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Evaluation of Current Desertification Status Based on IMDPA with Emphasis on Climate, Wind Erosion, Water, Soil and Vegetation: Case Study of Bordekhun Region of Boushehr

A. Pahlavanravi[a], F. Bahreini[a*]

[a] *Faculty of Natural Resources, University of Zabol, Zabol, Iran*

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Abstract

This study used quantifying factors affecting desertification based on the Iranian model of desertification potential assessment (IMDPA) to assess the current status of desertification in Bordekhun region, Iran. Bordekhun region has an area of 214.11 km^2 and is located near the city of Daiyer in Boushehr province. First, a working unit map of the region was selected as the basic map for evaluation of factors and indices of interest. Regional conditions for the five criteria of climate, wind erosion, water, soil, and vegetation were calculated as essential for the study of desertification intensity. The scores for the indices were determined using IMDPA; for each index, a map was prepared employing the calculated weighting. A qualitative map of the criterion was obtained using the geometric mean of indices related to each criterion. A map of current desertification potential was then created for the study area by combining the layers produced for each criterion, determining their geometrical means, and classifying the resultant map. Analysis of the study criteria showed that climate was rated high with a quantitative value of 3.15, wind erosion was high with a value of 2.87, water was medium with a value of 1.77, soil was high with a value of 2.66, and vegetation was medium with a value of 2.37. The results showed that of the total area, 49.12% is classified in the high desertification class, 48.9% is in the moderate class and about 0.99% is not classified. The quantitative value of desertification intensity on the basis of the five criteria for the entire study area was desertification map (DM) = 1.55, which is indicative of the average desertification intensity in the region. The study area is located such that it has the potential for severe desertification. Climate was found to be the dominant criterion and plays an important role in desertification.

Keywords: desertification; IMDPA model; criteria; Bordekhun region**;** Boushehr

1. Introduction

Desertification affects very large areas of land that has lost productivity caused by human activity and natural causes. In order to understand this phenomenon, the physical and manmade processes and their interrelations must be identified (Sciortino et al., 2000). A widely accepted definition of desertification is land degradation in arid, semi-arid, and sub-humid areas resulting from factors including climatic variation and human activity (Reynolds and Stafford-Smith, 2002; UNCCD, 1994). This process affects semi-arid shrubland globally, and the resulting severe erosion and flooding has a high economic impact (Andreu et al., 1998; Garcia-Ruiz et al., 1996; Thurow, 2000).

Arid and semiarid environments cover more than 40% of the global land surface (Deichmann and Eklundh, 1991) and provide habitat to more than 1 billion humans (UNCDD, 1997; Reynolds and Stafford-Smith, 2002). It is widely recognized

* Corresponding author. Tel.: +98 542 2232600,
Fax: +98 542 2232600.
E-mail address: F_Bahreini88@yahoo.com

that these lands are prone to desertification, which is a serious threat to the environment and human welfare (Mainguet, 1994; Williams and Balling, 1996; Reynolds and Stafford-Smith, 2002). About 80% of Iran is arid and semi-arid and one-third is prone to desertification. Deserts cover about 20% of the land in Iran; remaining land comprises rangeland (55%), agriculture (11%), forests (8%), and industrial and residential areas (6%) (NAP[1], 2005).

In view of the increasing desertification of Iran, it is necessary to identify areas liable to desertification before identifying mitigation and control measures. Desertification can be measured using qualitative and quantitative models. These studies are instrumental in understanding desertification myths to effectively fight desertification. Extensive research and development has been done on various models that evaluate desertification. The Mediterranean desertification and land use (MEDALUS) model (Kosmas et al, 1999) has been used to identify environmentally sensitive areas (ESAs).

It is important to identify the driving forces behind land degradation to properly understand the phenomenon on a local scale (Lavado et al, 2008). To develop a model with national applications that is adaptable, it is necessary to design effective indicators of desertification (Zakerinejad and Masoudi, 2010). IMDPA[2] is a comprehensive desertification model that was developed by the Faculty of Natural Resources at the University of Tehran in a project entitled Determination of Methodology of Desertification Criteria and Indices in Arid and Semi-Arid Regions of Iran (Ahmadi, 2004). In Iran, IMDPA was used to categorize Jarghooyeh region in Isfahan province (Shakerian et al, 2011), Segzi pediment in Isfahan province (Jafari et al, 2011), Mazayijan plain in Fars province (Zakerinejad and Masayijan, 2010), and Kaherkonarak region (Raiesi, 2007) and Jazinak region (Zolfeghari, 2010) in Sistan-Baluchestan province. The objective of this study was to survey the current status of desertification in southwestern Bushehr province using IMDPA and geographic information system (GIS) tools.

1- National Action Programme

2 - Iranian Model of Desertification Potential Assessment

2. Materials and Methods

2.1. Study Area

The study area is located at 51° 28' 47" to 51° 32' 59" longitude and 27° 59' 55" to 28° 12' 21" latitude and has an arid and semi-arid climate according to extended Dumbarton climatic classification. This region covers an area of 214.14 km^2 in Bushehr province in southwestern Iran. Annual precipitation is about 242.37 mm. The temperature varies from 39°C in July to 14.2°C in winter. The annual relative humidity is about 55.2%. The maximum elevation is 1015 m and minimum elevation is 3 m. In southwestern Bushehr province, low precipitation, arid climate, blowing winds with velocities greater than threshold velocity of wind erosion, water resource restrictions, decreasing groundwater level, increased water and soil salinity, and degradation of vegetation all influence the stability and productivity of the desert ecosystem.

After specifying the work units (geomorphological facies), numerical values were determined for each index for each work unit. A data layer for each index was prepared and the layer for each criteria was specified by calculating the geometric mean of its index score. A desertification severity map was created by combining and determining the geometric mean of the criteria. The layers were created in GIS using a spatial analyst tool.

IMDPA recognizes the five criteria of climate, wind erosion, water, soil and vegetation to be essential to the study of desertification. Each criterion includes the following indices:

- Soil: depth, electrical conductivity (EC) and texture and percentage of gravel;
- Water: ground water table, EC, Cl concentration, sodium absorption ratio (SAR);
- Climate: annual precipitation, aridity index, drought;
- Wind erosion: dust storm index, vegetation cover percentage, density of non-vegetation cover (gravel>2 mm) on the soil surface, erosion intensity;
- Vegetation cover: cover rehabilitation, cover efficiency, cover condition (Ahmadi et al, 2004).

A score ranging from 1 to 4 was assigned to each index based on the weight of each factor. The desertification intensity is the result of the geometric average of the five criteria as follows:

$$\text{Desertification intensity} = (\text{water} \times \text{soil} \times \text{wind erosion} \times \text{climate} \times \text{vegetation cover})^{1.5}$$

The final map as classified into four subtypes as shown in Table 1.

A value of zero was assigned to areas where the measure was not appropriate and to those that were not classified. Figure 1 shows the flowchart of the IMDPA results of the study area.

Table1. Classification of desertification intensity

Order	Numerical value	Class
1	0-1.5	Low
2	1.6-2.5	Medium
3	2.6-3.5	High
4	3.6-4	Very High

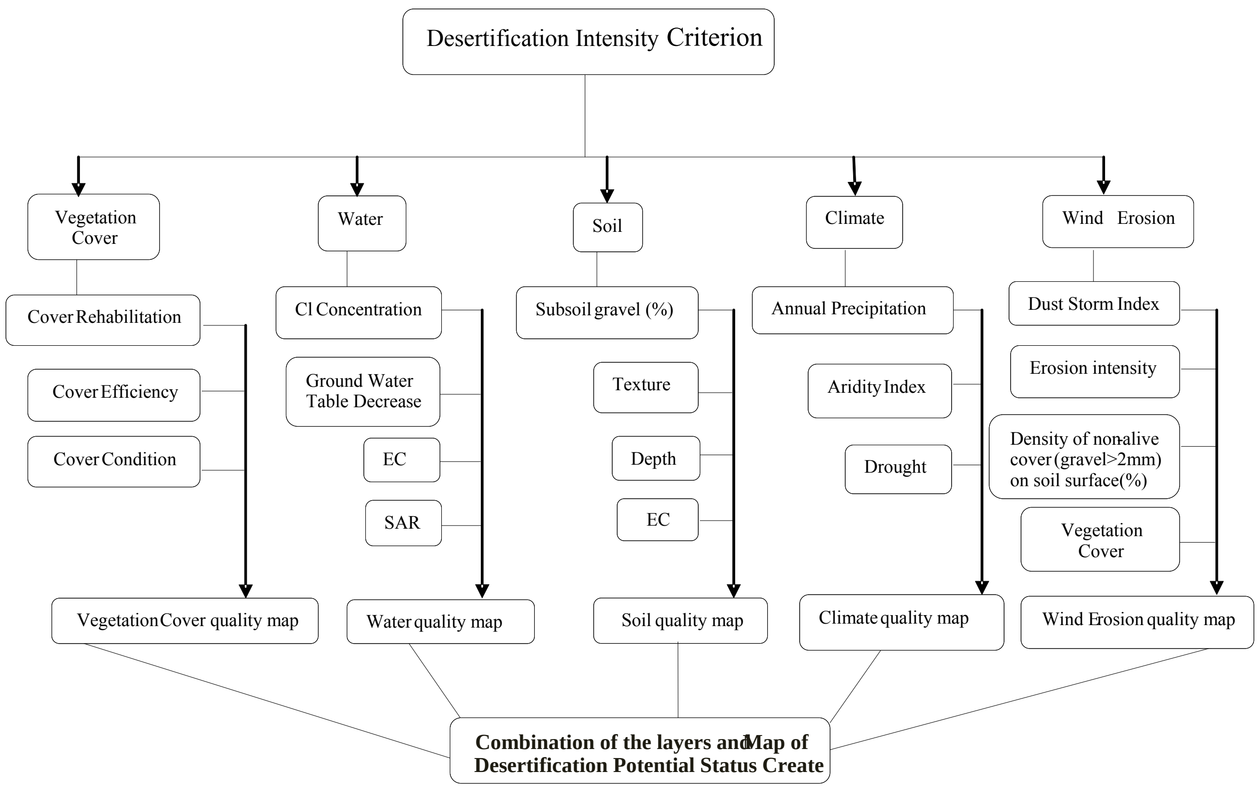

Fig. 1. Flowchart IMDPA (IRANIAN Model of Desertification Potential Assessment) Model in study area

3. Results and Discussion

To assess the proposed method with respect to all information in the methodology and evaluation method, it was implemented for 214.11 km^2 in Bordekhun region and the data obtained was analyzed. The results of IMDPA are shown in Tables 2- 6 and Figure 7.

3.1. Soil criterion assessment

The soil criterion had a weighted average of 2.66, which corresponds to the high class of desertification. The mean value of the factors involved in soil resource deterioration indicate that the soil depth index with a geometric average of 3.52 falls into the very high class and was the most effective factor in the increasing soil degradation intensity of the region. Figure 2 shows the layer for soil criteria; 4.48% of the area is in the low class, 46.29% is in the medium class, and 49.22% is in the high class of desertification.

$$\textit{Soil criteria} = (2.94\times2.61\times1.87\times3.52)^{1.4} = 2.66$$

Table 2. Geometric average of the quantitative values of soil indices

desertification intensity Class	current desertification status	Index	Value
III	high	Soil texture	2.94
III	high	Ec	2.61
II	medium	Subsoil gravel (%)	1.87
IV	very high	Soil depth	3.52

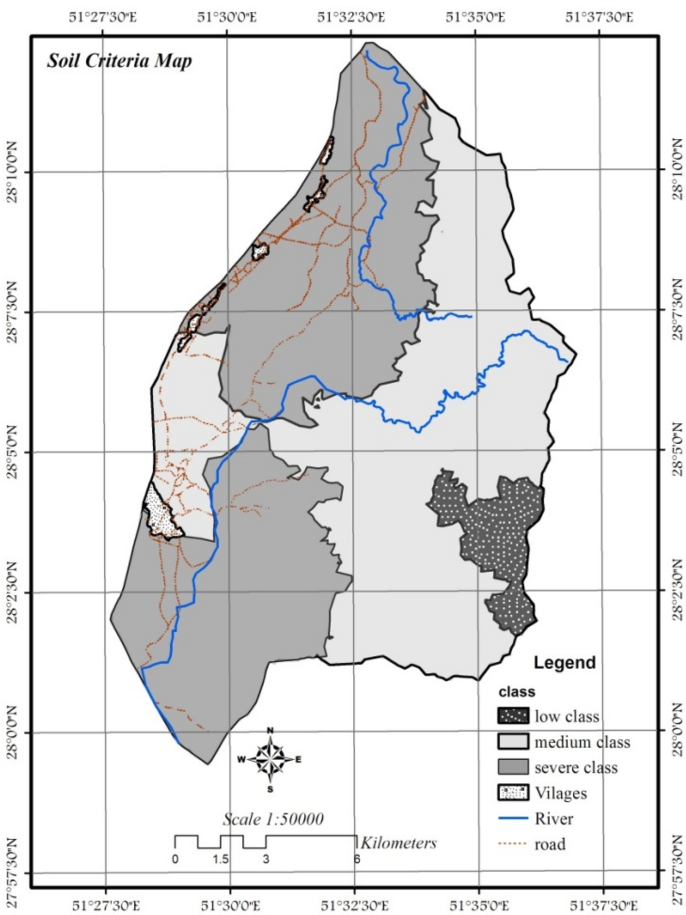

Fig. 2. Map of Soil Criteria

3. 2. Water criterion assessment

The water criteria had a weighted average of 1.77, which falls into the medium class for desertification. The EC index, with a weighted average of 3.07, was the most effective and the indices of Cl and SAR, with weighted averages of 1.18 and 1.18, respectively, were the least effective for desertification of the region. The layer for water criteria of the area is shown in Figure 3. It is clear that the area is dominated by the medium desertification (64.59%).

$$\textit{Water criterion} = (1.18\times3.07\times2.33\times1.18)^{1.4} = 1.77$$

Table 3. Geometric average of the quantitative values of water indices

desertification intensity Class	current desertification status	Value	Index
I	low	1.18	CL (Mgr/liter)
III	high	3.07	EC (µmhos/cm)
II	medium	2.33	Groundwater table decrease (cm/year)
I	low	1.18	SAR

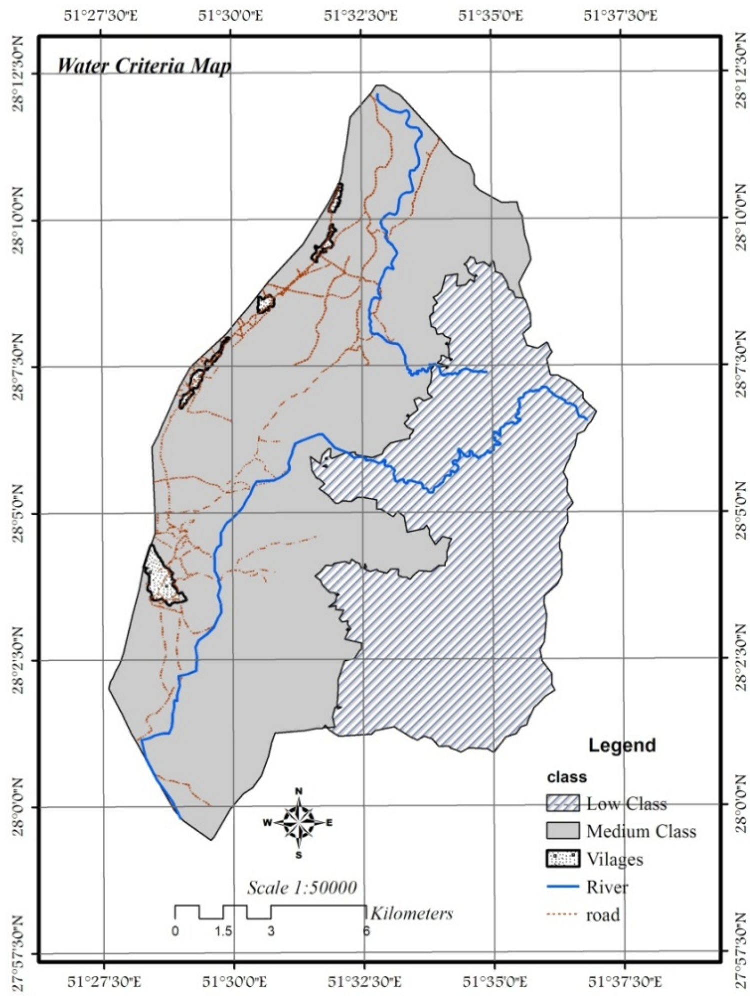

Fig. 3. Map of Water Criteria

3.3. Vegetation cover criterion assessment

The vegetation cover criteria had a weighted average of 2.37 and was classified in the medium desertification class. An analysis of the numerical values for the four effective indices shows that cover efficiency was the most effective for increasing desertification intensity. Figure 4 shows that most of the territory is characterized by medium class (approximately 65%).

Vegetation cover criteria $= (2.79 \times 1.96 \times 2.52)^{1.3} = 2.37$

Table 4. Geometric average of the quantitative values of Vegetation Cover indices

desertification intensity class	current desertification status	Value	Index
III	high	2.79	Cover Efficiency
II	medium	1.96	Cover Rehabilitation
III	high	2.52	Cover Condition

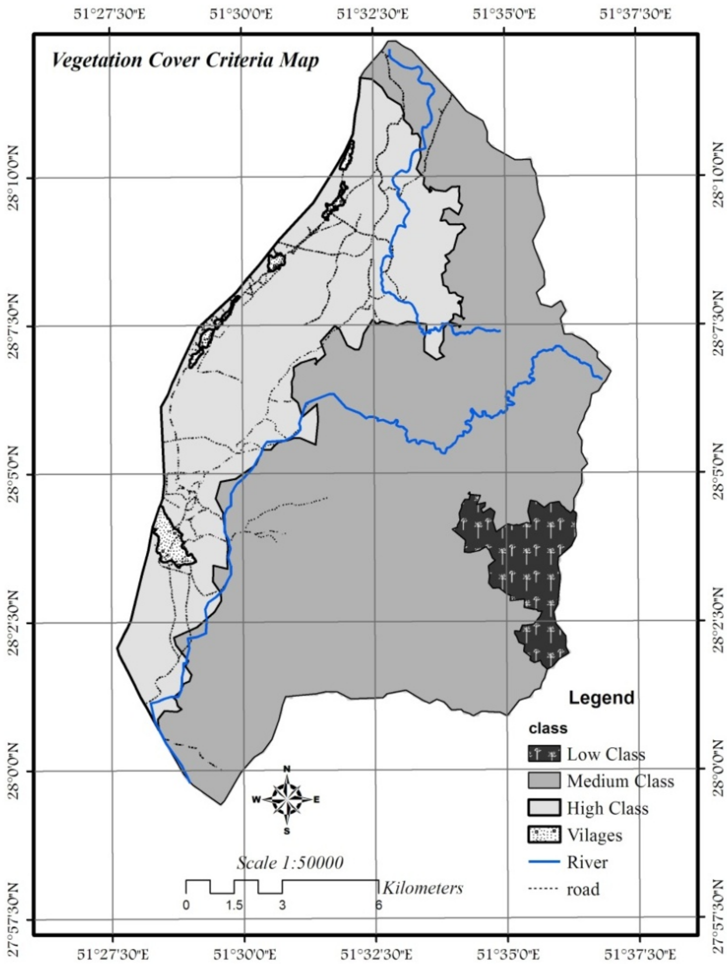

Fig. 4. Map of Vegetation Cover Criteria

3. 4. Wind erosion criterion assessment

The wind erosion criteria had a weighted average of 2.87, which is indicative of high desertification intensity in the region. The density of non-vegetation cover index, with a weighted average of 3.02, fell into the high class and had the greatest role in increasing desertification intensity. The wind erosion layer criteria of the area is shown in Figure 5, which indicates that 31.74% was in the medium, 63.58% was in the high, and 4.67% was in the very high desertification intensity class.

Wind erosion criteria$=(3.01\times3.02\times2.78\times2.72)^{1.4}=2.87$

Table 5. Geometric average of the quantitative values of Wind Erosion indices

desertification intensity class	current desertification status	Value	Index
III	high	3.01	Erosion intensity (IRIFR E.A.)
III	high	3.02	Density of non-alive cover (gravel>2mm) on soil surface (%)
III	high	2.78	Percentage Cover
III	high	2.72	Dust Storm Index

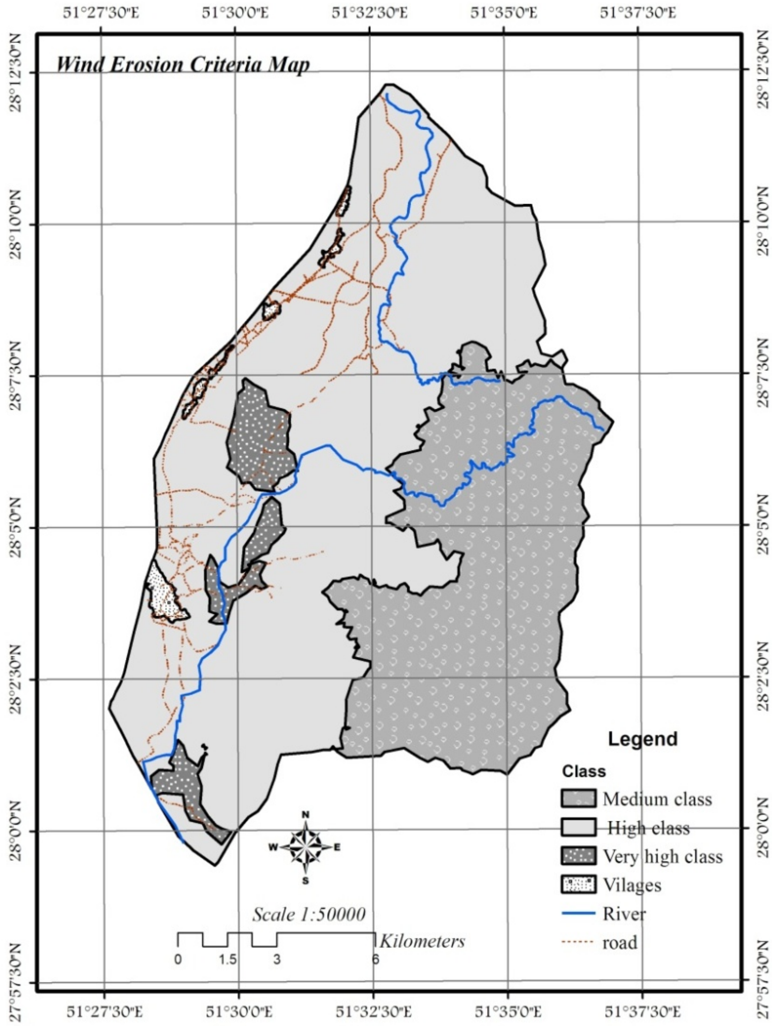

Fig. 5. Map of Wind Erosion Criteria

3.5. Climate criterion assessment

Climate criteria had a weighted average of 3.15 and was classified in the high desertification class. The annual precipitation index fell into the medium class and the aridity and drought indices fell into the very high desertification. The layer of climate criteria is shown in Figure 6.

$$\textit{Climate criteria} = (3.75\times3.65\times2.37)^{1.3}=3.15$$

Table 6. Geometric average of the quantitative values of Climate indices

desertification intensity Class	current desertification status	Value	Index
II	medium	2.37	Annual Precipitation
IV	very high	3.75	Aridity Index
IV	very high	3.65	Drought

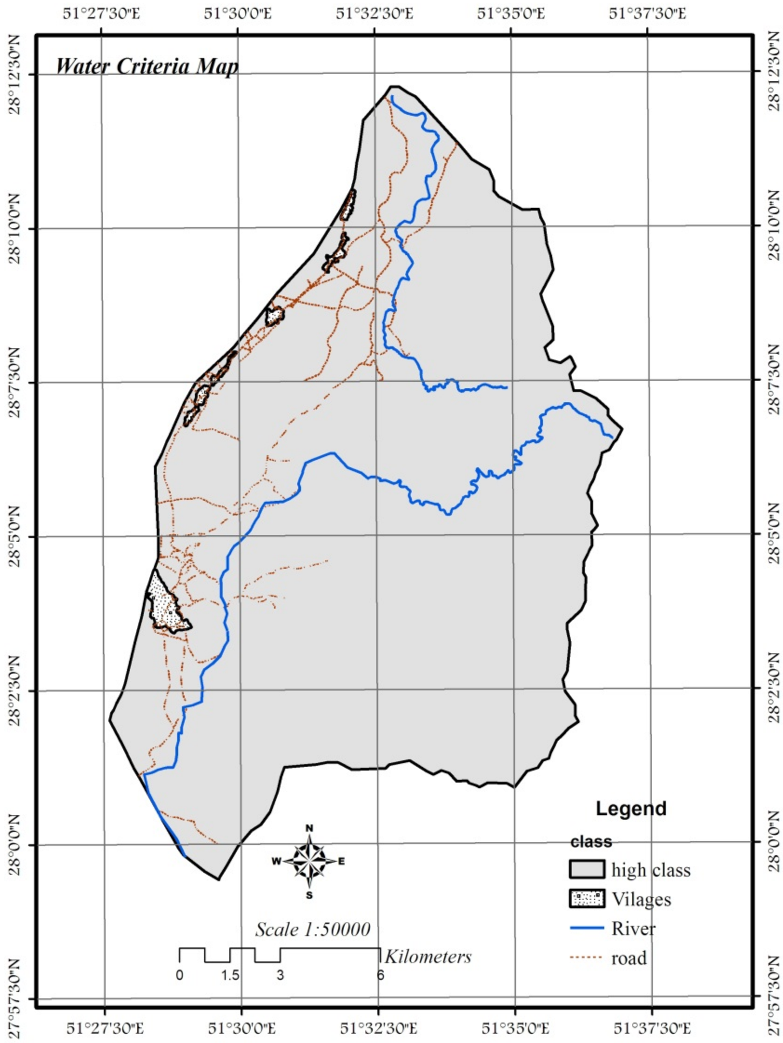

Fig. 6. Map of Climate Criteria

Table 7 shows the surface areas of each desertification class. Figure 7 shows that the map of the current desertification status, which uses two classes of desertification.

Table 7. Frequency distribution current desertification status intensity classes

Area (%)	Area (ha)	Value	Signum	Classification desertification intensity Class
0.99	212.66	0	N	No-Classified
-	-	0-1.5	I	low
49.12	10514.71	1.6-2.5	II	medium
48. 9	10682.78	2.6-3.5	III	high
-	-	3.6-4	IV	very high

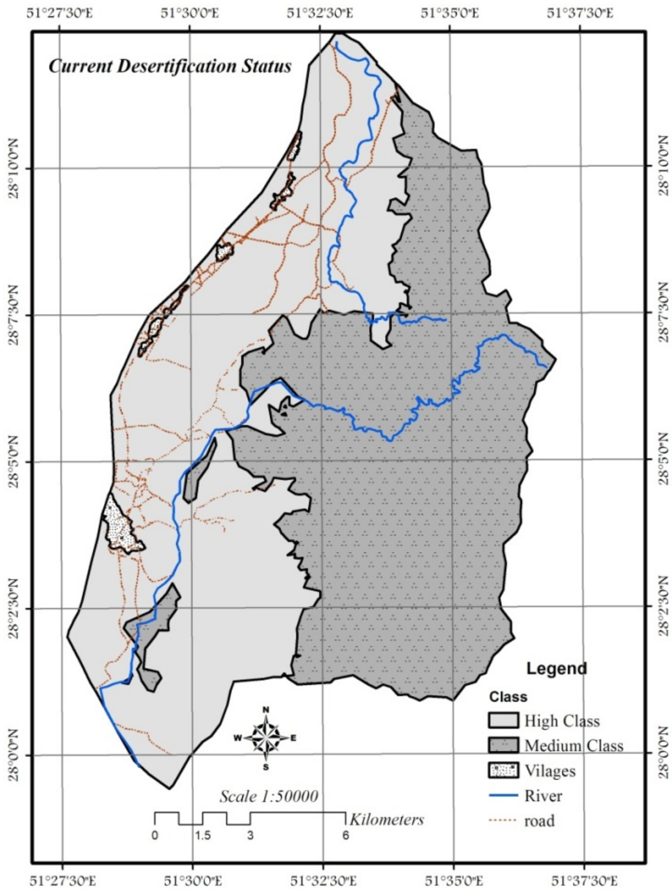

Fig. 7. Map of current desertification status caused by IMDPA Model

Analysis of the criteria in Bordekhun region showed that climate, with a weighted average of 3.15, was the dominant criterion and had the most important role in desertification. Wind erosion, soil, vegetation cover, and water resources are next in order of contribution to desertification. Of the indicators investigated, aridity, drought duration, and soil depth with weighted averages of 3.75, 3.65, and3.52, respectively, were the most effective indices. Chlorine, SAR, and subsoil gravel percentage, with weighted averages of 1.18, 1.18 and1.87, respectively, had the least effective on desertification. The results showed that, of the total area, 49.12% was in the high desertification class (10682.78 ha), 48.9% was in the moderate class (10514.71 ha), and 0.99% (212.66 ha) was not classified. The quantitative value of desertification intensity for the study area was desertification map (DM[1]) = 1.55. These five criteria are indicative of average desertification intensity for the region and the study area has the potential for severe desertification.

4. Conclusion

From the present study, can be concluded that the entire study area is affected by desertification. This destructive phenomenon is caused by natural and human factors. The natural factors affecting desertification in the study region (dryness and drought duration) are not under the control of humans. An evaluation of the factors shows that climate and wind erosion have an intensive effect on desertification throughout the study region. Zolfaghari (2010) studied potential desertification of the Jazinak region of Sistan-Baluchestan using

1- Desertification Map

IMDPA. He found that, because of hydrological drought, severe storm, dust, and the lack of suitable vegetation cover, wind erosion and climate were the strongest criteria for desertification of Jazinak region.

A very small percentage of vegetation cover, high severity of erosion, undesirable water quality, decreased groundwater, the sandy texture of the soil and the shallow depth of the soil that cause low infiltration were the most important factors affecting desertification in this region. Because of past institution of reclamation practices in the watershed area (mulching, enclosure, etc.), the severity of desertification in the study area had decreased. In recent years, however, due to inadequate management and the over-utilization of natural resources in the region, in particular, the increase in well drilling and the rapid decline in the groundwater table, has caused a major area of agricultural land to convert back to barren land, which in turn, is a precursor to desertification. Moreover, climate changes in recent years have tended toward drought and anthropogenic factors have also intensified desertification.

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