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Assessment and Mapping of Land Degradation in Abuzaydabad, Iran using an IMDPA Model with Emphasis on Land Criteria

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Abstract

Land degradation, or desertification, is specific to arid, semi-arid, and dry sub-humid regions. The rate of this phenomenon is high in developing countries such as Iran. This research investigated desertification and mapping of desertification in Abuzaydabad, near Kashan, Iran, with an emphasis on land criteria using an IMDPA model. Different studies have assessed land degradation or desertification and resulted in the production of different regional models. The application of such models to another region requires reinvestigation of the criteria and adjustments for local conditions. The present study used the newest and best model for assessment. Three key regional criteria were defined for desertification: geology-geomorphology, soil, and wind erosion. A working unit map was made using a geomorphologic method and land use in each working unit was determined. Thematic databases were integrated and enhanced using GIS and its spatial modeling function. Using the developed land degradation or desertification mapping, it was found that of the total study area (16161 ha), medium desertification was found in 4792 ha and high desertification was found in 11369 ha.

Keywords: Geology-geomorphology Index; Soil Degradation Index; Wind Erosion Index; IMDPA Model; GIS

1. Introduction

Desertification occurs in arid, semi-arid and dry sub-humid regions as a result of climatic factors and human activity and is forming at a high rate in developing countries. Ekhtesasi-Mohajeri (1995), Jafari (2001), Chamanpira (2002), Abrisham (2004), Rafiei Amam (2003), Khosravi (2004), Babaev Orlovsky (1993), Kosmas et al. (1999), FAO-UNEP-NESCO (1979), and FAO-UNEP (1984) have all evaluated desertification and mapping.

Because of the lack of a comprehensive model for assessing desertification in Iran, Ahmadi et al. (2005) have suggested use of the Iranian Model of Desertification Potential Assessment (IMDPA). This model has nine criteria (climate, geology-geomorphology, wind and water erosion, agriculture, soil, water, plant cover, socio-economic, and urban development) and 35 indicators. IMDPA has been applied to evaluate desertification in Iran and has been calibrated in arid, hyper-arid, and semi-arid regions. A significant feature of IMDPA is how it measures criteria, indicators, and ability of the map to use geometric means for the criteria and indicators.

2. Materials and Methods

2.1. Study area

The study area was 16161 ha and is located 20 km southeast of the city of Kashan. It is located at 33° 58', 33° 42' latitude and 51° 59', 51° 30' longitude (Fig. 1). Abuzaydabad is a suburb of Kashan. The region is 975-1015 m in elevation. Kashan erg is located northeast of Abuzaydabad. The average annual temperature

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of the region is approximately18.5 C°. The hottest month of the year is August; the annual rainfall is 127 mm.

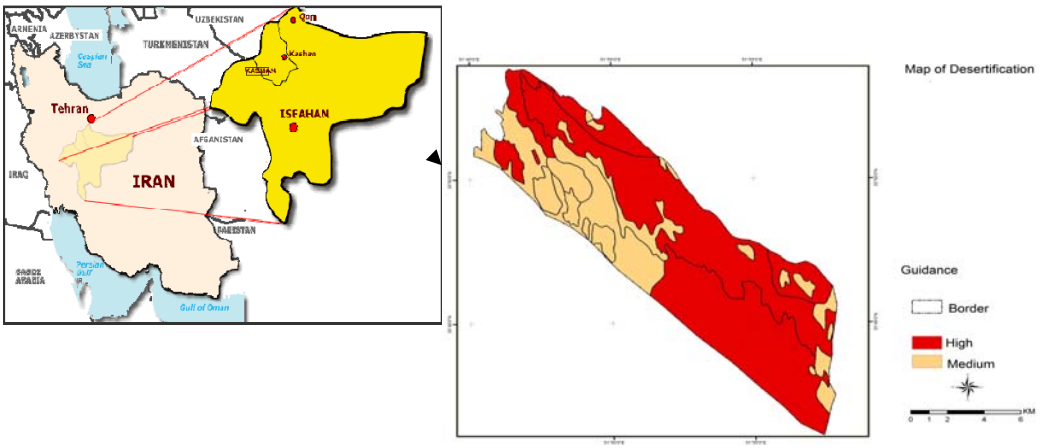

Fig. 1. Location of the study area

2.2. Materials and methods

The following databases were employed in this study:

- Topographical maps (1:50000 scale)
- Geological maps (1:50000 scale)
- Satellite images (Landsat TM; 1:100000 scale)
- Aerial photos (1:50000 scale)
- Field work to evaluate the IRIFR model and profile digging
- Experimental studies

2.2.1. Desertification mapping based on IMDPA

In this step, three of the nine benchmarks were selected for desertification mapping; each benchmark had indicators of a weighted value for desertification. A desertification map of the region was prepared using these individual benchmarks and geometric means.

2.2.1.1. Geology-geomorphology benchmark

Geology-geomorphology properties such as slope, sensitivity of rocks to erosion, and type of land use were defined as indicators (Table 1). Then, the geology-geomorphology benchmark was scored using standard tables that categorize desertification in each working unit. The geology-geomorphology benchmark ($Q_{1.1}$) was measured by geometric mean of slope ($Q_{2.1}$), sensitivity of rocks to erosion ($Q_{2.1}$), and type of land use ($Q_{3.1}$) layers using the following algorithm:

$$Q_1 = \sqrt[3]{(Q_{1.1}) \times (Q_{2.1}) \times (Q_{3.1})} \quad (1)$$

Table 2 shows evaluation of current desertification as measured by the geology geomorphology benchmarks according the three indices.

Table 1. Geology-Geomorphology benchmark

$Q_{.1}$	Indicator	Benchmark
$Q_{1.1}$	Slope of earth	Geology-Geomorphology
$Q_{2.1}$	Stone sensitiveness to erosion	
$Q_{3.1}$	Type of land use	

Table 2. Evaluation of current condition of desertification caused by Geology geomorphology benchmark according three indices

Intensity	Class	Weight Mean of Three Indices	Name of Facies
Severe	III	4	Agricultural Land
Medium	II	2.5	Medium Reg Pavement
Severe	III	3.3	Reg Pavement Fine
Severe	III	3.3	Clay Plain
Severe	III	3.3	Fix Sand Dune
High Severe	IV	4.6	Active Sand Dune
HighSevere	IV	4.6	Changing Rangeland to Agricultural Land
Severe	III	3.3	Rural Area

2.2.1.2. Soil benchmark

The soil benchmark for desertification is related to soil erosion. Electrical conductivity, soil texture, percentage of gravel cover, and soil depth are indicators of the soil benchmark. Each indicator was scored according to the standard table of soil that categorized desertification (Table 3).

Table 3. Desertification indicators from aspect of soil benchmark

Classification				Assessment factor
Very sever	Sever	Medium	Low	
<20	20-50	50-80	>80	Soil depth (centimeter)
Course- verycourse	Light	Moderate	Heavy-Very heavy	Soil texture
>65	35-65	15-35	<15	Gravel cover (Percentage)
>16	8-16	4-8	<4	Electrical conductivity (ds/m)

The soil benchmark (Q_2) was measured using the geometric mean of soil depth ($Q_{1.1}$), soil texture ($Q_{2.2}$), gravel cover ($Q_{3.2}$), and electrical conductivity ($Q_{4.2}$) layers using the following formula:

$$Q_2 = \sqrt[4]{(Q_{1..2}) \times Q_{(2.2)} \times Q_{(3.2)} \times Q_{(4.2)}} \quad (2)$$

The results of the evaluation of current desertification by the soil benchmarks are shown in Table 4.

Table 4. Evaluation of current condition of desertification caused by soil benchmark

Intensity	Class	Mean Weight	Name of facies
Low	I	2.1	Agricultural Land without problem
Severe	III	3.3	Agricultural Land with problem
Medium	II	1.9	Medium Reg Pavement
Severe	II	2.9	Reg Pavement Fine
Severe	III	3.3	Clay Plain
Medium	II	2.2	Fix and Active Sand Dunes
Low	II	1	Changing Rangeland to Agricultural Land

2.2.1.3. Wind erosion benchmark

The wind erosion benchmark is important to this region because the most of it is covered by sand dunes. The soil is exposed to the erosion by wind, the most remarkable manifestation of which is shifting sand that causes the destruction of orchards, farms, and cultivated lands and represents a serious threat to residential and industrial zones and civil and military installations.

This benchmark was assessed using indicators such as percentage of gravel cover, vegetation cover, DSI, and wind erosion intensity (WEI). The wind erosion factor was measured empirically using the Iran Research Institute of Forest and Rangelands (IRIFR) model (Ekhtessasi-Ahmadi; date). Each factor was scored in the field (Table 5).

Table 5. Indices used for evaluation of wind erosion benchmark

Very high	High	Medium	Low	Value/Indicate
3.6-4.5	2.6-3.5	1.6-2.5	0-1.5	
Active sand dunes intensive callotak	Ripple mark Yardang Callote Desert pavement with low congestion	Parabolical Surfaces surfaces Gravel appearance pavement desert	Without wind erosion forms and disturbanse during a year	Appearance of erosive facies
0<IRIFR<25	20<IRIFR<80	50<IRIFR>80	IRIFR>80	Wind erosion intensity (IRIFR 1,2)
GC<20	20<GC<40	40<GC<80	GC<80	Gravel cover percentage (GC)
PC<10	10<PC<20	20<PC<40	PC<40	Plant cover percentage (PC)
DSI< 60	<30DSI<60	10<DSI<30	DSI<10	Dust storm Intensity (DSI)

WEI was measured using the geometric mean of the wind erosion features related to sensitivity to desertification using the following formula:

$$Q_3 = \sqrt[3]{(IRIFR) \times (DSI) \times (GCorPC)} \quad (3)$$

The results of evaluation of current conditions of desertification caused by wind erosion is shown in Table 6.

2.2.1.4. Final desertification map

The final map showing desertification of the region was prepared using geometric means of all criteria according to the following formula:
Desertification map = (geology-geomorphology benchmark × soil benchmark × wind erosion benchmark)^3

Values were then assigned from Table 7; consequently, a map was prepared based on the given values and each benchmark was measured using the following formula:

$$Index = \{(layer)^1.(Layer)^2 \ldots..(Layer\ _n)\}^{1/n} \quad (4)$$

Index = given benchmark
Layer = indicator of each benchmark
where n= number of indicators for each benchmark

Table 6. Evaluation of current condition of desertification caused by wind erosion

Intensity	Class	Mean Weight	Name of Facies
Low	I	1.5	Agricultural Land
Medium	II	2.5	Medium Reg Pavement
Medium	II	2.5	Reg Pavement Fine
Medium	II	2.3	Clay Plain
Severe	III	3.3	Sand Dune
High Severe	IV	3.5	Active Sand Dune
Severe	III	3.4	Changing Rangeland to Agricultural Land
Low	I	1.3	Rural Area

Table 7. Classes of desertification intensity for IMDPA model

Desertification Intensity	Score	Symbol
Low	0 - 1.5	I
Medium	1.6 - 2.5	II
High	2.6 - 3.5	III
Very high	3.6 - 4	IV

Three maps were obtained exhibiting the conditions of the benchmark. These maps can be used to study the quality and effect of each benchmark on desertification. The final map showing desertification of Abuzaydabad was prepared using the geometric means of all benchmarks (Fig. 2).

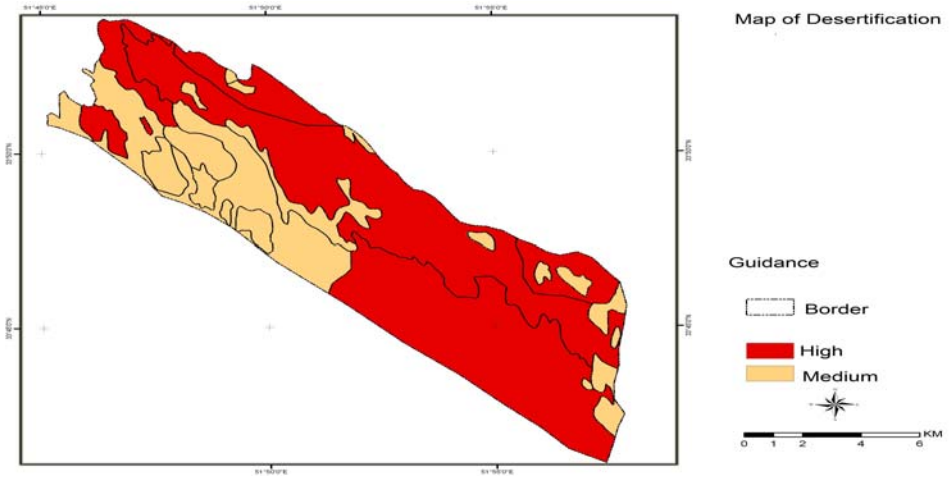

Fig. 2. The map of desertification status in Kashan

3. Results

Analysis of the desertification benchmarks in IMDPA for Abuzaydabad showed that the geology-geomorphology benchmark is the strongest benchmark with a value of 3.5; wind erosion was second with a value of 2.8. The results of the benchmarks are shown in Table 8. The mean weight of the quantitative value for land use according to the three benchmarks is shown in Table 9.

Table 8. Mean weight of benchmark

Row	Benchmark	Score	Desertification intensity
1	Geology-Geomorphology	3.5	Severe
2	Wind erosion	2.8	Severe
3	Soil	2.3	Medium

Table 9. Mean Weight of quantitative value in each of land use

Row	Indicator	Quantitative value	Desertification class
1	Slope	3.9	Very severe
2	Stone sensitiveness to erosion	3.5	Very severe
3	Wind erosion	3.4	severe
4	Menagement of land use	3.4	severe
5	EC	3.4	severe
6	Soil cover-vegetation orgravel	2.6	Medium
7	DSI	2.6	Medium
8	Texture	1.7	Medium
9	Depth soil	1.7	Medium
10	Gravel percentage	1.3	Low

Analysis of the geology-geomorphology benchmark showed that the slope index predominated, with a value of 3.9. The results of the indices are shown in Table 10.

Table 10: Mean weight of Geology-Geomorphology indices

Benchmark	Indicator	Desertification class
Geology-Geomorphology	Slope of earth	3.9
	Stone sensitiveness to erosion	3.5
	Type of land use	3.3

Based on the results, the geology-geomorphology benchmark classified that about 31% of the area experienced very high desertification, 49% high, 19% medium, and 1% in low desertification (Fig. 3).

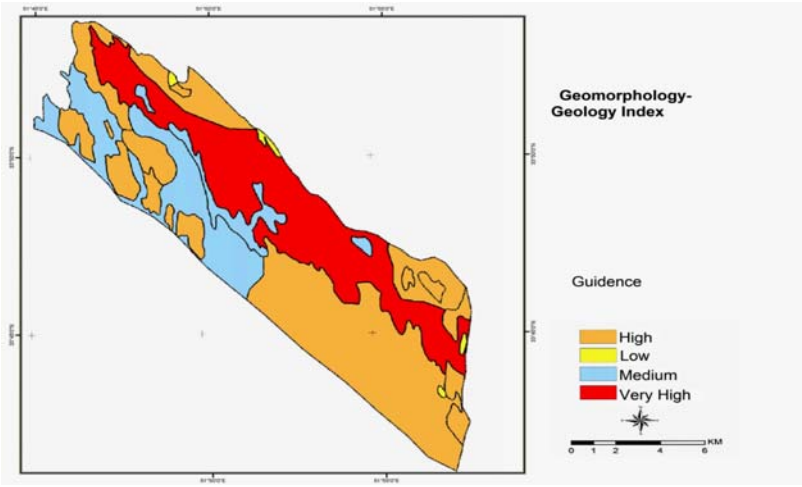

Fig. 3. The map of desertification status according to Geomorphology – geology benchmark

The results of the case study show that, for the soil benchmark, the electrical conductivity index had the highest value. The results of the indices are shown in Table 11.

Table 11. Mean weight of soil indices

Benchmark	Indicator	Desertification class
Soil	Soil depth (centimeter)	1.7
	Soil texture	1.7
	Electrical conductivity (ds/m)	3.4
	Gravel cover (Percentage)	1.3

The soil benchmark was classified as 3.7% in the high, 80.9% in the medium, and 15.4% in the low desertification category (Fig. 4).

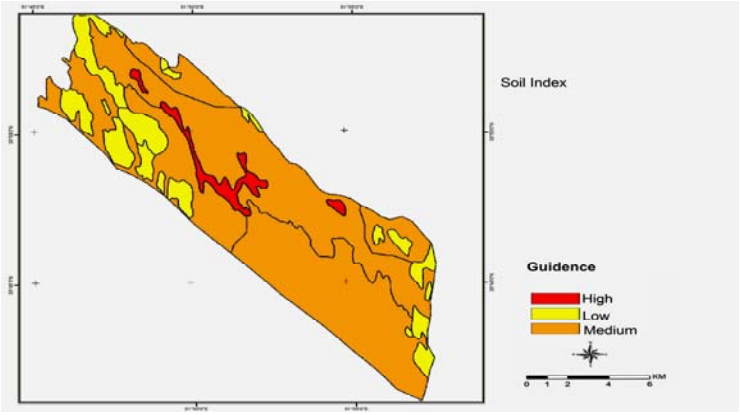

Fig. 4. The map of desertification status according to Soil benchmark

Analysis of the wind erosion benchmark showed that IRIFR had the predominate value of 3.4. The results of the indices are shown in Table 12.

Table 12. Mean weight of wind erosion indices

Benchmark	Indicator	Desertification class
wind erosion	Wind erosion intensity	3.4
	Soil cover percentage	2.6
	Dust storm Intensity (DSI)	2.4

Based on the results, the wind erosion benchmark classified about 41.8% in the high and very high, 45.8% in the medium and 12.3% in the low desertification categories (Fig. 5).

4. Discussion and Conclusion

The results of the current study indicate that the IMDPA model was highly efficient for mapping desertification in Abuzaydabad and the results correspond with real-life Abuzaydabad conditions. This method was also used in Hableh Rood watershed and Segzy Plain and showed positive results.

The IMDPA model has benchmarks and indices for desertification assessment based on regional conditions and the use of GIS and geometric means are advantages of the model. The case study for Abuzaydabad showed that the slope benchmark had the strongest effect on desertification, the sensitivity of rocks to erosion benchmark was the second strongest.

The study area was classified into about 70.34% (11365 ha) for high desertification and 29.6% (4792 ha) for medium desertification. The research showed that slope, sensitivity of rocks to erosion, wind erosion intensity, and land use indices with values of 3.9, 3.5, 3.4, 3.4, respectively, had the highest effect on desertification. Future studies should focus on conducting numerous regional studies in different climates of Iran to calibrate the benchmarks and indicators and obtain more accurate results.

This model was confirmed by Abdy (2007) with an emphasis on water and soil criteria. Results of the IMDPA model showed that geology-geomorphology and wind erosion are the most important criteria for desertification in Abuzaydabad region.

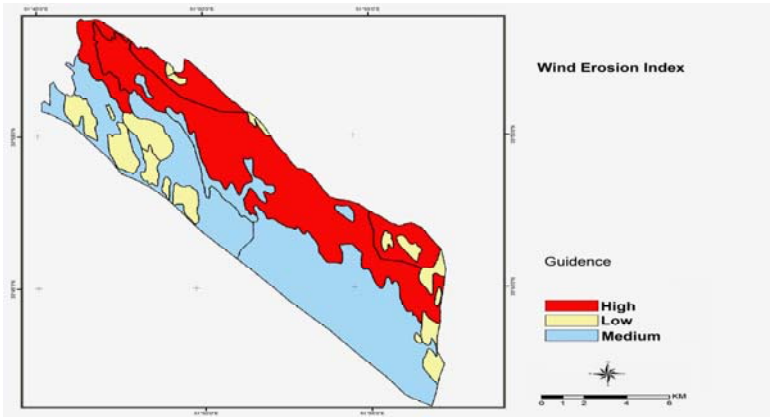

Fig. 5. The map of desertification status according to Wind erosion benchmark

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