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Desertification Assessment by Using Water Criterion in Iran's Central Arid Regions

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ABSTRACT

Desertification is expressed as an important process that accelerates the degradation of ecosystem components. This process occurs in arid and semi arid regions where water is the main limiting factor in the dynamics of an ecosystem. Appropriate models may be used to desertification assessment. In this regards, models may be used as decision support systems on desertification issues. In this study, the Iranian model desertification potential assessment (IMDPA) that developed by Tehran university's faculty of natural resources, was used to assess desertification intensity in Biabanak region, in the central of Iran. Desertification intensity was assessment based on water criterion and five indices including groundwater table downfall, electrical conductivity (EC), sodium absorption ratio (SAR), chlorine (Cl) and total dissolved solids (TDS) indices. The result from the IMDPA model has shown that the TDS index had been the most appropriate index to assess desertification hence, it concluded that TDS index played a main role in the desertification of Biabanak region. Also, final classes of desertification intensity were grouped into two classes including medium and severe classes, which cover 57.70%, 42.29% of all area of Biabanak region, respectively. Finally, as a general conclusion it can be said that Biabanak region has severe desertification status based on water criterion with a geometric average of 3.53. Therefore, management practices must be implemented to control desertification and mitigate its effects in Biabanak region and other central arid regions of Iran.
KEYWORDS: Desertification, IMDPA model, Water criterion, Severe desertification class, Arid regions of Iran.

INTRODUCTION

In the recent decades specified, which desertification has an important role in the destruction of the resources potential, depletion of soil and vegetation cover, destruction of the structure and composition of the soil, degradation of water resources etc. [1, 2, 3, 4, 5, 6]. This process occurred in arid and semi arid areas as well as in some parts of sub humid areas [7]. The term desertification is used for the land degradation especially in arid areas, that cover over 40% of the total earth surface [8].

Desertification is expressed as the third challenge of the international community after water shortage and climate change challenges [9]. This process is depends on many factors such as the level of soil fertility, wind and water erosion, decline water quality and etc, which accelerated by natural and anthropogenic activities [10, 11, 12, 13,]. Because increasing concern about the phenomenon of desertification and consequently unprecedented changes on the environment on global and regional scale has draw attention from the scientific communities to this issue and criteria and indices for desertification assessment have provided. Many researches have been done in order to evaluation of desertification, so far and also have been developed many models for this purpose [14, 15, 16, 17, 18, 19, 20, 21, 22].

The most important models for desertification assessment including FAO-UNEP [23], LADA [24], ICD [25], MICD [26], MEDALLUS [27], and IMPDA [28] models which are useful tools for desertification studies and also help to control and reduce damages of desertification. Some deficiencies of these methods and models include ignoring special conditions of local ecosystems, suitability only on a small and local scale, qualitative indices, the lack of possibility for dissociation of natural and human effects, and expertise error especially in the case of FAOUNEP model [3]. Other models had calibrated in the number of the smaller areas and they had very deficiencies [25]. In particular, among different models the IMDPA is one of the models [28] that is being used widely to assess the desertification that developed in Tehran University's faculty of Natural Resources. Also some studies on the performance of the

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IMDPA model showed that it is a suitable model for desertification assessment in the arid regions, especially in Iran's arid central regions [19, 29, 30, 31, 32, 33].

Wang et al., 2006 [34] based on the seven climatic and anthropogenic parameters in china country during 50 years showed that both factors listed are effective in the desertification process. Lavado-Conntador et al., 2008 [15] concluded that created desertification map by ESAs model is the beater in comparison with other models. Vesali., 2008 [32] assessment biophysical indices of desertification affected by human activities in Kashan and Aran Va Bidgol counties and reported that these areas located in medium desertification class. Nateghi 2008 [33] assessment the desertification intensity by IMDPA model in Sagzi plain and finally stated that water, geology and vegetation criteria have values of 3.97, 3.26 and 3.12, which were represent very severe, severe and severe classes of desertification, respectively. Rasmy et al., 2010 [35] simulated potential statues of desertification by MEDALUS model in Egypt country and they concluded that urbanization, salinity and lack of implementation of appropriate policies were key factors in the development of desertification in this region. Shekohi., 2011 [36], evaluated soil and water criteria based on IMDPA model in Yazd plain and stated that desertification intensity class is medium for the entire Yazd plain. Zakerinejad et al., 2012 [37] assessment desertification intensity by using IMDPA model in relation with groundwater criterion in Zarin Dasht region and concluded that 37.41% and 62.59% of region occupied by severe and very severe desertification classes, respectively. They also stated that the importance of water in arid areas is higher than other areas. Since different factors affected desertification hence, define and determine major criteria and key indices to desertification assessment and prevent its consequences, is essential. Therefore in this study, based on review of importance of water criterion in the process of desertification and also desertification models in literature. Finally, water criterion and five indices were used based on IMDPA model in an arid region in the south of Semnan province, which this region is susceptible to degradation and desertification.

MATERIALS AND METHODS

STUDY AREA

The Biabanak region includes about 35464.26 hectare of arid lands located in the south of Semnan province (35'56"N, 53' 54"E), in the center of Iran (Fig. 1). Based on data obtained from the meteorological stations in Biabanak region in the south of Semnan province, the total annual precipitation is 76.3 mm, the mean annual temperature is 20.3°C, and the total annual open pan evaporation rate in the area are 2763 mm, respectively. The climate type is classified as arid region according to the De-martonne classification, with a distinct dry season during summers and relatively semi humid during the winters. The study area is contain gray Marlies and calcite faces as well as yellow evaporate sediments, which lies within a relatively flat basin physiography.

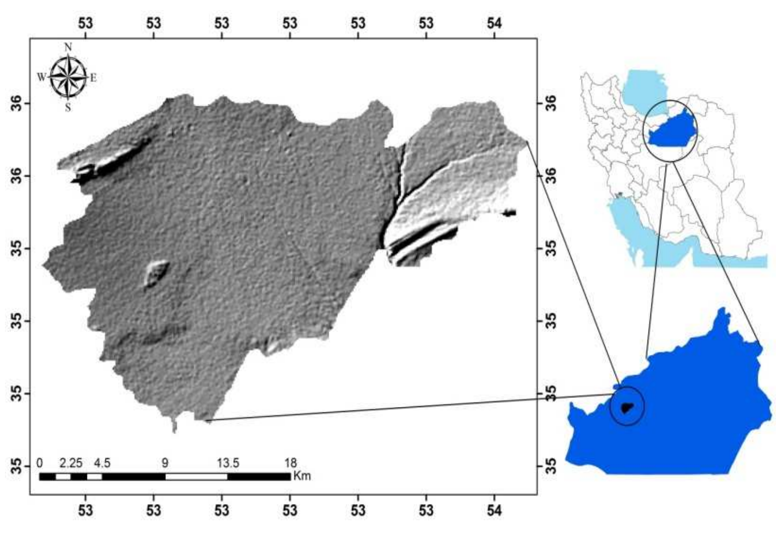

Fig. 1. The location of Biabanak region in Semnan province, Iran country.

THE IMDPA MODEL DESCRIPTION

The IMDPA model (Iranian model desertification potential assessment) have been developed by Tehran university's faculty of Natural Resources [28]. This model based on some of the earlier models developed such as

FAO-UNEP [23], LADA [24], MEDALUS [27], ICD [25] as well as national model MICD [26] was developed. The IMDPA model consist of 9 criteria and 35 indicia. At first, assigned a score ranging from one to four to each index [38] then the value of each criterion obtained as geometric average of scores of single indices according to the Eq. (1) and eventually, final score of desertification potential (or intensity) calculated by using Eq. (2) [28, 38].

$$\text{Criteria} - \text{X} = [(\text{Layer} - 1) \times (\text{layer} - 2) \times \ldots\ldots (\text{Layer} - \text{n})]^{1/n} \qquad \text{Eq. (1)}$$

$$\text{Desertification intensity} = \sqrt[9]{Q_{1 \ldots\ldots\ldots} Q_9} \qquad \text{Eq. (2)}$$

Where criterion-X, Layer and n, represent a specific criterion, index of each criterion and number of indices, respectively. Also symbols of Q1 to Q9 are indicative of different criteria from one to nine.

METHODOLOGY

At the present study, selected the water criterion based on time shortage and also uses of previous studies in this region [39]. The water criterion have 5 indices, which including groundwater table downfall, electrical conductivity (EC), sodium absorption ratio (SAR), chlorine (Cl) and total dissolved solids (Table 1) [28, 38]. The required data obtained from the 19-year (1994-2013) statistics of the Regional Water Company (RWC) of Semnan province. Then, to determine the status of water quality in different parts of study area, data on 17 piezometer wells were analyzed during 19 years (Fig. 2).

Table 1. Classes and values of various indices used for water criterion assessment.

Indices	Class	Low	Medium	Severe	Very severe
	Value	1-1.5	1.5-2.5	2.6-3.5	3.6-4
Groundwater table downfall (cm/year)		<20	20-30	30-50	>50
EC (µmhos/cm)		<750	750-2250	2250-5000	>5000
Cl (Mgr/liter)		<250	250-500	500-1500	>1500
SAR		<15	15-26	26-32	>32
TDS		0-1000	1000-2000	2000-3000	>3000

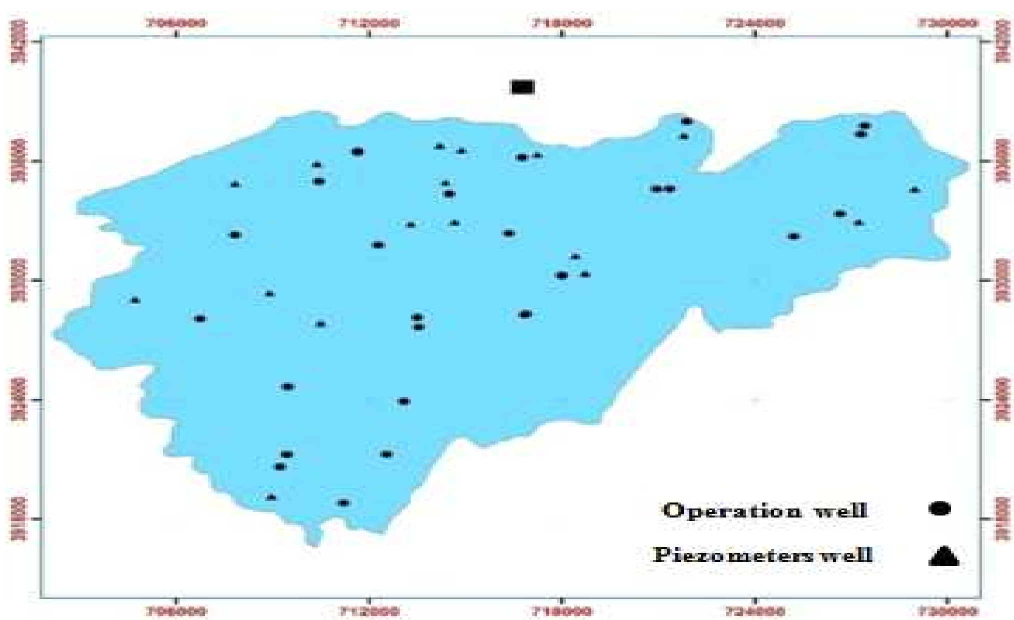

Fig. 2. Map of distribution piezometer and operation wells in Biabanak region.

In this study, evaluated the risk of desertification based on water criterion, in this way, assigned a score ranging from one to four to each index based on weight of each factor. So that values "1" , "4" were used for good condition and deteriorate condition, respectively [28, 38]. Table (1) shows scores and classes of different indices to assess desertification in relation with water criterion in this research. Also figure (3) shows water criterion and indices used in this study.

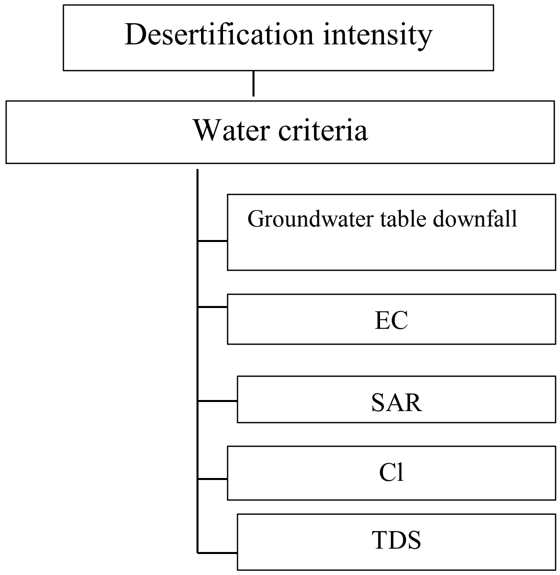

Fig 3. Schematic diagram of desertification assessment by IMDPA model relation with water criterion and its indices.

When the scores were assigned, then the value of the index for each elementary unit within an index is obtained as the geometric average of scores for single indices. In the end, map of every index was prepared. Five maps were produced, which representing the condition of each index. Then, desertification intensity map was produced as the geometric average of the indices by using Eq. (3) and eventually this map were grouped into four classes based on table 2. In this research, each desertification class was divided into three sub-categories, represented by 1, 2, and 3. It should be noted that the larger values of sub-categories means a higher desertification intensity. It is noteworthy that all the calculations were performed in the ArcGIS9.3 software environment during this study.

$$\text{Desertification intensity in relation with} = \sqrt[5]{\text{groundwater table downfall} \times \text{EC} \times \text{SAR} \times \text{Cl} \times \text{TDS}} \quad \text{Eq. (3)}$$

Table 2. The distribution of frequency of the current situation of desertification intensity classes

Numerical value	sub-categories	Numerical value	Qualitative classification of desertification intensity
1 - 1.166	1	1-1.5	Low
1.17 - 1.32	2		
1.33 - 1.5	3		
1.51 - 1.843	1	1.51-2.5	Medium
1.843 - 2.176	2		
2.176 - 2.5	3		
2.51 - 2.843	1	2.51-3.5	Severe
2.843 - 3.176	2		
3.176 - 3.5	3		
3.151 - 3.676	1	3.51-4	Very severe
3.676 - 3.842	2		
3.842 - 4	3		

RESULTS

At first based on table (1) and the all information mentioned in the methodology, the maps of different indices were prepared. Finally, assessment desertification intensity based on Eq. (3). Generally, in order to determine the desertification intensity in relation with the water criterion following stages were performed.

GROUNDWATER TABLE DOWNFALL INDEX

The map of groundwater table downfall index were classified into four classes of desertification in Biabanak region (Fig. 4). These classes were include low (or negligible), medium, severe and very severe classes, which have occupied 15.8%, 7.078%, 13.58% and 63.45% of the study region, respectively (Table 3). The geometric average of quantitative value of groundwater table downfall index was 3.156 (Table 3), which shows a severe desertification class in this region. Therefore, it can be said that this index has a significant effect on groundwater degradation in the Biabanak region.

Table 3. Surface frequently distribution of desertification intensity classes based on groundwater table downfall index

Desertification class	Area (ha)	Percent of area	Geometric average of desertification intensity	Qualitative classification of desertification intensity
Low (or negligible)	5633.66	15.88	**3.156**	**Severe**
Medium	2510.35	7.078		
Severe	4816.76	13.58		
Very severe	22503.49	63.45		
Total	35464.26	100		

Electrical Conductivity (EC) Index

In this study, water Salinity (EC) variability was very high and in different locations were not similar. Water salinity depends on soil texture, type of minerals in different geologic faces and formations, the amount of groundwater exploiting, the amount of hydraulic gradient etc. Approximately, 99% of the study region were considered as severe and very severe desertification intensity classes (Table 4). Results showed that, the central and the southern parts of the study region are at very severe desertification status based on EC index (Fig. 4). The geometric average of quantitative value of EC index was 3.451, which shows study region has the severe desertification status. On other hand, because variability of EC index on spatial and temporal scales was high hence, selected this index as a suitable index to assess desertification in Biabanak region.

Table 4. Surface frequently distribution of desertification intensity classes based on electrical conductivity (EC) index.

Desertification Class	Area (ha)	Percent of area	Geometric average of desertification intensity	Qualitative classification of desertification intensity
Low (or negligible)	0	0	**3.451**	**Severe**
Medium	211.2	0.59		
Severe	18869.55	53.20		
Very severe	16383.42	46.19		
Total	35464.17	100		

SODIUM ABSORPTION RATIO (SAR) INDEX

Results showed that the SAR index had been not high fluctuations in the study area and just classified in low (or negligible) class of desertification (Table 5) and whole of study region occupied with low class (Fig. 4). The geometric average of quantitative value of this index was 1.18, which indicates this index don't has any effect on desertification in Biabanak region. The SAR index also was no sensitivity on the spatial and temporal scales, hence it is not chosen as a suitable index to desertification assessment in this region.

Table 5. Surface frequently distribution of desertification intensity classes based on sodium absorption ratio (SAR) index

Desertification Class	Area (ha)	Percent of area	Geometric average of desertification intensity	Qualitative classification of desertification intensity
Low (or negligible)	35464.17	100	1.18	Low

CHLORINE (CL) INDEX

The concentration of Cl is an important parameter to assess desertification. At present study, Cl index just classified in low (negligible) class and the geometric average of it was 1.173 (Table 6). Figure (4) shows that whole of study area occupied with low or negligible class of desertification intensity based on Cl index. Also Cl index was no sensitivity and flexibility to changes occurred in Biabanak region, hence the Cl index is not a suitable index to desertification assessment in this region. It recommended that do not use Cl index for desertification assessment in this region.

Table 6. Surface frequently distribution of desertification intensity classes based on chlorine (Cl) index.

Desertification class	Area (ha)	Percent of area	Geometric average of desertification intensity	Qualitative classification of desertification intensity
Low (or negligible)	35464.17	100	**1.173**	**Low**

TOTAL DISSOLVED SOLIDS (TDS) INDEX

Results showed that desertification status of Biabanak region is very unsuitable based on TDS index (Table 7). Figure (4) shows that desertification intensively based on TDS index has been classified in three classes, which including medium, severe and very severe classes. Because the value of TDS index is gradually increasing (Table 7), hence desertification class were determined as severe class based on TDS index. Generally, the more 64% of study area lies at the very severe class (Table 7). Therefore, TDS index selected as primary and the most important index for desertification assessment in Biabanak region in the south of Semnan province.

Table 7. Surface frequently distribution of desertification intensity classes based on total dissolved solids (TDS) index.

Desertification class	Area (ha)	Percent of area	Geometric average of desertification intensity	Qualitative classification of desertification intensity
Medium	769.03	2.16	**3.53**	**Very severe**
Severe	11763.4	33.16		
Very severe	22931.76	64.66		
Total	35464.17	100		

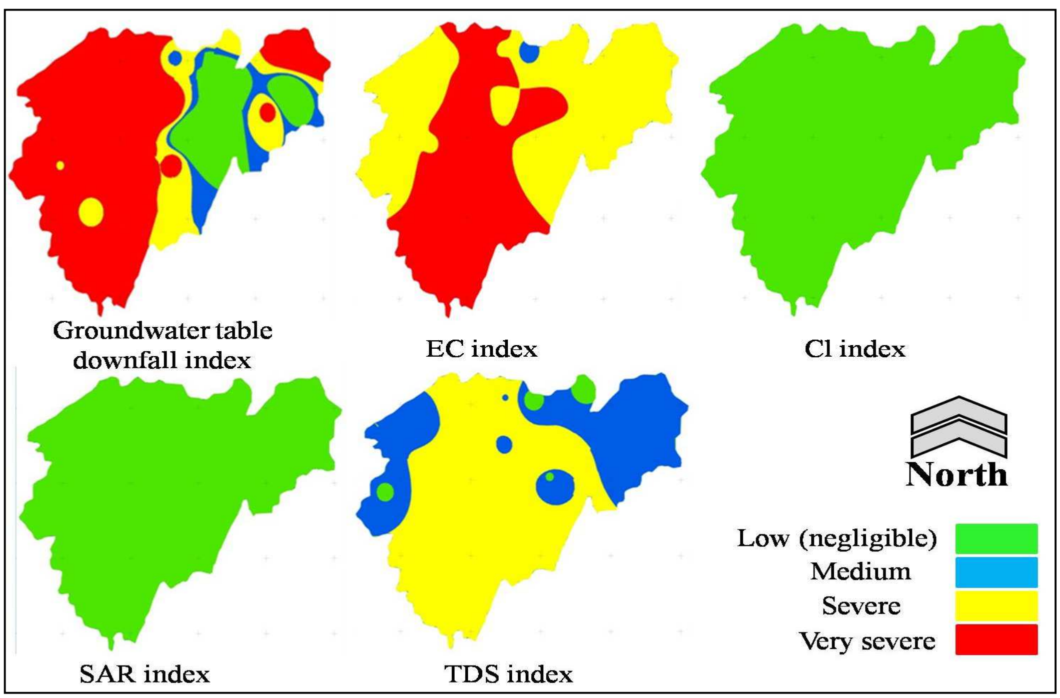

Fig. 4. Indices of water criterion in Biabanak region.

Figure (5) shows the geometric average of different indices of water criterion, which among different indices TDS, EC and groundwater table downfall were the most effective indices on water criterion. Also, SAR and EC indices were considered as inappropriate indices to assessment of desertification intensity in Biabanak region.

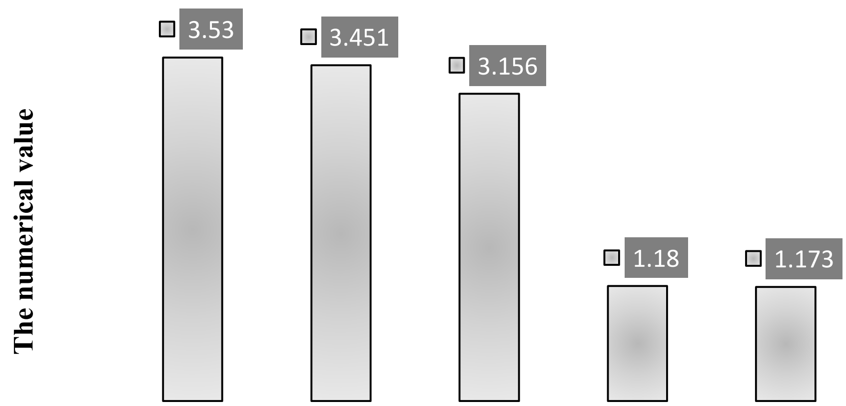

Fig. 5. The geometric average of various indices affecting water criterion in Biabanak region.

After layers (maps) of different indices were prepared (Fig. 4.), then the desertification intensity map in terms of water criterion was generated based on Eq. (3). Finally, the desertification intensity map based on table (3) were grouped into two classes (Fig. 6). In this region desertification intensity classes were include medium and severe classes which, covering 57.70% and 42.29% of study area (Table 8). Also results showed that water criterion with a geometric average of 3.53 classified in very severe class of desertification. At last, it was found that Biabanak region is at severe desertification status based on water criterion.

Table 8. Surface frequently distribution of desertification intensity classes based on water criterion.

Desertification class	Area (ha)	Percent of area	Geometric average of desertification intensity	Qualitative classification of desertification intensity
Medium	20465.18	57.70	**2.262**	**Very severe**
Severe	14999.01	42.29		
Total	35464.17	100		

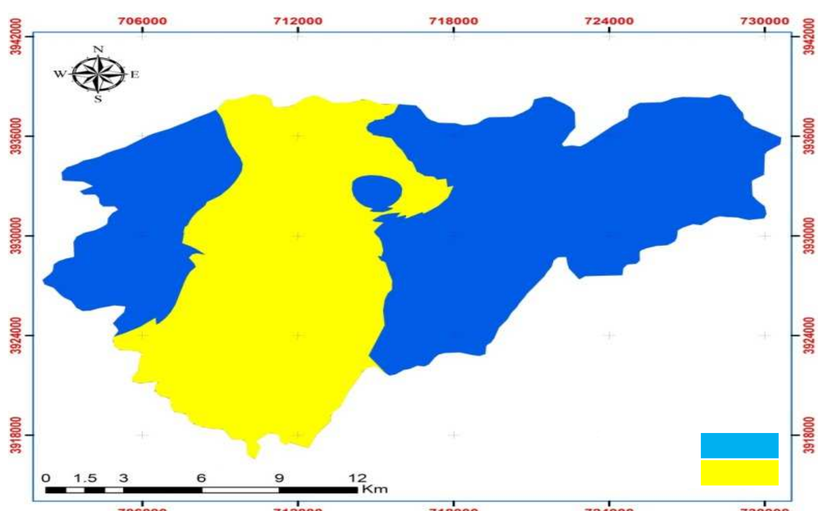

Fig. 6. Final map of desertification intensity by using IMDPA model in relation with water criterion in Biabanak region, in the center of Iran country.

DISCUSSION AND CONCLUSION

The more than 85% of Iran country is occupied by arid, semi-arid, and hyper-arid regions and hence, a large part of the country is susceptible to desertification. Therefore, evaluation of factors influencing the desertification intensity is essential [6, 31].

In this research, assessment desertification intensity by using IMDPA model in relation with water criterion. This criterion selected based on previous studies in this region [39]. Result showed that the TDS, EC, groundwater table downfall, Cl and SAR indices are in a range from the most suitable to the most unsuitable in the Biabanak region, respectively. Therefore, the TDS index selected as the most important and the most suitable index for desertification assessment in the south of Semnan province. Finally, it concluded that TDS index played the main role in the desertification of Biabanak region. Several former studies have also been consistent with result of this study [20, 21, 31, 37, 40, 41,].

Also the EC and the groundwater table downfall indices were relatively suitable for desertification assessment in this region due to their high spatial variation in the study region (Fig. 4). So that, the EC and the groundwater table downfall indices classified into three and four classes of desertification, respectively (Table 3 and 4).

Also some previous researchers [20, 42] have been stated that the EC and the groundwater table downfall indices are appropriate indices to desertification assessment in relation with water criterion that their results are in accordance with findings of our research. Also in this study it was found that, indices of SAR and Cl were not suitable indices to assessment of desertification status due to their low spatial variation in Biabanak region. Shakerian et al., 2011[20] and Khosravi et al., 2014 [31] have indicated that, indices of SAR and Cl are not appropriate indices to assess desertification in the arid regions of Iran.

The final map of desertification intensity in the Biabanak region was grouped into two classes including medium and severe classes (Fig. 6). The medium and severe desertification intensity classes cover 57.70%, 42.29% of the total area, respectively. In this study, results showed that water criterion with a geometric average of 3.53 classified in very severe class of desertification.

Some previous studies have been concluded that in the central arid regions of Iran, desertification class is severe due to water shortage, climatic limitations, low level of soil fertility and etc [33, 40, 41]. Given that, water is subject to various factors such as climate, droughts, agricultural activities and irrigation, it can be recommended that the more indices used in order to desertification intensity assessment in relation with water criterion.

Also IMDPA is a strong model with high flexibility, because it can be to include or exclude criteria in every situation and also have high precision of desertification assessment. On other hand , one of the disadvantageous of the proposed method is difficulty of measuring all effective indices due to constrains of time, financial and technical, which more researches need to find solutions for overcoming these problems. Shakerian et al., 2011 [20] have stated that mathematical modeling should be developed for the operational monitoring of different indices contributing in desertification process.

As a general conclusion it can be said that Biabanak region as one of Iran's arid central regions has severe desertification status. So conservation and management measures must be implemented to control desertification and mitigate its effects in Iran's arid central regions. Results obtained in this study can be used for decision-making and the for the adoption of certain management practices in other arid lands of Iran's central regions.

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