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Selection The Most Suitable Species type for stabiliting sand dunes in dealing with the spread of desertification for environmental sustainability using TOPSIS method (Case study: Chah Jam Erg in South of Haj Ali Gholi Playa in Central part of Semnan Province, Iran)

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ABSTRACT

The protection of environment and natural resources has high importance in achieving sustainable development. Desertification is one of the major issues threatening human communities. This phenomenon threatens about 40% of the global land surface and has influenced the life of 785 million people. In recent years, desertification control and reduction have been the most important projects in national and international organizations. Many methods have been developed for assessment and mapping of desertification hazards. Decision making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multiple criteria decision making (MCDM) problem. Purpose of this study is ranking of plant species in order to stabilize sand dunes in dealing with the spread of desertification.according this research Haloxlylon Species with (0/943) point promotes in first rank among 7 studied Species and thus it is the most appropriate Species for stabilize sand dunes in dealing with the spread of desertification and Alhagi maurorum with (0/020) point goes down to the last rank and so it isn`t suitable for stabilize sand dunes and Species (Salsola Kali, Peganum harmala, Seidlitzia rosmarinus, Astragalus, Tamarix hispida) with (0/629, 0/559, 0/485, 0/394, 0/329) points are located in next ranks.

Introduction

According to Glantz,s theory, desertification term has about one hundred definitions(Glantz, 1977).The common point in all these definitions is the severe demolition of the environment due to desertification..Some of these definitions are: ecosystem degradation (Reining, 1978), degradation of plant species (Le Houerou, 1975), decrease of ecosystem production and a decrease in biological production. Each of these definitions shows the ecosystem change from favorable conditions to unfavorable conditions and decrease of biological production. According to the definition given in the Convention to Combat Desertification taken by the United Nations (1994), desertification is any land degradation in arid, semi-arid and dry subhumid areas, resulting from various factors, including climatic variations and human activities. Arid, semi-arid and dry sub humid areas are defined as lands having a Precipitation / Potential Evapotranspiration ratio (P/ETP) ranging between 0.05 and 0.65. Land degradation (soil salinity, sodicity, acidity and erosion) is a reduction of current or future capacity of soil to produce (Dregne, 1987;Higgins, 1988). It can be occurred because of erosion, decline in fertility, changes in aeration and moisture content, salinization, or achange in soil flora or fauna (Barrow, 1997).Success in combating desertification will require an improved understanding of its causes and impacts and especially the linkage between desertification and some change in climate, soil, water, land cover and socio-economic factors. During the desertification process because of climate change and human impacts, soil characteristics changes during the desertification impacts. Soil salinity and alkalinity degrades soil structure and consequently decrease productivity. Therefore, evaluation of soil changes can be as a suitable indicator to assess desertification intensity. To evaluate the situation of soil degradation as an indicator, which is affected by desertification, related indices of soil, should be considered. Therefore, through evaluation of soil, it is possible to determine desertification intensity. These indices have three characteristics which are very important in Iran; simplicity, availability, and finally existing comprehensive basic data. Thus, selected indices must be able to show the changes in productivity and potential of production. At present desertification is a serious problem plagued many countries of the world. Considering and paying attention to desertification for a country like Iran which 80 million hectares of which is covered by dry and semi dry areas, is a necessary and inevitable issue.12 million hectares of this area is covered by running sands , 6 million of which is formed of active sand hills (Refahi , 2006) . Wind erosion due to wind blowing usually happens on bare areas with no surface vegetation cover. Wind is said to horizontal movements of the atmosphere. Wind is subject to pressure, therefore changes of pressure produces different winds in the atmosphere. At the low levels of the atmosphere, molecules are near to each other, the contacts are great and the pressure is high, therefore the wind blows in the direction which has the highest pressure (Moghimi 2006). Soil erosion is a phenomenon, in which soil is displaced due to environmental

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factors like water, wind, gravity force and so on and after carrying, is deposited in another area. The under study area is considered as one of the driest areas in the world and wind erosion is actively salient in this area and each year, makes a great deal of soil out of access. In the areas with no control on erosion, the soils are gradually eroded and lose their fertility. Erosion, not only weakens the soil and desolates the farms and makes great and irreparable damages, but also through sedimentation of materials in water ways, dam reservoirs, ports and decreasing their impounding capacity, makes Rstages. Such situation is visible in the study area which is a large part of Sistan plain and Hamoon Lake. Wind erosion is saliently active in this region. During wind erosion, the particles are moved by three methods of creeping, jumping and suspension. Particles mostly move by jumping movements. Diameters of jumping particles are usually between 0.05 up 0.5mm. umping movements of particles are usually happened at the limit of 0.1up to 0.15mm (Refahi 2006).increase of soil erosion, in addition to the soil features and nature depends greatly on the jumping particles. So that the particles which are moved by jumping method, when contacting with the ground surface, move the resting particles of the ground surface. During this process, the particles which their threshold speed is more than the wind rate will move. Different methods are presented for assessment and desertification of hazard zonation. The most important methods which can be noted are ICD3 method (Ekhtesasi and Mohajeri, 1995), MICD4 method with emphasis on wind erosion process (Ahmadi *et al*., 2005), FAO/UNEP method (1984), Turkmenistan academy of sciences method (Babaev, 1985), MEDALUS method (Kasmas *et al*., 1999) and desertification risk index (Dafang *et al*., 2006). Ladsia (2000) studied desertification in Barry, Italy, with MEDALUS model. In this research indices such as soil, climate, vegetation, land use, management quality and anthropogenic factors were evaluated. Doran and Parkin (1994) proposed a minimum data set for characterizing and monitoring soil indicator. Quantitative indicators of soil includes soil attributes and properties such as texture, rooting depth, bulk density, infiltration, water retention characteristics, soil organic matter, electrical conductivity, extractable N, P, and K, microbial biomass, and soil respiration. There are many examples of applications of TOPSIS in literature (For instance: The evaluation of service quality[Tsuar,2010]; Inter company comparison [Deng,2012]; The applications inaggregate production planning [Wang,2012], Facility location selection [Chu,2014] and large scale nonlinear programming [Abo-Sina,2014]. Purpose of this study is ranking of plant species in order to stabilize sand dunes in dealing with the spread of desertification using TOPSIS method

Methods and materials

Geographical position:

The studied field is located in south of Haj Ali Gholi playa, in central part of Semnan province, IRAN (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 windy geomorphic process have been dominated upon other processes around of this playa. So, we can observe some kinds of windy features erosion in this region. Chah Jam erg, with extent about 25260 hectares, is one of the most important of ergs of Haj Ali Gholi playa that is located rregularly along northeastern - southwestern edge of playa with 10 to 12 km length (Ahmadi, 2007). Studied field (Chah Jam erg) is bounded between latitudes 350, 45 to 350ó, 50 N and between longitudes 540, 40 to 550, 10 E (Fig. 1).

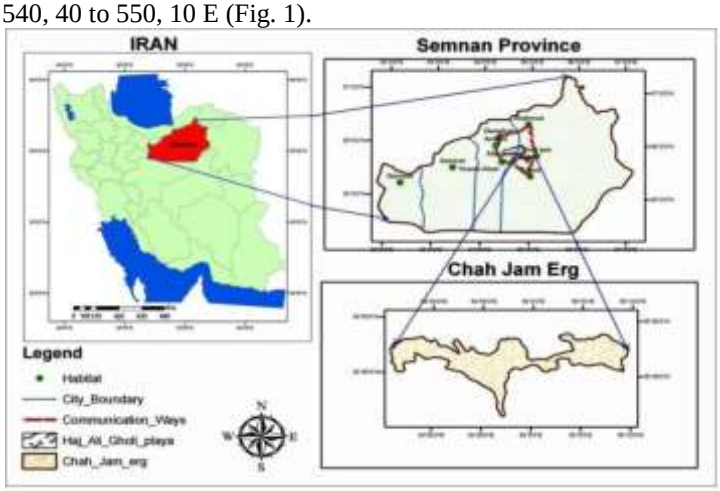

Figure (1): mathematical situation of studied area

Climatic conditions

The typical geographical position of studied area is caused opposite climatic conditions in different seasons of year. Furthermore, human and natural intensified factors of desertification are other reasons of opposite climatic conditions in this area. Position of field in south of Alborz chain mountain, vicinity with dry plains of Central Iran, remote from moisture masses, be influence of rainy masses, direction and length of chain mountains and locally dry winds are caused a arid climate for 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 about 4.9 knots, although dusty winds occasionally come from the other direction**.**

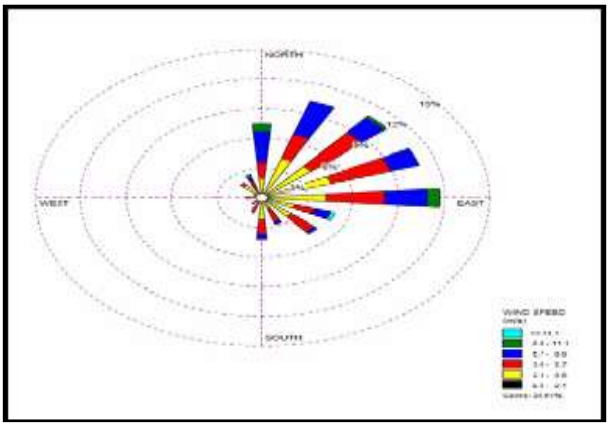

Figure 2. Wind rose of Damghan, in north of Chah Jam erg (from 2005 to 2012)

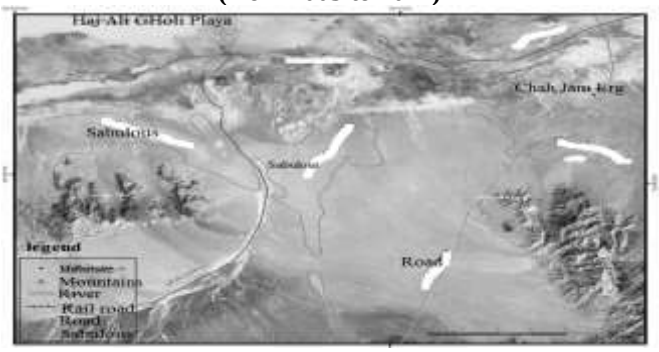

Figure 3:Spread of Sand Dunes

Methods and techniques

Firstly, studied area was investigated by the satellite images of Google Earth and its limitations were determined. Then

Descriptive and analytical methods were used for studying of Nebkas. In addition morphometric characteristic of selected nebkas were measured during the fieldwork.. After identification of study area using aerial photos and satellite images, morphometric characteristic were measured. In fact, we identified ten transects and selected some Nebkas in transects, morphometric characteristic were measured. Also statistical parameters of samples using SPSS software were calculated. Finally, the studied Nebkas were prioritized using comparative evaluation by TOPSIS Method.

-Problem solving process using TOPSIS method

TOPSIS model includes 8 processes which are described in the following parts (Olson, 2003-2).

1. Establishing data matrix based on alternative n and indicator k:

Generally, in TOPSIS model, matrix **n×m** with **m** alternative and **n** criteria is evaluated. In this algorithm, it is supposed that each indicator and criterion in Decision Making matrix has steady increasing and decreasing utility.

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

2. Standardizing data and preparing normalized matrix (matrix R) by Equation (1):

Since it is possible that quantitative amount of criteria and indicators don`t have equal unit , the dimensions of their units should be omitted. Thus, all amounts of entries of Decision Making matrix should be changed into dimensionless amount with following formula:

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

$$\begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ . & . & & . \\ . & . & & . \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix}$$

3. Determining weights for whole indicators (W_j) by equation (2) and modifying calculated (W_j) by equation (3):

In this process, the weights of all indicators are calculated by expertise theories and approaches, Linmap method, AHP model, Antropi model and based on the importance of criteria. It is considerable that sum of criteria weights should be equal to 1. In this study, AHP model has been used to calculate the amount of (W_j) 9Table 3).

$$\sum_{j=1}^{n} w_j = 1 \quad : (2)$$

$$w'_j == \frac{\lambda_j . w_j}{\sum_{j=1}^{n} \lambda_j . w_j} :(3)$$

4. Creating dimensionless weighted matrix (V) to implement vector W as an input for algorithm:

In order that the amounts of entries in matrix R gain equal value, , sum of weights of parameter (W_j) are multiplied to the column of this matrix one by one. The acquired matrix is normalized and weighted matrix which is shown by sign (V) (Table 4).

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

Determining positive ideal (A^+) and negative ideal (A^-) by equations (4) and (5) respectively:

5. $$d_{i+} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^+_j\right)^2} ; i = 1, 2, \dots, m \quad (4)$$

6. $$d_{i-} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^-_j\right)^2} ; i = 1, 2, \dots, m \quad (5)$$

7. Calculating distance size of i-alternaive with ideals and using Euclidean method, by equations (6) and (7):

$$d_{i+} = \text{dictance of i} - \text{alternative from positive ideal} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^+_j\right)^2} ; i = 1, 2, \dots, m \quad (6)$$

$$d_{i-} = \text{distance of i} - \text{alternative from negative ideal} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^-_j\right)^2} ; i = 1, 2, \dots, m \quad (7)$$

Calculating relative closeness for i-alternative (A_i) i to ideal solution using equation (8):

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

As you can see, if $A_i = A^+$, then $d_{i+}=1$ and $cl_{i-}=0$, on the contrary if $A_i = A^-$, then $d_{i+}=1$ and $cl_{i-}=0$. In sum, the more alternative A_i is closer to ideal solution, the more value of cl_{i+} is closer to unit.

8. Ranking alternatives based on descending order of cl_{i+} :

This amount is fluctuating between 0 and 1. Thus, cl_{i+} =1 represents the highest rank and cl_{i+} =0 the lowest rank.

Discussion

Nowadays, environmental crisis and loss of natural resources are the principle causes for the creation of environmental management systems. The optimal management of natural resources requires the assessment and classification of ecological and environmental potentials. By this method, we can recognize the abilities and restrictions of resources, and predict their future trends. Thus, 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. Thirty 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 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. Systemic geomorphology is based on recognition of geomorphic forms and processes and relationships between them. Efficiency of this stand point, when there are linear and nonlinear reciprocal relationships between parts and elements of system, is very important. The studied system in this research is Sand Dune landscape in the south of Haj Ali Gholi playa. Sand dunes are open and natural systems and are capable of modeling in different levels Sand Dunes are one of the most important factors of Desertification. Desertification is one of the major issues threatening human communities.

Table 1. Values of climatic elements of 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

Table (2): Decision Matrix (X)

Criteria / **Species**	**The rate of compatibility**	**The height of the plant (cm)**	**Density (ha)**	**The diameter of the canopy (cm)**	**The level of the canopy** (%)
Seidlitzia rosmarinus	5	75	80	30	22
Astragalus	4	80	70	80	45
Peganum harmala	6	55	90	40	17
Alhagi maurorum	1	35	40	45	23
Salsola Kali	7	45	105	42	30
Tamarix hispida	2	130	50	75	80
Haloxlylon	9	115	110	90	85

Table (3): Dimensionless Matrix (Matrix R)

0.3434	0.3408	0.3705	0.1846	0.1647
0.2747	0.3635	0.3242	0.4922	0.3368
0.4121	0.2499	0.4168	0.2461	0.1272
0.0687	0.1590	0.1852	0.2769	0.1721
0.4808	0.2045	0.4863	0.2584	0.2245
0.1374	0.5908	0.2316	0.4615	0.5988
0.6181	0.5226	0.5094	0.5538	0.6362

Table (4): Paired Comparison Matrix of different criteria (S)

1	3	5	7	9	0.5028
0.33	1	3	5	7	0.2602
0.2	0.33	1	3	5	0.1344
0.14	0.2	0.33	1	3	0.0678
0.11	0.14	0.2	0.33	1	0.0348
1.78	4.67	9.53	16.33	25	1

Table (5): Weighted dimensionless Decision Matrix (V)

0.1727	0.0887	0.0498	0.0125	0.0057
0.1381	0.0946	0.0436	0.0334	0.0117
0.2072	0.0650	0.0560	0.0167	0.0044
0.0345	0.0414	0.0249	0.0188	0.0060
0.2417	0.0532	0.0653	0.0175	0.0078
0.0691	0.1537	0.0311	0.0313	0.0208
0.3108	0.1360	0.0684	0.0375	0.0222

Table(6): Amounts of positive and negative ideals (highest and lowest function of indicator)

Criteria	**The rate of compatibility**	**The height of the plant (cm)**	**Density (ha)**	**The diameter of the canopy (cm)**	**The level of the canopy** (%)
A+	0.310804	0.153734	0.068442	0.037533	0.022152
A-	0.034534	0.04139	0.024888	0.012511	0.00443

Table (7): Distance o i-alternative by ideals using Euclidean method

Species / Distance	Seidlitzia rosmarinus	Astragalus	Peganum harmala	Alhagi maurorum	Salsola Kali	Tamarix hispida	Haloxlylon
D_i^+	0/148	0/120	0/170	0/006	0/211	0/120	0/396
D_i^-	0/485	0/394	0/559	0/020	0/629	0/329	0/943

Table (8): relative distance of i-alternative(A_i) to ideal solution

Cl_i	C1	C2	C3	C4	C5	C6	C7
Amount	0/485	0/394	0/559	0/020	0/629	0/329	0/943

Table (9): Points and Ranks of zones

Species	Seidlitzia rosmarinus	Astragalus	Peganum harmala	Alhagi maurorum	Salsola Kali	Tamarix hispida	Haloxlylon
Point (Fuzzy Logic)	0/485	0/394	0/559	0/020	0/629	0/329	0/943
Rank	Fourth	Fifth	Third	Seventh	Second	Sixth	First

This phenomenon threatens about 40% of the global land surface (Veron *et al*., 2006) and has influenced the life of 785 million people (Rangzan *et al*., 2008).

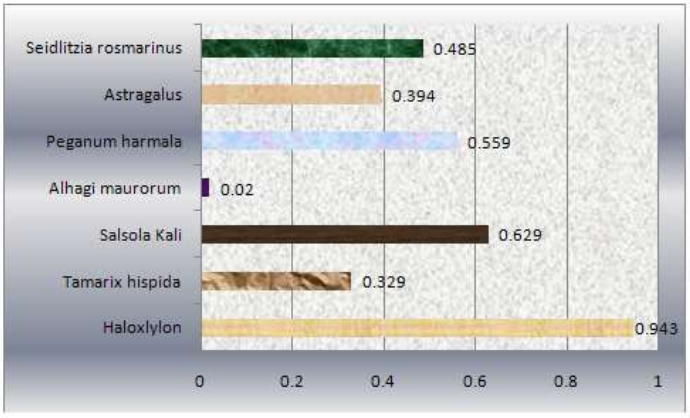

Figure 4: Points and Ranks

In recent years, desertification control and reduction have been the most important projects in national and international organizations. In general, the effective factors on intensifying the wind erosion in the area under study can be divided in to two human and environmental factors. Environmental factors are mainly rooted in the structure of climatic changes, geology, pedology and geomorphology, and human factors (management) can be used for uncontrolled grazing of livestock, clearing plants, changing forest and pasture lands toagricultural lands and non controlled and inappropriate use of lands. Although for specifying the priorities , it is sometimes required to use the statistics and comparing the under study parameters inparticular time periods , but until achieving this methods , it is possible to use the information, experiences and expressions of the people who have obtained during the long times of living in this area.TOPSIS proved to be a cost-effective and flexible method, as it provides a screening tool to identify, prefer and weight indicators for further investigation. However, this approach is not intended to substitute a scientific analysis of the indicators based on experimental research. After ranking indicators based on expert (and policy) relevance, they have then to be transformed into operational indicators, by conducting field research where necessary, to actually develop and integrate them into structured indicator sets. Furthermore, indicators can be selected and substituted to match the specific characteristics of each type. Since the land degradation conditions are various in different regions, the method can be applied with proper adjustment, provided the principal factors affecting desertification are identified and the relevant data layers are available. The results of TOPSIS method to ranking of plant species in order to stabilize sand dunes in dealing with the spread of desertification using are showed in tables (2-9) .

Figure 5: Sand dunes in study area and their effect on desertification and disturbance of human infrastructure

Conclusion:

At present, 65 percentage of Iran plateau is being located in arid and semiarid climate, and dry regions with Aeolian sand dunes (fig 5) and sparse vegetation are covering million 80 hectares from its area. Mobile sand dunes occupy million 12 hectares from this extent, approximately (Refahi, 2004). Interaction among climatic processes, obstacles of earth surface and Aeolian sediments characteristics are causes of creation of Sand dunes in study area. Sand dunes have been forming from quick sand, and is placement and lateral movements is the most important of their characteristics. These features igrate along prevailing wind, while approximately maintain their crescent shape. The Purpose of this paper is stabiliting of Sand Dunes in dealing with the spread of desertification.

The research has shown that Haloxlylon Species with (0/943) point promotes in first rank among 7 studied because of high rate of compatibility with environment,also this plant has high height and Prevent sediment movement in other hand this shrub Species is the most appropriate Species for stabilizing sand dunes in dealing with the spread of desertification and Alhagi maurorum with (0/020) point because of low rate of compatibility with environment and low capacity for prevent sediment movement goes down to the last rank and so it isn`t suitable for stabilize sand dunes and Species (Salsola Kali, Peganum harmala, Seidlitzia rosmarinus, Astragalus, Tamarix hispida) with (0/629, 0/559, 0/485, 0/394, 0/329) points are located in next ranks.

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