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Abstract: Executive practices on desertification control should be based on the recognition of current desertification state and its severity. So, it's essential to assess the ways which can give zoning based on logic, active principles and theoretical foundation for the management of desert regions. For this aim 30 effective indices on desertification were determined in two human and natural sections. The significance of indices relative to each other and also the importance of each index in per work unit were determined using the Delphi method. Bonissone method in the framework of the Fuzzy Multiple Attribute Decision Making (FMADM) method was used to combine indices and determine desertification intensity in each working unit. Then data were converted to Fuzzy layer using Chen and Wang method, and Fuzzy analysis was performed on data. Finally, Fuzzy data were changed to non-Fuzzy, and desertification intensity was estimated. The results showed that 9.35% of the study area was in very high class regarding desertification intensity and 9.36% of the region was in relatively high class. Desertification with moderate intensity (50.64%) and relatively moderate intensity (29.45%) had the most shares in the study area respectively. Also, the quantitative value of desertification potential in the whole area, from all of the components was obtained as 0.083, relatively high. This study shows efficiency and ease of Fuzzy logic application for assessing desertification intensity. The results provide the possibility of planning to minimize desertification due to the development projects implementation and also can create a balance between the development plans and environment according to the priorities and vulnerability desertification zoning.

Keywords: fuzzy logic; Bonissone method; madm; vulnerability; zoning.

1 Introduction

Desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from climatic changes or human activities [30]. According to the United Nations Convention to Combat Desertification (UNCCD), desertification will threat more than 785 million people living in arid areas which accounts for 17.7% of the world's population [15]. Also in Iran, desertification is a serious threat because 16 provinces with 57.5 million hectares are located in desert regions [18]. In these communities, desertification is a primary restriction for sustainable development [29]. So identification of the status quo is a fundamental step to achieve balanced growth. Identifying the status quo and determining ecological capacity in each region prevent environmental degradation during development, ensure the additional value of national and regional investment in the most stable and appropriate state and also make it possible to achieve the desired goals and policies. Hence, methods of assessing desertification intensity and also preparing zoning map of desertification are considered as the most essential tools for planning and management of natural resources to achieve sustainable development [32]. Many studies have been done about assessment of desertification potential in different areas including preliminary research for assessing classification map of desertification [12], Environment Sensitive Area to Desertification (ESA) [10], Iranian classification of desertification (ICD) [11], Iranian Model of Desertification Potential Assessment (IMDPA) [2], Modify Numerical Taxonomy (MNT) [21], Environmental vulnerability index (EVI) [22], Shannon Entropy Model [24] and Principal Component Analysis (PCA) [27].

In 1984, FAO-UNEP published a method entitled "preliminary research for assessing classification map of desertification." In this method, the current situation, rate, and risk of desertification are described. Desertification processes in this research include the destruction of vegetation, wind erosion, soil structure erosion and degradation, reduction of soil organic matter, salinity and alkalinity, waterlogging and accumulation of toxins. These processes are based on ground observations, aerial photos interpretation and available information which were classified into four classes (low, moderate, high and very high) using statistical modeling [12]. Then in 1996, Ekhtesasi and Mohajeri provided a method for classifying the type and severity of desertification in Iran. In this method, active factors in desertification are evaluating with weight balance method, and criteria for assessing these factors are usually descriptive and qualitative [11]. Then in 1999, United Nation provided ESA model in the framework of Mediterranean Desertification and Land Use project (MEDALUS) for assessing and mapping of desertification. In this model, four indices including soil quality, climate quality, plant cover quality, and management were defined as the most important indices of desertification. Finally, desertification map was obtained from the geometric average of the mentioned indices [10]. In 2006, Iranian Model of Desertification Potential Assessment (IMDPA) was provided at the University of Tehran, faculty of natural resources. This model tried to classify selective criteria and indices according to the environmental conditions of Iran. Therefore nine following criteria were considered: climate, geology, soil, plant cover, agriculture, erosion (wind and water), water and irrigation, socio-economic issues and industry and urbanism. Also, 35 indices were considered by experts for assessing desertification potential. Criteria scoring were expressed as a ranking way to minimize the error of rating and ease of rating [2]. Sadeghravesh et al. (2009) provided a model entitled Modify Numerical Taxonomy (MNT) [21]. This model has a hierarchical structure and is based on paired comparisons. To reduce the error of indicators valuation, this method uses the incompatibility index for automatic control on judgments in addition to Delphi method which is based on questionnaires.

The studies conducted on these methods have shown some defects on them including non-native and qualitative indices, the degree of error, the small-scale, impossibility of separating human and natural factors in conclusion, etc. Although these defects were resolved mainly in other models, especially in the Taxonomy model, these models have still major weaknesses, so that in evaluating indices, only the absolute value of each index is considered in per work unit and their priority is not considered in creating the critical condition which leads to unrealistic results. Hence, Sadeghravesh presented three models including EVI (Environmental Vulnerability Index), Shannon Entropy Model and Principle Component Analysis model during 2012- 2016. Like MNT model, these models have a hierarchical structure and estimate desertification potential or region vulnerability based on indices priority and each index importance in per work unit. But these models have a restriction and ignore the Fuzzy judgment of decision-makers. Real phenomena are always Fuzzy, imprecise and vague and Fuzzy logic is more realistic and closer to human behavior when it's necessary to select and make a decision [6] [16]. Some researches with the application of Fuzzy logic are as follow: Assessment of water management projects [28], security management in production [8], selecting resources planning systems [7], staff selection [9] [13] , election of suppliers [31], assessing companies efficiency [3], selecting location of waste disposal site [17], prioritization and ranking of desertification indices [20], assessment of energy resources [16], zoning of wind erosion potential [23] and evaluation of desertification strategies [25] [26].

The usual methods using definitive data are ambiguous in evaluation and ranking of indicators. In other words, there is no rational framework for uncertainty in decision making. But in natural options including the identification and evaluation of desertification indicators the researcher faces uncertainty. According to investigations, it was apparent that Fuzzy method has not been used in desertification intensity zoning, while this method quickly developed in different science. This study, using fuzzy logic and the use of inaccurate and non-deterministic data, makes it possible to study the conditions of uncertainty in the ranking and prioritization of desertification indicators. Bonissone Fuzzy method was used to achieve zoning purpose in the framework of multiple attribute decision making models. In this model, desertification intensity is estimated based on indices priority and their importance in each work unit. The results can be the basis for a new method and modification of the proposed methods in order to manage risk, evaluate and monitor desertification.

2 Materials and Methods

2.1 Study Area

Khezr Abad region with an area of 78180 ha is located in 10 km west of Yazd. This region extends from 53° 55’ to 54° 20’ eastern longitude and from 31° 45’ to 32° 15’ northern latitude. The average height of the region is 1397 m, and 84.79% of the region (663 km^2) has a slope lower than 10%. So the most extent of this area includes flat land with an average slope of 9.41%. Soil resources of the region are usually Entisols containing salt and gypsum which are formed under physical degradation and also are affected by water and wind erosion and degradation. Soil temperature regime is thermic, and soil moisture regime is aridic. The climate of this region is cold and arid based on Amberje climate classification method. Annual mean precipitation of this region is 121 mm. The direction of the dominant wind is Northwest with an occurrence frequency of 16.97% and a maximum speed of 16.3 km/hr. About 130 km^2 (16.5%) of the region include sanddunes. Ashkezar erg, site of sandstorms occurrence, with an area of 89 km^2 and eroded and degraded faces located on the north part of the study area. About 1,995 ha (26.5%) of all agricultural lands of the region consists of degraded lands resulting from human activities and natural factors. These characteristics of the area show its typical condition of desertification and also a requirement of identifying and preparing desertification vulnerability map of the area.

2.2 Methodology

There are different quantitative techniques for estimating and zoning desertification which are used to facilitate planning and assist in decision making.

In this research, Multiple Attribute Decision-Making method was used considering the number of effective indices in desertification zoning; also fuzzy logic was used for combining indices.

The usual process within MADM method and Fuzzy logic consist of 6 stages: determining effective indices, determining work units, determining the importance of indices and also each index importance in each work unit, Fuzzy data making, Fuzzy process and converting Fuzzy data to non-Fuzzy.

2.2.1 Determining effictive indices to assess desertification intensity

30 effective indices on desertification were determined in two human and natural sections based on the gained data through natural resources assessment and field study (table 1). In order to select indices, three main factors including relationship with desertification, ease of access and ease of updating were considered in the framework of time and expense factors [19] [22] [26].

Table 1

effective indexs on desertification vulnerability of the study area

Natural, effective indices on vulnerability	Human effective indices on vulnerability
Annual mean precipitation (mm)	Tilling and fallow
Average wind speed (m/s)	Irrigation method
Aridity index (P/ET_p)	Irrigation efficiency (%)
Soil texture	Irrigation system
Soil salinity (EC-mmhos/cm)	Groundwater depletion
Soil drainage (in/h)	Soil moisture
Soil depth (cm)	Use of machinery, chemical and organic fertilizer
Slope (%)	Cropping pattern and production management
Wind and water erosion	People's participation
Water salinity (EC-µmohs/cm)	Literacy (%)
The depth of groundwater level (cm)	Employment status
Vegetation cover density (%)	Population biological density (N/Km^2)
Shrubs and trees removing (%)	Land use changes
Carrying capacity of rangelands (AU/100 day)	Awareness of degradation results
Livestock pressure (capacity of rangeland/ existing livestock)	The land division into small parts

2.2.2 Determining work units

Work units were determined using geomorphology method to provide a proper framework for preparing vulnerability zoning map of desertification, [1]. For this aim, after collecting data from the interpretation of aerial photos, available digital data in map format and reports of organizations and offices, digital data were entered into ArcGIS software, and finally, maps of geomorphology, land use, and vegetation types were obtained. These layers were overlapped, and then the final layer of work units was formed (Fig1). 12 work units were selected according to the study goals.

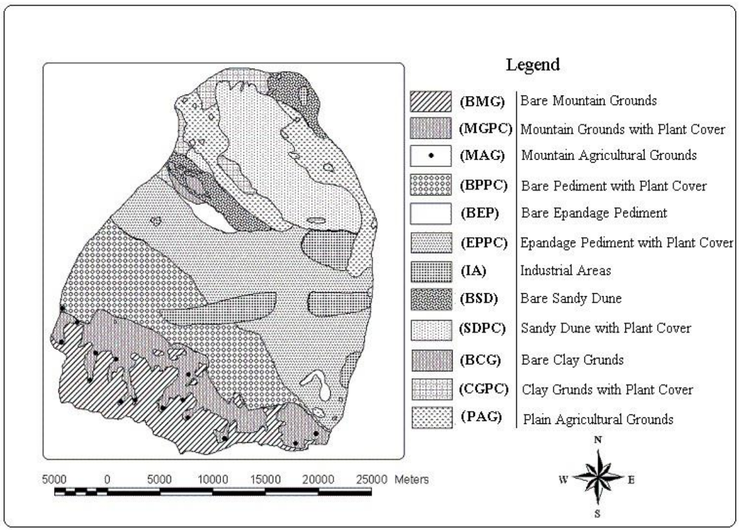

Figure 1
work units of Khezr Abad

2.2.3 Determining the importance of effective indices on desertification relative to each other and also in each work unit

The significance of indices relative to each other (w_j) and also the importance of each index in per work unit (r_{ij}) were determined using the Delphi method in the framework of MADM. To assess w_j and r_{ij}, a questionnaire was prepared and filled based on the seven-rank scale of Chen and Wang by experts familiar with the study area.

Table 2
Fuzzy preference and importance degree, Chen and Wang method

Linguistic indicators	Numerical value	Number of Linguistic indicators			
		2	3	5	7
Very Low	0≤, >1			(0, 0, 0, 1.2)	(0, 0, 1, 0)

Low	1≤, >2		(0, 0, 0,2, 0.4)	(0.1, 0.25, 0.25, 0.4)	(0.1, 0.2, 0.2, 0.3)
Relatively Moderate	2≤, >3				(0.2, 0.3, 0.4, 0.5)
Moderate	3≤, >4	(0.4, 0.5, 0.5, 0.8)	(0.2, 0.5, 0.5, 0.7)	(0.3, 0.5, 0.5, 0.7)	(0.4, 0.5, 0.5, 0.6)
Relatively High	4≤, >5				(0.5, 0.6, 0.7, 0.8)
High	5≤, >6	(0.5, 0.8, 0.8, 1)	(0.6, 0.8,1 , 1)	(0.6, 0.75, 0.75, 0.9)	(0.7, 0.8, 0.8, 0.9)
Very High	6≤, >7			(0.8, 0.9, 1, 1)	(0.8, 0.9, 1, 1)

Then judgments were combined using a geometric mean (Eq.1), and pairwise comparison matrix was gained. It was assumed that all experts' comments have the same importance degree.

$$\bar{a}_i = \left(\underset{K=1}{\overset{N}{\pi}} a_i{}^k \right)^{1/N} \tag{1}$$

a_i^k is related to k^{th} person in estimating importance degree of each index.

Then, using the concept of normalization (Eq.2) and weighted mean or the average of each row in the normalized matrix (Eq.3), the importance of indices (W_j) were estimated (Table 3) [5].

$$z_{ij} = \frac{a_{ij}}{\sum_{i=1}^{M} a_{ij}} \tag{2}$$

$$W_i = \frac{\sum_{i=1}^{N} z_{ij}}{N} \tag{3}$$

Table 3

The normalized matrix of the importance of indices relative to each other and determining the priority of each index

Indicator (I_i)	I_1	I_2	…	I_n	[2]W_i
I_1	[1]z_{11}	Z_{12}	…	Z_{1N}	W_1
I_1	a_{21}	a_{22}	…	Z_{2N}	W_2
:	:	:	…	:	:
I_M	Z_{M1}	Z_{M2}	…	Z_{MN}	W_M

2.2.4 Making Fuzzy data

This process includes shifting and converting inputs by the Fuzzy controller. The process has two stages including membership and rating functions. Membership function has different forms such as triangular, trapezoidal and arched. In this study, trapezoidal-shaped membership function was used.

The basis of Fuzzy logic is Fuzzy sets which are a general state of sets theory. These sets range from discontinuous set {0, 1} to continuous sets {0, 1}.

In the Fuzzy sets, assessment of each variable is performed using linguistic variables by importance degree and based on normal logic generalization to multi-valued or continues logic. Linguistic variables performance of a reference set like U in a trapezoidal function operates according to Eq. 4.

$$\tilde{A}(x) = \begin{cases} \frac{(e - x)}{(L - M)} e & L < x < M \\ e & M \le x < M' \\ \frac{(U - x)}{(U - M')} & M' \le x \le U \\ 0 \end{cases} \quad (4)$$

Otherwise, the membership function is trapezoidal-shaped.

Due to the multiplicity of linguistic variables, the Fuzzy numbers corresponding to them were used. Different methods have been provided for converting linguistic variables to the Fuzzy numbers corresponding to them. In this study seven-ranking scale of Chen and Wang was used (Table. 2).

According to the type of selected Fuzzy numbers (trapezoidal), Bonissone method was chosen among multiple attribute decision-making methods. In this method, it's assumed that algebraic operations on Fuzzy trapezoidal numbers (L-R) can be estimated as parametric. Bonissone showed each Fuzzy trapezoidal number ($\tilde{D}$) with four parameters (L, M, M′ and U) as the following equations:

The first Fuzzy number: $\tilde{D}_1 = (L_1, M_1, M_1', U_1)$ (5)

The second Fuzzy number: $\tilde{D}_2 = (L_2, M_2, M_2', U_2)$ (6)

Algebraic operations on these numbers are defined as the following equations (7-10):

$$\tilde{D}_1 + \tilde{D}_2 = (L_1 + L_2, M_1 + M_2, M_1' + M_2', U_1 + U_2) \quad (7)$$

$$\tilde{D}_1 - \tilde{D}_2 = (L_1 - U_2, M_1 - M_2', M_1' - M_2, U_1 - L_2) \quad (8)$$

$$\tilde{D}_1 \times \tilde{D}_2 = (L_1 \times L_2, M_1 \times M_2, M_1' \times M_2', U_1 \times U_2) \quad (9)$$

$$\frac{\tilde{D}_1}{\tilde{D}_2} = \left(\frac{L_1}{U_2}, \frac{M_1}{M_2'}, \frac{M_1'}{M_2}, \frac{U_1}{L_2} \right) \quad (10)$$

2.2.5 Converting Fuzzy data to non-Fuzzy and assessment of desertification intensity, determining the utility of each work unit (U_i)

Fuzzy utility index was used to assess efficiency. This index is a combination of the relative Fuzzy importance of indices compared to each other (W_j) and each index Fuzzy influence in each work unit (R_{ij}) regarding desertification. It was calculated based on equation 11 in each work unit [4] [6].

$$U_i = \sum_{j=1}^{n} W_j . R_{ij} \quad (11)$$

2.2.6 Calculating the importance degree of any trapezoidal Fuzzy utility number from another Fuzzy number

To determine the work units' weight or desertification intensity, it's necessary to arrange the amounts of all U_i after calculating them. So the importance degree of each Fuzzy number relative to other Fuzzy numbers was computed using equation 12, and the matrix of each work units magnitude degree was formed.

$$\begin{cases} V(D_1 \geq D_2) = 1, \\ M_1 \geq M_2' \\ V(D_1 \geq D_2) = hgt(D_1 \cap D_2) = \dfrac{U_1 - L_2}{(U_1 - L_2) + (M_2 - M_1')} \\ Otherwise \end{cases} \quad (12)$$

2.2.7 Calculating the importance degree of any trapezoidal Fuzzy utility number from other k- Fuzzy trapezoidal numbers (P_i)

After determining the magnitude degree of each Fuzzy number relative to different Fuzzy numbers, the importance degree of any trapezoidal Fuzzy utility number from different k- Fuzzy trapezoidal numbers (P_i) was calculated using equation 13.

$$P_i = \min V(D_1 \geq D_K), \quad i, k = 1, 2, \ldots, n \quad (13)$$

The numbers gained from this process shows abnormal weights of work units.

2.2.8 Normalization of abnormal weights of work units and assessing desertification potential

Finally, using equation 14, abnormal weights of work units were normalized to estimate desertification potential in each work unit [4] [6].

$$N_i = \frac{P_i}{\sum_{i=1}^{k} P_i} \quad i = 1,2,\ldots,n \tag{14}$$

3 Result

After determining effective indices (Table 1) and preparing maps of work units (Fig 1), group matrix of the indices importance relative to each other (W_j) and the importance of each index in each work unit (r_{ij}) was formed (Table 4).

Table 4

Group matrix of each index importance relative to each other and in each work unit regarding desertification

Desertification index	1	2	…	29	30
Group matrix of the indices importance relative to each other					
Importance	0.89	3.9	…	4	5.5
Linguistic words	Very low	Moderate	…	Relatively high	high
Trapezoidal Fuzzy component ($\tilde{D}$)	(0, 0, 0.1)	(0.4,0.5, 0.5, 0.6)	…	(0.5, 0.6, 0.7, 0.8)	(0.7, 0.8, 0.8, 0.9)
Group matrix of each index importance in each work unit					
BMG	3.5	3.8	…	0.75	0.78
MGPC	4.6	3.8	…	0.63	0.5
.	…	…	…	…	…
.	…	…	…	…	…
IA	4.4	3.8	…	0.35	0.95
MAG	3.6	3.8	…	0.5	4.8

Then, to make Fuzzy data, the seven-ranking scale of Chen and Wang (table 2) was used (Table 4 & 5).

Table 5
Fuzzy group matrix of each index importance in each work unit

TMUs \ I	1	2	…	29	30
(BMG)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0, 0.1, 0)
(MGPC)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0, 0.1, 0)
.	…	…	…	…	…
.	…	...	…	...	...
(IA)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0, 0.1, 0)
(MAG)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0.5, 0.6, 0.7, 0.8)

Then Fuzzy utility index (U_i) of all work units was estimated using equation 11 and utility matrix was formed (Table 6).

Table 6
Utility of each work unit based on Fuzzy logic

TMUs \ Fuzzy numbers	U	M′	M	L
(BMG)	7.03	4.45	3.91	2.76
(MGPC)	7.2	4.47	3.99	2.77
(BPPC)	7.02	4.14	3.65	2.43
(BEP)	5.95	3.33	2.91	1.95
(EPPC)	6.44	3.53	3.26	2.21
(PAG)	11.28	8.02	6.91	4.62
(CGPC)	7.53	4.68	4.14	2.82
(BCG)	6.64	3.9	3.39	2.28
(BSD)	6.21	3.51	3.13	2.07
(SDPC)	7.08	4.23	3.82	2.58
(IA)	7.48	4.49	3.86	2.48
(MAG)	12.5	9.14	7.99	5.5

Finally, to determine desertification intensity, magnitude degree of each Fuzzy number relative to other Fuzzy numbers was calculated using equation 12 and the matrix of all work units magnitude degree relative to each other was formed. Then, the abnormal weight of all work units (P_i) was determined using equation 13. These weights were normalized (N_i) using equation 14 (Table 7).

Table 7
The matrix of each work unit magnitude degree

TMUs	(BMG)	(MGPC)	**…**	**…**	(IA)	(MA)	P_i	N_i
(BMG)	1		…	…	1.1548	0.3029	0.3029	0.066
(MGPC)	1.1384	1	…	…	1.1428	0.3244	0.3244	0.071
...	…	…	…	…	…	…	…	…
...	…	…	…	…	…	…	…	…
(IA)	1.1400		…	…	1	0.3613	0.3613	0.079
(MAG)	1	1	…	…	1	1	1	0.22

Estimated values of desertification intensity (N_i) using equation 14 are continuous values which were estimated due to the ease of reading and understanding the results. Based on the Table 8, desertification intensity of the study area was classified into six levels.

Table 8
Classification of desertification intensity in Khezr Abad region and the area of each class

Class	Desertification intensity	Class	Area	
			Km^2	%
Low	$0.025 \leq N_i$	I	0.943	1.2
Relatively Moderate	$0.05 \leq N_i < 0.025$	II	23.113	29.45
Moderate	$0.075 \leq N_i < 0.05$	III	39.756	50.65
Relatively high	$0.1 \leq N_i < 0.075$	IV	7.339	9.35
High	$0.125 \leq N_i < 0.1$	V	-	-
Very High	$0.125 > N_i$	VI	7.336	9.35

Each work unit was located in one of the desertification classes and eventually, from combining the work units with the same classes, the final map of desertification potential with the scale of 1.50000 was gained using ArcGIS (Fig 2).

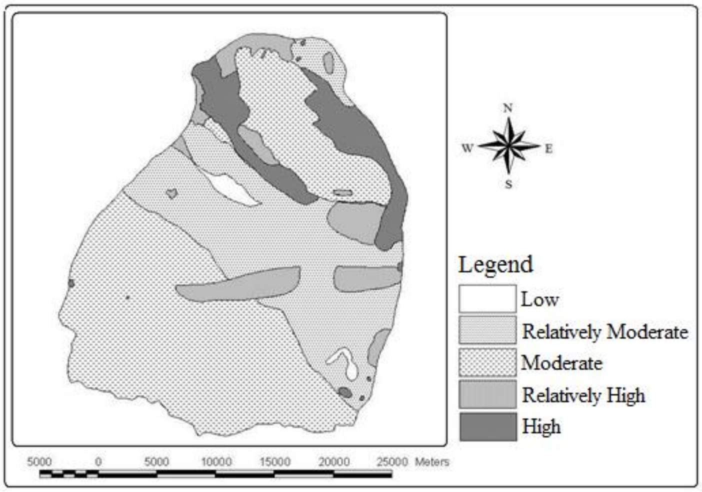

Figure 2

Zoning map of desertification intensity in Khezr Abad

4 Disscusion

The following results were gained based on assessing desertification intensity in each work unit. In terms of vulnerability caused by desertification, mountain agricultural grounds (MAG) and plain agricultural grounds (PAG) units were in very high class, with the most quantitative value equal to 22%. Clay grounds with plant cover (CPGC) with quantitative value of 0.083 was in relatively high class and other work units were located in moderate, relatively moderate and low classes.

In the determination of the importance of indices relative to each other, the quantitative values of groundwater level, irrigation system, irrigation method, and soil depth were estimated equal to 7 or very high. Also, the quantitative costs of irrigation efficiency, tilling and fallow, land division into small parts, cropping pattern and production management, biological population density, carrying capacity of rangelands and livestock pressure were estimated equal to 6 or high. Other indicators were not crucial in the assessment of desertification according to experts.

The most essential human indices affecting desertification in units include: inappropriate tilling and fallow (30- 50% of lands are not cultivated due to different factors), improper and low use of agricultural machinery, overuse of pesticides and fertilizers, traditional and inappropriate irrigation method with low efficiency (less than 40%), severe drop of groundwater table (45 cm/year), high population density (between 200 to 550 people per square kilometer), improper land use changes, unemployment, insignificant extent of agricultural lands and poor participation of native people.

The most important natural indices affecting desertification in units include: an extended dry period in which much of the area has no wet month, several days with Aeolian sand (more than 10 days per year), winds with velocity more than the threshold velocity of erosion (39%), the low ratio of precipitation to evapotranspiration (0.03- 0.05).

Low rainfall (less than 60 mm/ year), soils with medium to fine texture and poor drainage (0.5 to 1 inch per hour), having limiting gypsum and limestone layers in soil depth especially in units CGPC, BCG and PAG, sand dunes movement (up to 10 meters per year), high amount of salt and chlorine in groundwater (7620 mmohs/cm and 2350 mg/liter respectively), poor plant types of rangeland with the negative tendency due to overgrazing and livestock pressure (3.7 to 5.1 times more than the tolerable level) and digging plants (40% to 50%).

The results of assessing desertification intensity based on Fuzzy logic were compared to the effects of the Environmental Vulnerability Index [22], Shannon Entropy model [24] and Principle Components Analysis model [27] which estimate desertification intensity based on indices priority relative to each other and also each index importance in every work unit. In all four models, mountain agricultural ground unit (MAG) and plain agricultural ground unit (PAG) have the most potential of desertification, and in next stage, clay ground with plant cover (CGPC) and sanddune with plant cover (SDPC) are located. So, the results of this study were consistent with the results of EVI, Shannon Entropy and Principle Component Analysis models. But the quantitative values of various models are different. This occurs because of models nature which provides quantitative values in different ranges and also the different classification of quantitative values based on the range of acquired values in each study. Also in this method, unlike Shannon Entropy model in which the importance of indices is gained from Entropy method and without considering the expert's judgment, the influence of indices was acquired using Delphi technique, like EVI and PCA models. In the Fuzzy way, the significance of indices was assessed based on Chen and Wang scale while in EVI model, the final influence was gained based on nine-Saaty scale, normalization logic, and weighted mean. The results of this study seem to be more accurate owing to the use of Fuzzy logic for determining the importance of indices relative to each other and also each index importance in each work unit. According to the results of the evaluation of desertification intensity in work units, the quantitative value of desertification for the whole region was equal to 0.083 (class IV or relatively high).

Conclusions

Generally, the results showed that from the entire region, 7336 hectares (9.35%) was in class VI or very high, 7339 hectares (9.36%) was in IV class or relatively high, 39756 hectares (50.65%) was in class III or medium, 23113 hectares (29.45%) was in class II or relatively medium and 943 hectares (1.2%) was in I or low desertification intensity class (Table 5 and Fig 2).

These results can be considered in future evaluations to invest in sustainable development, ensure the additional value of investments and also protect marginal ecosystems of the study area. On the other hand, these results help the manager of desert areas to utilize limited facilities and stock, allocated to the control of desertification phenomenon, in regions with more vulnerability and prevent the waste of national funds.

To use this model in other regions, effective factors in desertification should be considered as inherent vulnerability indices, and also the impact of each factor on desertification should be emphasized.

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References

[1] H. Ahmadi: Applied geomorphology, desert and wind erosion. University of Tehran press, 2005, ISBN: 978-9640340359.

[2] H. Ahmadi, Gh. Zehtabian, M. Jafari, H. Azarnivand, S. Feizniya: Iranian model of desertification potential assessment. Faculty of Natural Resources, University of Tehran, 2006, pp. 480.

[3] H. Aghajani, M. Ahmadpour: Application of fuzzy topsis for ranking suppliers of supply chain in automobile manufacturing companies in Iran. Fuzzy Information Engineering, 2011, Vo. 3, No. 4, pp. 433-444, ISSN: 1616-8666, DOI: 10.1007/s12543-011-0096-3

[4] MJ. Asgharpour: Multi-criteria decision making. 15th edition, Tehran University Press, 2014, pp. 400.

[5] A. Azar, A. Rajabzadeh: Applied decision making with an approach of multi-attribute decision making (MADM). 7nd edition. Tehran, Publication of Negah Danesh, 2017, ISBN: 978-9641570837.

[6] A. Azar, H. Faraji: Science of fuzzy management. fifth edition, Mehraban press, 2016, ISBN: 978-9647725552.

[7] U Cebeci: Fuzzy AHP- based decision support system for selecting ERP system in the textile industry by using a balanced scorecard. Expert System with Applications, 2009, Vol. 36, pp. 8900-8909, ISSN: 0957-4174 DOI:10.1016/j.eswa.2008.11.046

[8] M. Dagdeviren, I. Yuksel: Developing an analytical hierarchy process (AHP) model for behavior-based management. Information Sciences, 2009,

Vol. 178, pp. 1717-1733, ISSN: 0020-0255, DOI: 10.1016/j.ins.2007.10.016

[9] M. Dagdeviren, S. Yavuz, N. Kilinc: Weapon selection using the AHP and TOPSIS methods under fuzzy environment. Expert Systems with Applications, 2009, Vol. 36, pp. 8143-8151, ISSN: 0957-4174, DOI: 10.1016/j.eswa.2008.10.016

[10] European commission: Mediteranean Desertification and Land use (MEDALUS) MEDALUS office. London, 1999.

[11] MR. Ekhtesasi, S. Mohajeri: Classification of the type and severity of desertification in Iran. The second national conference on desert areas issues, Kerman, Iran, 1995, pp 35-52

[12] FAO-UNEP: Assessing and Preparing Desertification Map. 1984, 145 pages

[13] Z. Gungor, G. Serhadlioglu, E. Kesen: A fuzzy AHP approach to personnel selection problem. Applied Soft Computing, 2009, Vol. l 9, pp. 641-646, ISSN: 1568-4946, DOI: 10.1016/j.asoc.2008.09.003

[14] Y. Malchefski: geographic information system and multi-criteria decision analysis, translated by Parhizgar, A and Ghafari Gilandeh, A., fourth edition, Samt press, 2016, 608 pages, ISBN: 978-3540747574

[15] MA. Meshkat, A. Rahbar: A temporary method for assessing and preparing desertification map. Forestry and Rangelands Research Institute, 1998, PP. 114.

[16] O. Meixner: Fuzzy AHP group decision analysis and application for the evaluation of energy sources. Institute of marketing, Vienna, Austria, 2012.

[17] M. Moeinaddini, N. Khorasani, A. Danehkar: Siting MSW Landfill using Hierarchical Fuzzy TOPSIS methodology (case study: Karaj). Journal of Natural Environment, Iranian Journal of Natural Resource, 2011, Vol. 64, No. 2, pp. 155-167, ISSN: 2008-7761

[18] Organization of Forests, Rangelands and Watershed Management of Iran: Summary of the program of desert areas management of the country. Forestry and Rangelands Research Institute, 2005, 65 pages

[19] S. Pishyar, H. Khosravi, A. Tavili, A. Malekian, S. Sabourirad: A combined AHP- and TOPSIS-based approach in the assessment of desertification disaster risk. Environmental Modeling and Assessment, 2020, Vol. 24, No. 2, pp. 1-11, ISSN: 1420-2026, DOI: 10.1007/s10666-019-09676-8

[20] A. Sepehr, MR. Ekhtesasi, SA. Modarresi: Development of desertification indicator system base on DPSIR (Take advantages of Fuzzy-TOPSIS). Geography and Environmental Planning Journal, 2011, Vol. 45, No. 1, 2011, pp. 33-50, ISSN: 2252-0910

[21] MH. Sadeghiravesh, H. Ahmadi, Gh. Zehtabian, M. Rehayi Khoram: Development of the numerical taxonomy model to assess desertification: an example of modeling intensity in central Iran. Journal of Philipp Agric Scientist, 2009, Vol 92, No. 2, pp. 213- 227, ISSN: 0031-7454

[22] MH. Sadeghiravesh, Gh. Zehtabian, M. Tahmores: Vulnerability assessment of environmental issue to desertification risk (case study: Khezrabad region, Yazd). Journal of Watershed Management Research, 2012, Vol. 96, No. 1, pp. 75-87, ISSN: 2676-4636

[23] MH. Sadeghiravesh, H. Khosravi H: zoning wind erosion potential risk in central iran using modified numerical taxonomy model. American-Eurasian Journal of Agricultural & Environmental Sciences, 2012, Vol. 12, No. 1, pp. 91-99, ISSN: ISSN 1818-6769

[24] MH. Sadeghiravesh: Zoning the potential of desertification hazard using MADM approach and shannon entropy model in Khezrabad region, Yazd province. Iranian Journal of Soil Research, 2014, Vol. 28, No. 3, pp. 572-588, ISSN: 2228-7124

[25] MH. Sadeghiravesh, H. Khosravi, S. Ghasemian: Application of fuzzy analytical hierarchy process for Assessment of combating-desertification alternatives in central Iran. Journal of Natural Hazard, 2015, Vol.75, pp. 653-667, ISSN: 2192-6395, DOI: 10.1007/s11069-014-1345-7

[26] MH. Sadeghiravesh, H. Khosravi, S. Ghasemian: Assessment of combating-desertification strategies using the linear assignment method, Solid Earth, 2016, Vol. 7, pp. 673–683, ISSN: 1869-9529, DOI: 10.5194/se-2015-133

[27] MH. Sadeghiravesh: Zoning the potential of desertification hazard using principle component analysis model in Khezrabad region. Journal of geographic space, 2016, Vol. 16, No. 56, pp. 241-261

[28] Sredjevic, YDP. Medeiros: Fuzzy AHP assessment of water management plans. water resources management, 2008, Vol 22, pp. 877-894, ISSN: 1573-1650, DOI: 10.1007/s11269-007-9197-5

[29] UN (United Nations): United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and Desertification, Particularly in Africa, UNEP/IPA, Nairobi, 1994.

[30] UNEP (United Nations Environmental Program): World atlas of desertification, editorial commentary by N. J. Middleton and D. S. G. Thomas Arnold: London. 1992, 69 pages

[31] JW. Wang, CH. Cheng, HK. Cheng: Fuzzy hierarchical TOPSIS for supplier selection. Appllied Soft Computing, 2009, Vol. 9, pp. 377-386, ISSN: 1568-4946, DOI: 10.1016/j.asoc.2008.04.014

[32] XD. Wang, XH. Zhong, SZ. Liu, ZY. Wang, MH. Li: Regional assessment of environmental vulnerability in the Tibetan Plateau: Development and application of a new method, Journal of Arid Environments, 2008, Vol. 72, No. 10, pp. 1929-1939, ISSN: 0140-1963, DOI: 10.1016/j.jaridenv.2008.06.005