, can be influenced by rainy masses, direction and length of chain mountains, and locally, dry winds caused a arid climate for the studied area (Table 1). Summer climate of this field is controlled by subtropical high-pressure, and its winter climate is controlled by western winds that originate from Mediterranean Sea. The prevailing wind direction in the study area is mainly from the E–NE with annual speed mean of about 4.9 knots, although dusty winds occasionally come from the other direction.

3. Materials and Methods

In this study, materials and tools were used to evaluate the morphologic Nebka and volume calculation of Nebka. For data review of Nebka, morphometry of the meter, inclinometer, and Global Positioning System (GPS) were used and also to characterize the study area from

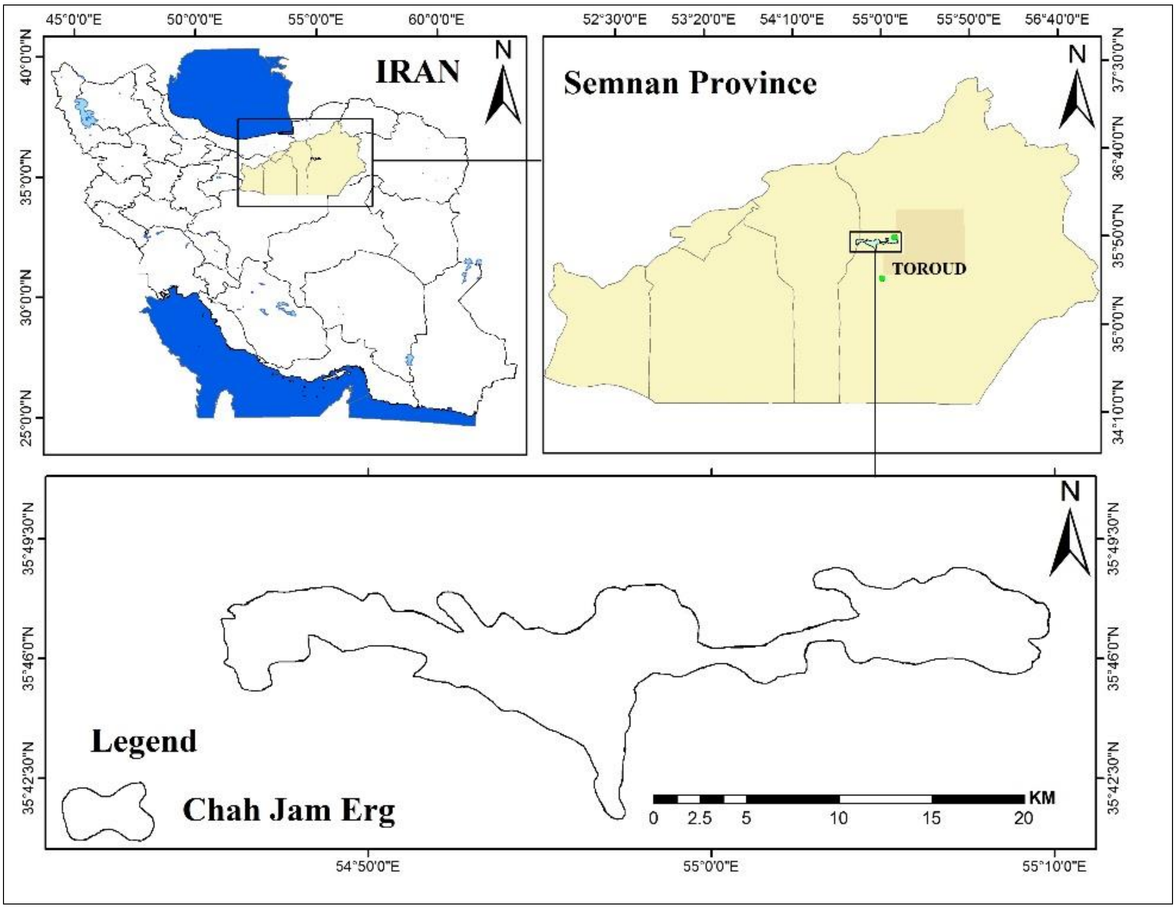

Fig.1. Situation of the studied area

Table 1. Values of climatic elements of the study area (average of 30 years period from 1978 to 2008)

Elements	Winter	Spring	Summer	Autumn	Annual
Average of minimum temperature in C	0.75	14.56	19.98	3.53	9.32
Average of maximum temperature in C	13.73	32.54	39.02	20.01	26.34
Average of minimum relative humidity in percent	41.01	26.33	29.81	37.73	32.33
Average of maximum relative humidity in percent	65.03	42.10	43.66	55.42	50.49
Average of precipitation in mm	56.16	20.76	2.55	16.33	85.81
Average of wind speed in knot	3.3	6.3	7.5	2.5	4.95

1:50,000 topographic maps, Google Earth satellite images and field visits was done. The methods of this study are divided into the following steps.

1. Specify the desired range of satellite imagery and field visits of the study area;

2. Overall views of the landscape and transect lines for ease of identifying and selecting Nebka a target harvested field.

In this study, 10 transects were used in order to harvest and study the samples. This study is based on one-dimensional sampling method and sampling unit length. This method allows a random sampling provided in the entire study area. Therefore, to cover the entire study area of 10 km transects using a GPS device was considered. Thus, this study is the first in the southern part of the study area transects that uses GPS to determine the primary points and it was over a kilometer to the north geographic path length and Nebkahs dealt with along the way were measured.

- Morphologic features the Nebka harvested in this study have been characteristics, such as height Nebka, volume Nebka, canopy cover Nebka, plant height and basal diameter (Table 2 and Fig. 2). To calculate the vegetation canopy diameter, the crown of the plant was measured to the height of the tallest plant to summit Nebka. In order to measure the height of Nebka, Nebka to peak height and basal diameter of its base Nebka, measuring the average diameter of the base was done with a tape. The cone volume was calculated using Equation 1 (Dougill and Thomas, 2002).

$$V=0.5\ (0.33\ \pi\ R2H) \quad (1)$$

where V is the volume of the cone Nebka square meter, H is the height in meters Nebka cone, R is the radius of the base of the cone Nebka in m.

- Identification of plant species that have led to the creation side Nebka. In total, 462 different species were evaluated in Nebka. From this Nebka *Seidlitzia florida* 150 samples, *T. macatensis*, 45 samples, *A. mannifera*, 60 samples, *Astragalus gummifer*, 28 samples, *Z. eurypterum*, 45 samples, *Salsola rigida*, 80 samples, and *Haloxylon aphyllum*, 54 samples (Table 2).
- Analysis of morphologic features of Nabakas was studied using MADM methods to select the best plant species to develop in the Nebka system.

3. 1. Multi attribute decision making (MADM)

The MCDM problems may be divided into two types of problem. One is the classical MCDM problems (Hwang and Yoon, 1981; Keeney and Raiffa, 1976; Feng and Wang, 2000) among which the ratings and the weights of criteria measured in crisp numbers. Another is the fuzzy multi-criteria decision-making (FMCDM) problems (Bellman and Zadeh, 1970; Boender et al., 1989; Chang and Yeh, 2002; Chen, 2000; Chen and Hwang, 1992; Hsu and Chen, 1996, 1997; Jain, 1978; Kacprzyk et al., 1992; Lee, 1999; Liang, 1999; Nurmi, 1981; Raj and Kumar, 1999; Tsaur et al., 2002; Tanino, 1984; Wang et al., 2003), among which the ratings and the weights of criteria evaluated on imprecision, subjective and vagueness are usually expressed using linguistic terms and then set into fuzzy numbers (Zadeh, 1965; Zimmermann, 1987, 1991). MCDM models are divided into two major categories, including MADM and MODM. MCDM process involves four basic steps, which are 1-Identification and Evaluation, 2-Weighting, 3- Select option using one of the methods of MCDM, 4-Sensitivity analysis and final choices. MADM process is as shown in Figure 4.

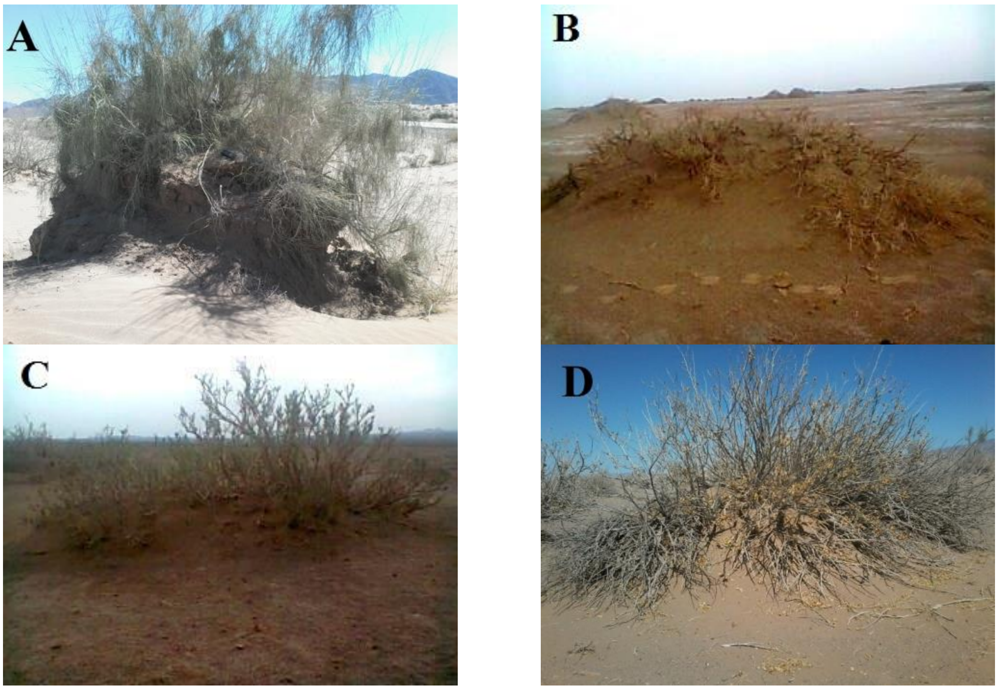

Fig. 2. Nebkas in the study area: A) *H. aphyllum*, B) *S. florida*, C) *T. macatensis*, D) *Z. eurypterum*

Table 2. Morphometric characteristics of the plant species

standard deviation	skewness	Maximum	Minimum	Average	Criteria	Plant species
4.23	0.619	0.45	0.09	0.23	Nebkha height (M)	Seidlitzia florida 150 samples
5.35	1.25	1.50	0.18	0.290	Nebkha volume (M^3)	
8.45	0.785	1.80	0.05	0.10	canopy cover (M^2)	
6.65	1.87	0.56	0.13	0.29	plant height (M)	
8.90	0.459	2.85	0.011	0.23	canopy diameter (M)	
4.54	0.574	1.10	0.45	0.7	Nebkha height (M)	Tamarix macatensis, 45 samples
3.65	1.90	1.80	0.8	1.6	Nebkha volume (M^3)	
6.60	0.885	5.50	0.80	3.10	canopy cover (M^2)	
4.80	0.490	2.10	0.84	1.50	plant height (M)	
0.011	1.20	0.95	0.12	0.38	canopy diameter (M)	
2.30	1.20	0.6	0.08	0.21	Nebkha height (M)	Alhagi mannifera, 60 samples
2.30	1.20	0.180	0.0060	0.019	Nebkha volume (M^3)	
2.10	1.90	0.96	0.25	0.64	canopy cover (M^2)	
6.35	0.45	0.45	0.12	0.32	plant height (M)	
1.98	0.459	0.65	0.32	0.62	canopy diameter (M)	
3.35	0.845	0.35	0.08	0.20	Nebkha height (M)	Astragalus gummifer, 28 samples
2.98	1.10	0.10	0.008	0.056	Nebkha volume (M^3)	
4.25	0.745	0.11	0.006	0.05	canopy cover (M^2)	
3.35	0.889	0.75	0.32	0.56	plant height (M)	
2.35	1.35	0.25	0.09	0.15	canopy diameter (M)	
4.35	0.745	1.10	0.20	0.60	Nebkha height (M)	Zygophyllum eurypterum, 45 samples
1.54	0.547	2.10	0.90	1.4	Nebkha volume (M^3)	
6.25	0.987	3.90	1.20	2.30	canopy cover (M^2)	
3.98	1.54	2.3	0.90	1.5	plant height (M)	
1.68	0.658	0.90	0.11	0.35	canopy diameter (M)	
2.35	0.658	0.35	0.10	0.21	Nebkha height (M)	Salsola rigida, 80 samples
5.65	1.65	0.85	0.30	0.62	Nebkha volume (M^3)	
3.54	0.956	1	0.40	0.60	canopy cover (M^2)	
1.45	1.65	0.80	0.35	0.40	plant height (M)	
1.35	0.658	0.31	0.07	0.23	canopy diameter (M)	
2.68	1.65	1.7	0.6	1.1	Nebkha height (M)	Haloxylon aphyllum, 54 samples
1.365	0.983	3.6	0.8	2.40	Nebkha volume (M^3)	
2.356	0.785	5.1	2.2	4.3	canopy cover (M^2)	
3.958	1.365	2.5	0.7	1.7	plant height (M)	
2.695	1.89	1.2	0.4	0.8	canopy diameter (M)	

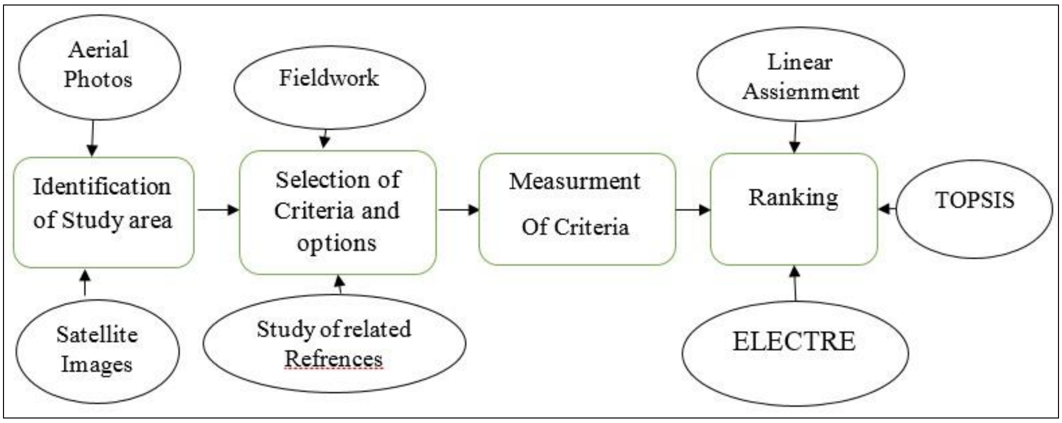

Fig. 3. Steps of the research

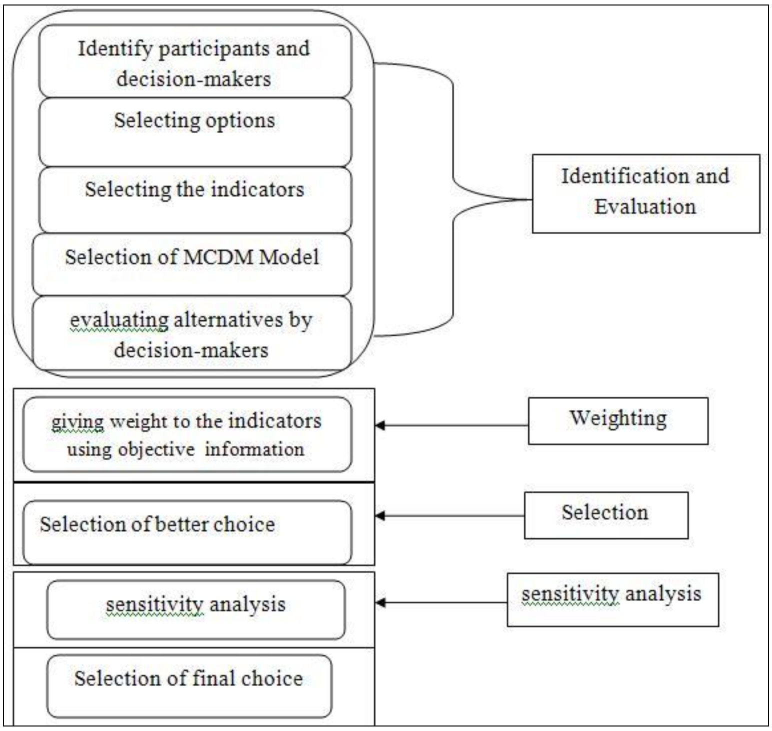

Fig. 4. Multi attribute decision making process

3. 2. Different methods of decision-making

3. 2. 1. Technique for order preference by similarity to ideal solution (TOPSIS)

TOPSIS proposed by Hwang and Yoon (1981) is one of the well-known methods for classical MCDM (Fig. 4).

The general TOPSIS process with six activities is listed below (Olson, 2004):

Step 1. Establish a decision matrix for the ranking. The structure of the matrix can be expressed as follows:

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

where A_i denotes the alternatives i, i = 1, ..., m; F_j represents j^{th} attribute or criterion, j = 1, ..., n, related to i^{th} alternative; and f_{ij} is a crisp value indicating the performance rating of each alternative A_i with respect to each criterion F_j .

Step 2. Calculate the normalized decision matrix R(=[r_{ij}]). The normalized value r_{ij} is calculated as (Equation 2):

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad (2)$$

where j = 1 ... n; i = 1, ..., m.

Step 3. Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights (Equation 3). The weighted normalized value V_{ij} is calculated as:

$$V_{ij} = R_{ij}.W_{n\times n} = \begin{bmatrix} v_{11,\dots} v_{1j,\dots} v_{1n} \\ . \quad . \quad . \\ . \quad . \quad . \\ v_{m1,\dots} v_{mj,\dots} v_{mn} \end{bmatrix} \quad (3)$$

where w_j represents the weight of the j^{th} attribute or criterion.

Step 4. Determine the PIS and NIS (Equations 4 and 5), respectively:

$$A^+ = \left\{(\max V_{ij} \mid j \in J), (\min V_{ij} \mid j \in J`) \mid i = 1,2,\dots m\right\} = \{V_1^+, V_2^+, \dots, V_j^+, \dots, V_n^+\} \quad (4)$$

$$A^+ = \left\{(\min V_{ij} \mid j \in J), (\max V_{ij} \mid j \in J`) i = 1,2,\dots m\right\} = \{V_1^-, V_2^-, \dots, V_j^-, \dots, V_n^-\} \quad (5)$$

where J is associated with the positive criteria and J` is associated with the negative criteria.

Step 5. Calculate the separation measures, using the m-dimensional Euclidean distance. The separation measure D_i^+ of each alternative from the PIS is given as (Equation 6):

$$d_{i+}\sqrt{\sum_{j=1}^{n}(V_{ij} - V^+_j)^2} ; i = 1,2,\dots,m \quad (6)$$

Similarly, the separation measure D_i^- of each alternative from the NIS is as follows (Equation 7):

$$d_{i-}\sqrt{\sum_{j=1}^{n}(V_{ij} - V^-_j)^2} ; i = 1,2,\dots,m \quad (7)$$

Step 6. Calculate the relative closeness to the idea solution and rank the alternatives in descending order. The relative closeness of the alternative A_i with respect to PIS V^+ can be expressed as (Equation 8):

$$cl_{i+} = \frac{d_{i-}}{d_{i+} + d_{i-}} ; 0 \le cl_{i+} \le 1 ; i = 1,2,\dots,m \quad (8)$$

where the index value of C_i lies between 0 and 1. The larger the index value, the better the performance of the alternatives.

3. 3. Linear assignment

Linear assignment is one of the MCDM (Fig. 4). Process steps are as follows:

Step 1. Establishing Decision Making matrix

First, decision Making Matrix is established based on quantitative data related to the indicators in each area.

Step 2. Ranking options according to available indicators.

Second, the areas are prioritized based on their ranks in each indicator.

Step 3. Establishing QG Matrix

Third, having access to determined weights of indicators (W), QG Matrix is established. Each element in QG Matrix equals (Equation 9):

$$^{q}/_{it} = \sum_{j=1}^{n} \pi itj \,.\, wj \quad (9)$$

If option i were in rank t in indicator j, then πitj= 1, otherwise it would be πitj.

Step 4. The following assignment problem is solved with variables (0, 1 hit) in order to determine the final priority of options (Equation 10).

$$\max: \sum_{i=1}^{m}\sum_{k=1}^{m} \gamma_{ik} \cdot h_{ik} \tag{10}$$

$$s.t \quad : \sum_{k=1}^{m} h_{ik} = 1 \quad ; \quad i = 1,2,\dots,m$$

$$\sum_{i=1}^{m} h_{ik} = 1 \quad ; \quad k = 1,2,\dots,m$$

$$h_{ik}\begin{cases} = 1 \\ = 0 \end{cases}$$

Step 5. Ranking Options. In the final stage, the options are ranked.

3. 4. ELECTRE

The use of ELECTRE in selection of plant species allows the decision-makers to incorporate unquantifiable information into decision model (Fig. 4). The steps of this model are as follows:

1. Establishing Decision Making Matrix

According to the criteria and numbers of options and evaluation of whole options for the different criteria, Decision Making Matrix develops as follow;

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \cdots & \cdots\cdot \\ x_{1m} & \cdots & x_{mn} \end{bmatrix}$$

in which the function of Xij (i = 1,2, ..., M) is in relation to the criteria I j (j = 1,2,3, ..., n).

2. Scale down the decision making matrix

In this stage, all criteria with different dimensions is changed into the dimensionless criteria and matrix R defined as follows. There are several methods to scale down, but generally the following equation used in electrical method (Vami, 1992).

$$R = \begin{bmatrix} r_{11} & \dots & r_{1n} \\ \vdots & \dots\dots & \dots \\ r_{m1} & \dots & r_{mn} \end{bmatrix} \quad r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{11}$$

3. Determining Weighted Matrix of criteria

$$W = \begin{bmatrix} w_1 & \dots & 0 \\ \vdots & w_2 & \dots \\ 0 & \dots & w_n \end{bmatrix}$$

As shown, Weighted Matrix (W) is a diagonal matrix in which the elements on main diameter are not zero and the amount of these elements equal to importance coefficient of the related vector.

4. Determining Weighted Normalized Decision Matrix

Weighted Normalized Decision Matrix is obtained by multiplying scale down Decision Making Matrix into the Weighted Matrix of criteria.

$$V = R \times W = \begin{bmatrix} v_{11} & \dots & v_{1n} \\ \vdots & \dots & \dots \\ v_{m1} & \dots & v_{mn} \end{bmatrix}$$

5. Establishing agree and disagree criteria set

The criteria set J = (1, 2... m) divides into two subsets; agree and disagree for each pair of options e, k (k, e = 1,2, ..., M, k # e). Agree Set (S_{Ke}) is a set of criteria in which option K is preferred to option e, and its complementary set is the opposite set (I_{Ke}) in mathematical language;

$$S_{ke} = \{j | v_{kj} \geq v_{ej}\} \tag{12}$$

$$I_{ke} = \{j | v_{kj} \prec v_{ej}\} \tag{13}$$

6.Establishing Agree Matrix

To establish agree matrix, its elements, agree indicators, should be calculated. Agree indicator is the sum of weight of criteria in agree set. Thus, indicator C_{ke} is between option k and option e equals to (Roy, 1991):

$$c_{ke} = \frac{\sum_{j \in s_{ke}} W_j}{\sum_{j=1} W_j} \tag{14}$$

For total normalized weights $\sum_{j \in 1} W_j$ equals 1, so:

$$c_{ke} = \sum_{j \in s_{ke}} W_j \tag{15}$$

Agreement represents the superiority of options k on option e which its amount changes in the range of zero to one (0-1). After calculating agree indicator for all options, matrix which is a m * m matrix is defined as follows. Generally, this matrix is not symmetrical.

$$C = \begin{bmatrix} - & c_{12} & \cdots & c_{1m} \\ c_{21} & - & \cdots & c_{2m} \\ \vdots & \vdots & - & \vdots \\ c_{m1} & \cdots & c_{m(m-1)} & - \end{bmatrix}$$

7. Determining Opposite Matrix

Disagreement indicator (opposite) is described as follows (TiLLe and Dumont, 2003).

$$d_{ke} = \frac{\max_{j \in I_{ke}} |v_{kj} - v_{ej}|}{\max_{j \in J} |v_{kj} - v_{ej}|} \tag{16}$$

The amount of disagreement indicator changes from zero to one. After calculating disagree indicator for all options, matrix which is a m * m matrix is defined as follows. Generally, this matrix is not symmetrical.

$$D = \begin{bmatrix} - & d_{12} & \cdots & d_{1m} \\ d_{21} & - & \cdots & d_{2m} \\ \vdots & \vdots & - & \vdots \\ d_{m1} & \cdots & d_{m(m-1)} & - \end{bmatrix}$$

8. Establishing agree dominant matrix

In the sixth step, how to calculate the agreement indicator C_{ke} is shown. Now, there is a determined amount for agreement indicator in this step which is called agreement threshold $\bar{c}$. If C_{ke} is larger $\bar{c}$, option k is preferred on option e, otherwise it is not. Agreed threshold is calculated by the following equation (Roy, 1991).

$$\bar{c} = \sum_{\substack{k=1 \\ k \neq e}}^{m} \sum_{\substack{e=1 \\ e \neq k}}^{m} \frac{c_{ke}}{m(m-1)} \tag{17}$$

Agree Dominated Matrix (F) is developed based on the amount of agreement threshold and its elements are determined in the equation below (Ghodsi Poor, 2009):

$$f_{ke} = \begin{cases} 0 & c_{ke} \geq \bar{c} \\ 1 & c_{ke} < \bar{c} \end{cases} \tag{18}$$

9. Establishing Opposed Dominance Matrix
Opposed Dominance Matrix (G) is established the same as Agree Dominated Matrix. First, decision makers should express opposite threshold $\bar{d}$ which is for example the mean of opposite indicators (disagreement) (Roy, 1991).

$$\bar{d} = \sum_{\substack{k=1 \\ k \neq e}}^{m} \sum_{\substack{e=1 \\ e \neq k}}^{m} \frac{d_{ke}}{m(m-1)} \tag{19}$$

Similar to the seventh step, it is better that the amount of opposite indicator (d_{ke}) become less, because opposite amount (disagreement) expresses superiorities dimension of option k on option is acceptable. In contrast, if (d_{ke}) were larger than $\bar{d}$, opposite amount would be very great and it would not be ignored. Thus, Opposed Dominance Matrix is defined as follows (Roy, 1991).

$$g_{ke} = \begin{cases} 0 & d_{ke} \geq \bar{d} \\ 1 & d_{ke} < \bar{d} \end{cases} \tag{20}$$

Each element in the matrix (G) shows the dominant relationship between options.

10. Establishing Final Dominant Matrix
Final Dominant Matrix (H) is developed after multiplying each element in Agree Dominated Matrix (F) into elements in Opposed Dominance Matrix (G) (Roy, 1991).

$$h_{ke} = f_{ke} . g_{ke} \tag{21}$$

11. Removing less satisfaction options and selecting the best option

4. Results and Discussion

The aim of this study was to compare Nebkas in the Chah Jam Erg, and introduce the most appropriate type for quicksand stabilization, using analysis of Nebka morphometric parameters, via ELECTRE, TOPSIS and linear algorithms. These algorithms are methods of MCDM, which combine the quantitative and qualitative indicators and weights according to the importance of each criterion, and can help decision makers to choose the best alternative. For this achievement, first, the most important morphometric parameters of 462 Nebkas from *A. gummifer*, *S. florida*, *T. macatensis*, *Z. eurypterum*, *A. mannifera*, *S. rigida*, and *Haloxylon* type were measured using linear sampling in the field. Then, the studied Nebkas were prioritized using comparative evaluation by ELECTRE TOPSIS and linear algorithms. The results of ELECTRE model show that *Haloxylon* Nebkas, with weight of 6, has the highest effect in stabilization of quicksand. *A. gummifer* and *A. mannifera* Nebkas, with weight of -6, have less importance (Table 5). Therefore, for implementation of stabilization projects of mobile sands in the study area, development of *Haloxylon* Nebka systems have the highest importance and efficiency.

TOPSIS is an important analysis method in systems engineering, especially in finite choices of decision-making. The basic thought of TOPSIS is: first, find out the best and the worst choice among finite choices after standardizing the original data matrix; second, calculate the distance between each choice and the best one, the same as the worst one. Then, the approached extent between each selection and the best one can be obtained. And according to this, every project can be evaluated. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. In short, the ideal solution consists of all the best values attainable of the criteria, whereas the negative ideal solution composed of all the worst values attainable of the criteria. The optimal alternative is the one which has the shortest

Table 3. The advantages of ELECTRE, TOPSIS and linear assignment models

Evalution Criteria / Methods	Stakeholderparticipation	Acceptance of diversitydata	ease of learning	Need todecision-makers	toexpandthe literature	Required time	optimism andrisk taking	the necessary tools	toexpandapplication of method	sustainability answer
ELECTRE	High	Medium	Medium	little	High	High	No	little	High	High
TOPSIS	little	High	Medium	little	Medium	Medium	No	little	Medium	Medium
Linear	High	High	High	little	little	Medium	No	Medium	Medium	little

Table 4. Collected data matrix

Criteria / Species	Height of nebkha	Volume of nebkha	canopy cover	Height of plant	canopy diameter
Seidlitzia florida	0.23	0.29	0.1	0.29	0.23
Tamarix macatensis	0.7	1.16	3.1	1.5	0.38
Alhagi mannifera	0.21	0.019	0.64	0.32	0.62
Astragalus gummifer	0.2	0.065	0.05	0.65	0.15
Zygophyllum eurypterum	0.6	1.4	2.3	1.5	0.35
Salsola rigida	0.21	0.62	0.6	0.4	0.23
Haloxylon aphyllum	1.1	2.4	4.3	1.7	0.8

Table 5. Ranking of species using ELECTRE

Species	Number of Win	Number of Defeat	Difference
Seidlitzia florida	1	5	-4
Tamarix macatensis	5	1	4
Alhagi mannifera	0	6	-6
Astragalus gummifer	0	6	-6
Zygophyllum eurypterum	4	2	2
Salsola rigida	3	3	0
Haloxylon aphyllum	6	0	6

distance from the ideal solution and the farthest distance from the negative ideal solution. The results of TOPSIS model (Table 6 and Fig. 5) show that *H. aphyllum* obtain the highest point (1) which has the highest effect in stabilization of quicksand. In contrast, *S. florida* species with 0/040 point goes down to the last rank and so it is not suitable for stabilization of quicksand and species of *T. macatensis*, *Z. eurypterum*, *A. gummifer*, *S. rigida*, *A. mannifera* with 0.606, 0.518, 0.087, 0.083, 0.078 points are located in the next ranks.

Linear assignment is one of the MCDM combines qualitative and quantitative indicators, weights criteria based on their importance and helps decision makers to select the best options at the same time. In this method, supposed options are ranked based on their points in each available indicator, then the final rank of the options is determined by the linear compensatory process. The results of linear assignment model (Table 7) show that *H. aphyllum* has the highest effect in stabilization of quicksand.

5. Conclusions

This study does not only investigate the MCDM and provide a complete algorithm to perform MCDM, but also examine ELECTRE, linear assignment and TOPSIS models. Then, select the desired option from the available options for selecting the best plant

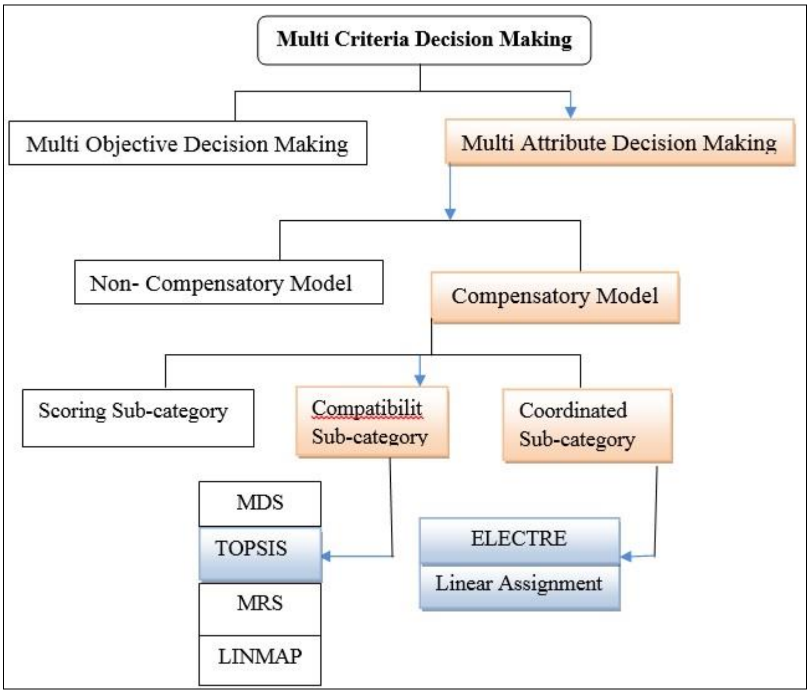

Fig. 5. Situation of ELECTRE, TOPSIS and Linear assignment model among MCDM models

Table 6. Ranking of species using TOPSIS

Species	Seidlitzia florida	Tamarix macatensis	Alhagi mannifera	Astragalus gummifer	Zygophyllum eurypterum	Salsola rigida	Haloxylon aphyllum
D_i^+	0.313	0.130	0.312	0.313	0.161	0.306	0
D_i^-	0.013	0.201	0.026	0.030	0.173	0.028	0.323
Cl_i^+	0.040	0.606	0.078	0.087	0.518	0.083	1
Rank	Seventh	Second	Sixth	Fourth	Third	Fifth	First

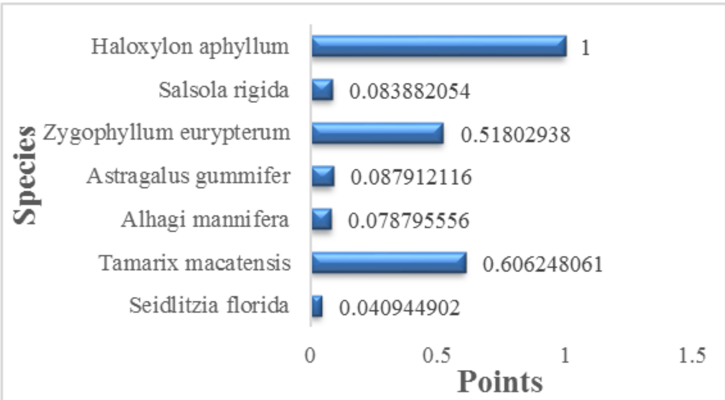

Fig. 5. Ranking of species using TOPSIS

Table 7. Ranking of species using linear assignment

Point Species								Rank
Seidlitzia florid	0	0	0	0	0	1	0	Sixth
Tamarix macatensis	0	1	0	0	0	0	0	Second
Alhagi mannifera	0	0	0	0	0	0	1	Seventh
Astragalus gummifer	0	0	0	1	0	0	0	Fourth
Zygophyllum eurypterum	0	0	1	0	0	0	0	Third
Salsola rigida	0	0	0	0	1	0	0	Fifth
Haloxylonaphyllum	1	0	0	0	0	0	0	First

species to development Nebkazars. However, Mousavi et al. (2012) have once investigated about choosing the best plant species using the method of analytic hierarchy process, but the results of the studies show that the results are different in different methods. Therefore, it is essential that the selection of the appropriate method for MCDM analysis should be carefully and more sensitive. However, certainly, a specific method cannot be proposed for a specific decision. Each of the methods has features which they use; results of the MCDM problems are more desirable. In choosing a suitable method for MCDM requires appropriate decision makers and it is necessary that the final choice of the method of MCDM analysis and sensitivity are selected. In addition, the group and integrated decision making and comments of participants agreeing with the decision-maker can be use to select the best option.

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