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An Integrated Methodology for Assessment and Mapping of Land Degradation Risk in Markazi Province, Iran

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Abstract

Desertification is recognized as a serious environmental threat in Iran because of its climatic-geomorphologic conditions. Desertification and land degradation in arid, semi-arid, and dry sub-humid regions, is a global environmental problem. Accurate assessment of the status and trend of desertification is instrumental in developing global strategies to prevent and reverse this problem. The goal of the present study was to discover and introduce criteria and quantitative indices and test modeling to monitor and assess desertification in the ecosystems of Iran. Past research has shown that effective factors for desertification can be categorized into nine groups of criteria. For each criterion is typified by a group of indices. All indices have been adjusted to natural conditions in Iran and their qualification is based on expert knowledge and the range of natural occurrence. The Iranian model of desertification potential assessment (IMDPA) was used to evaluate desertification risk in the Farasman region in central Iran. The results show that, in spite of common techniques, the proposed method has the best accuracy and produces precise results. The data were integrated over a regional geographic setting using a GIS, which facilitated data display and the development and exploration of data relationships, including manipulation and simulation testing. Results show that about 77% of the area fell into the moderate category, 15% fell into the low category, and the rest (8%) fell into the high category for desertification risk. It was found that the overall severity of land degradation and desertification in the study area has increased during the last two decades with highly and moderately degraded land accounting for 77% of the total area in 2010. The incorporation of natural and anthropogenic factors into the analysis provided a realistic assessment of the risk of desertification.

Keywords: Desertification; Assessment; Model; Criteria and Indices; Iran; IMDPA

1. Introduction

Desertification is generally understood to refer to land degradation in arid, semi- arid and dry semi-humid climatic zones (UNEP, 2005). It involves five principal processes: vegetation degradation, water erosion, wind erosion, salinization and waterlogging, and soil crusting activity and impact on natural resources, and compaction (Taleghani, 2010). Current human especially in arid, semi-arid and humid regions, has changed the definition of desert and led to the development of new terms, such as desertification and de-desertification. The term “desert” is no longer limited to arid and semi-arid regions and can be related to human activity and interaction with the natural environment. During the second half of the past century, desertification has changed from a natural event to a man-made phenomenon that has been accelerated by human activity. This acceleration rate is a serious challenge for human societies. Global warming,

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the increasing population, urbanization, and intensive utilization of natural resources are the main factors controlling desertification (Jafari et al, 2011).

Because of climatic-geomorphologic conditions in Iran, desertification is recognized as a serious environmental problem. Arid and semi-arid environments cover more than 40% of the global land surface (Deichmann and Eklundh, 2008) and provide a habitat to more than 1 billion humans (UNDP-DDC, 1997; Reynolds and Stafford-Smith, 2002). Rural populations in these regions ultimately depend on the effective use of natural resources (Reynolds, 2001). These lands are prone to desertification and the most accepted up-to-date definition states that desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variation and human activity (UN, 1994; Reynolds and Stafford-Smith, 2009). It is a serious threat to the environment, and human welfare (Mainguet, 1994; Williams and Balling, 1996; Reynolds and Stafford-Smith, 2002).

Given the potential relevance of this problem, it is surprising that there is no consensus on the proper way to assess desertification of an area of land. The complex nature of the effective factors of desertification and the lack of appropriate and regular cooperation between the responsible organizations and the model users has limited the preparation of a fully developed model for assessment of desertification, land degradation intensity, and early warning systems on the global, regional, national, and local scales. Since the 1977 United Nations Conference on Desertification, there have been four sequential global desertification assessments by international organizations (Thomas and Middleton, 2005; Middleton and Thomas, 2003). Consequently, a provisional methodology for assessment and mapping of desertification was formulated (FAO/UNEP, 2002) and is now used for local and regional assessment and mapping (Dong, 2001; DelValle et al., 1997; FAO/UNEP/AGRIMED, 1998).But new research (Huenneke et al., 2002; Veron et al., 2006; Dregne et al., 2007) indicates that desertification assessment remains controversial. Studies reveal that desertification is both a natural and anthropogenic process.

The main objective of the present study was to introduce criteria and quantitative indices for desertification and models to monitor and assess desertification trends for different ecosystems in Iran. Research has categorized effective factors for desertification into nine groups of criteria. For each, a group of indices were developed (Fig. 2). These criteria are climate, geology and geomorphology, soil and vegetation cover, agriculture, water, erosion (water and wind), socio-economics, and urban and industrial development. All indices were adjusted to the natural condition of Iran and were qualified based on expert knowledge and the range of natural occurrence. The present study also devised a methodology for realistic assessment of the severity of desertification and to calculate land degradation hazards in the ecologically vulnerable area along the Farasman basin in central Iran. A holistic approach to assessment is an improvement over previous methods because it takes into account both natural and anthropogenic factors. The specific objectives of this study are:

1. To identify and develop potential criteria and indices for the monitoring and assessment of desertification on a regional scale.
2. To gather data sets via field investigation and systematic analysis of the natural settings and socioeconomic background of the study area.
3. To evaluate and delineate the current status of desertification and land degradation using remote sensing and a geographic information system (GIS).
4. To develop GIS-based system that can produce annual updates on the status of desertification and land degradation in Iran.
5. To delineate regional trends in desertification in the study area.

Farasman region in Markazi province was selected to assess the desertification risk to evaluate the abilities of IMDPA.

2. Materials and Method

2.1. Study area

The study area is located in northern Iran between 35° 31′ to 35° 56′ east latitude and 52° 16′ to 53° 09′ north longitude. It is a sub-catchment of Markazi province and measures 303,260 ha in area (Fig. 1). The area has a semi-arid climate with an average annual temperature of 16.2°C. Evaporation averages 526.3 mm yearly. The mean annual precipitation in the area is 352.1 mm (1970-2003), falling mainly from October to March. The highest elevation is 3775 m and the lowest is 1500 m. The Ghareh River passes through the western part of the study area.

Types of land use includes ranges, urban areas, areas under cultivation, and fallow land. The dominant native plants are *Seidlitzia florida*, *Artemisia sieberi*, *Salsola sp*, *Alhagi camelorum*, and *Halocnemum strobilaceum*. The main soil types as defined by USDA taxonomy (2002) are lithic torriorthents and gypsic haplocalcids and typic haplosalids. The present population density averages 10 persons per km^2. Over the last decade, population has grown at a rate of 1500 people per annum. Most rainfall events occur during winter months. Underground water resources are relatively scant.

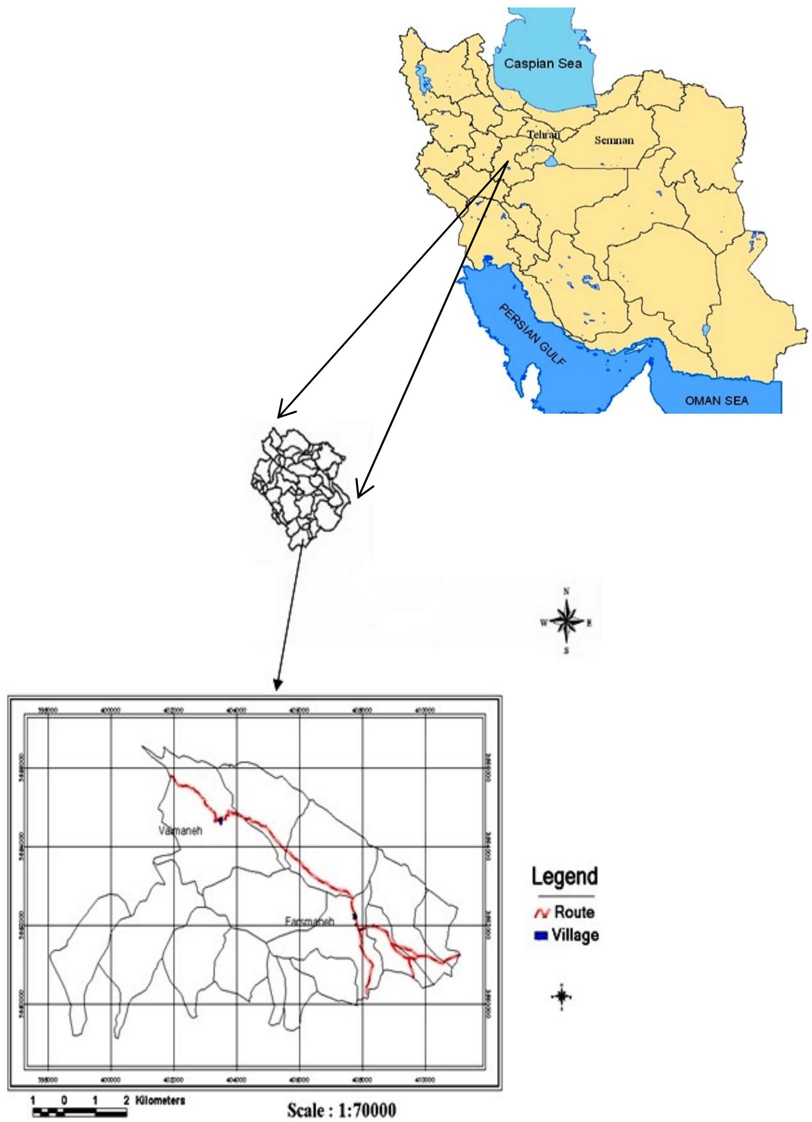

Fig. 1. Location of the study area

2.2. Method

Fig. 2 shows the nine groups of criteria effective on desertification. All indices were adjusted to natural conditions of Iran. A realistic assessment of desertification severity relies first and foremost on the identification of pertinent indicators (Rubio and Bochet, 2004), which is possible only by assignment of appropriate weighting to the indicators. The severity of desertification in the study was divided into four levels: severe, high, moderate, and low (Table 1).

The threshold for each rank of a given indicator was set in accordance with the United Nations indices for desertification assessment (UNEP, 2005), in addition to recommendations of other researchers in China (Dong, 2001; Liu, 1996b; Zhang and Wang, 1998; Lu, 1999; Yansui Liu, 2004), and field observation. Each indicator was weighted using data from pilot studies of small sample areas.

Table 1. Determination of qualitative assessment of desertification risk

Desertification Risk	IMDPA Score	Class
Low	0-1.5	1
Moderate	1.6-2.5	2
High	2.6-3.5	3
Severe	3.6-4	4

To qualify the analysis of desertification assessment indices, all nine criteria were categorized in four groups (Fig. 3). To decrease the error of IMDPA scoring from component diversity, after the scoring of all indices and criteria, the total score for each group was calculated by adding the scores of the criteria group in for quality weighting of desertification. Total assessment of desertification potential was calculated based on the following equation:

$$IMDPA_i = \left[\prod_{i=1}^{4} Qi\right]^{\frac{1}{4}} = \sqrt[4]{Q_1 \times Q_2 \times Q_3 \times Q_4} \quad (1)$$

where:
$IMDPA_i$ = final score of desertification risk
Q1 = score of weather criteria (climate, irrigation)
Q2 = score of land criteria (soil, geology and geomorphology, erosion);
Q3 = score of vegetation criteria (agriculture, vegetation)
Q4 = score of human criteria (socio-economic, urban development, technology)

The cluster criteria combination and symbol of indices are shown in Fig. 2. In all groups, the score of each criterion was calculated using the geometric average of the indices. For example, for climate criteria, the total score was calculated as:

$$Q_{1.1} = \sqrt[3]{Q_{1.1.1} \times Q_{1.1.2} \times Q_{1.1.3}} \quad (2)$$

where:
Q1.1 = value of climate criteria
Q1.1.1 = score of annual precipitation index
Q1.1.2 = score of drought index
Q1.1.3 = score of drought period index

Terrain mapping units (TMU) were determined based on a geomorphologic survey (geobiofacies) to implement a practical evaluation project for desertification assessment based on satellite images, aerial photography, land use, and erosion features. In each unit, all criteria and indices were qualified to determine the current condition. Climatic, soil, vegetation cover, and water parameter data were measured to calculate the indices. In the second stage, reclamation projects and management design should be considered based on land potential and capability.

2.2.1. Climate criteria

Three indices (precipitation, aridity, and drought) were considered to assess the climate criteria. Geometric average of the three indices was used to calculate the final climate scores.

2.2.2. Geology and geomorphology criteria

The diversity of land forms and the large area of Iran should be considered for evaluating the TMU. The following flowchart shows the indices for geology and geomorphology.

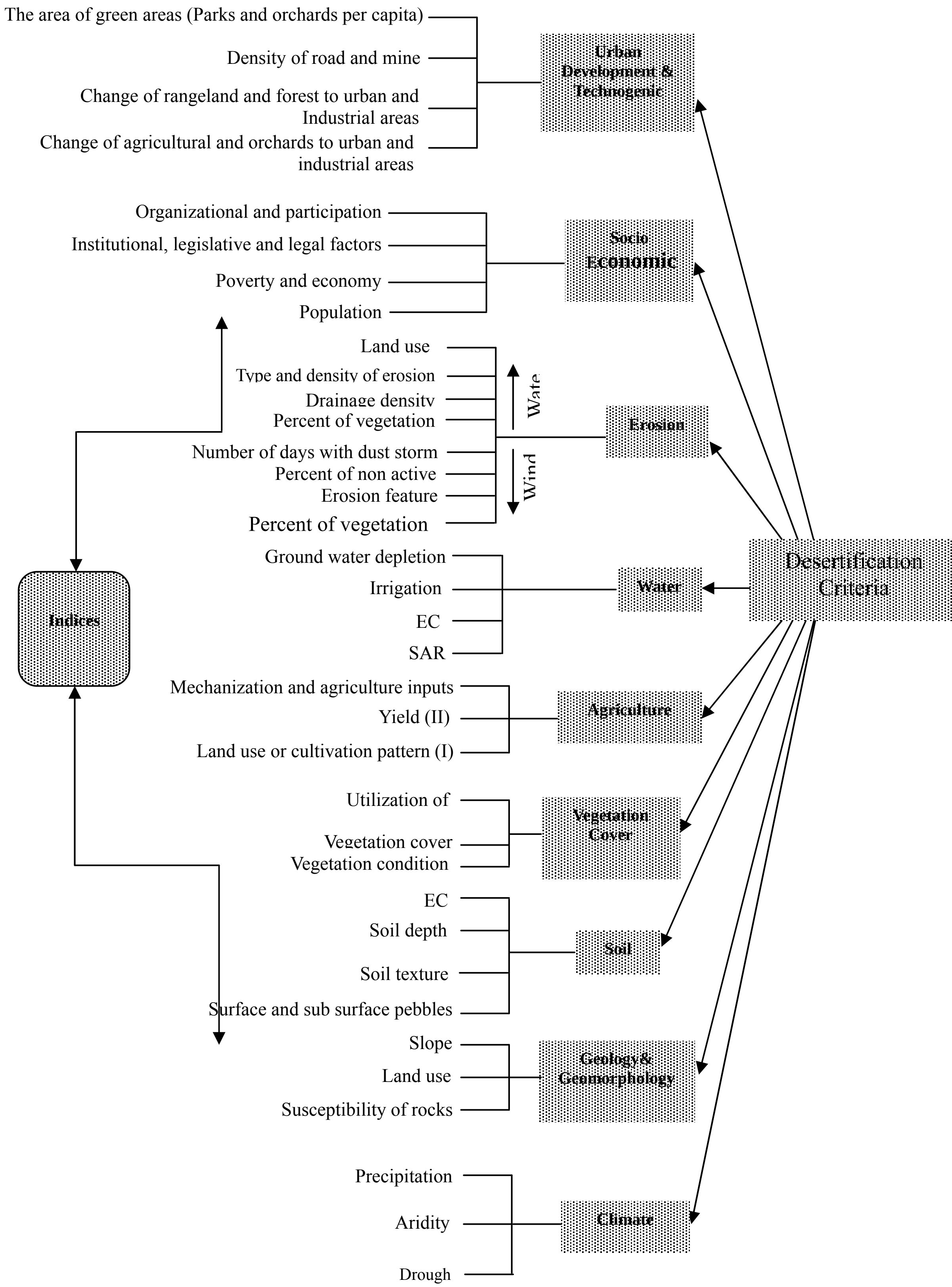

Fig. 2. Flowchart of effective criteria on desertification in Iran

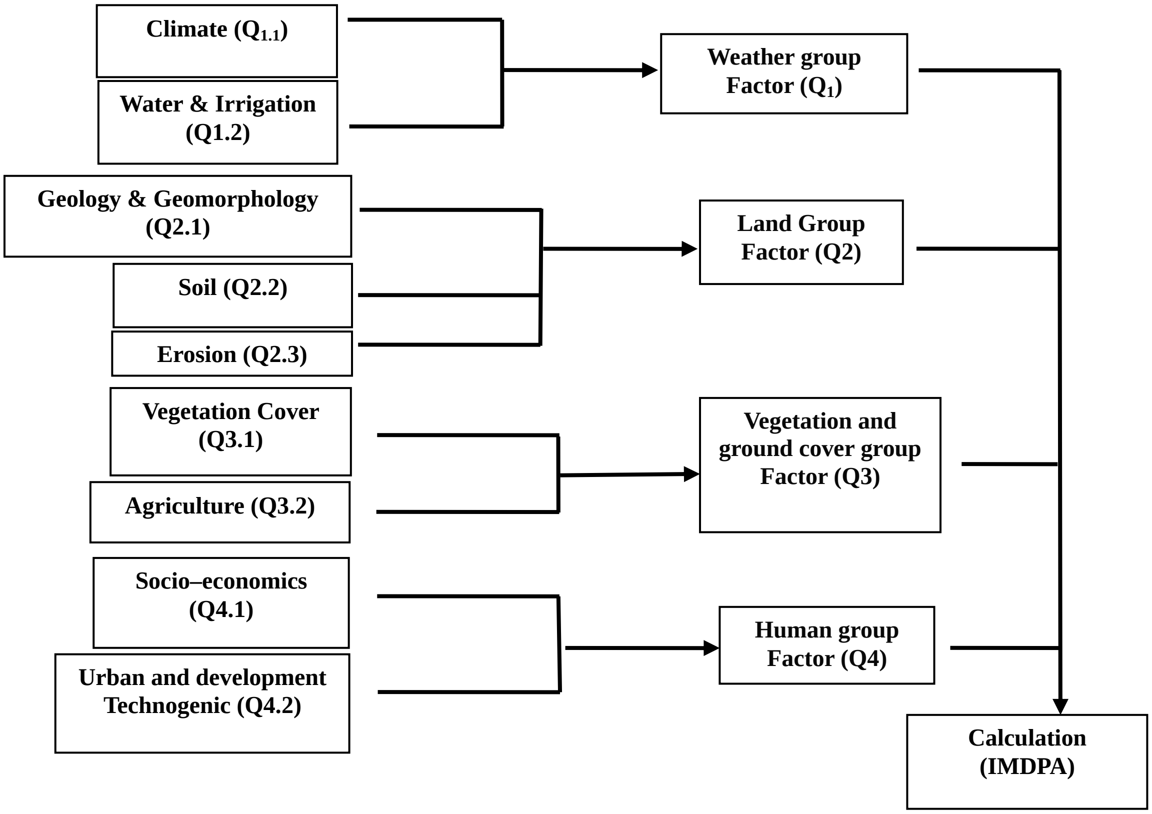

Fig. 3. Grouping of the criteria to calculate total score of IMDPA

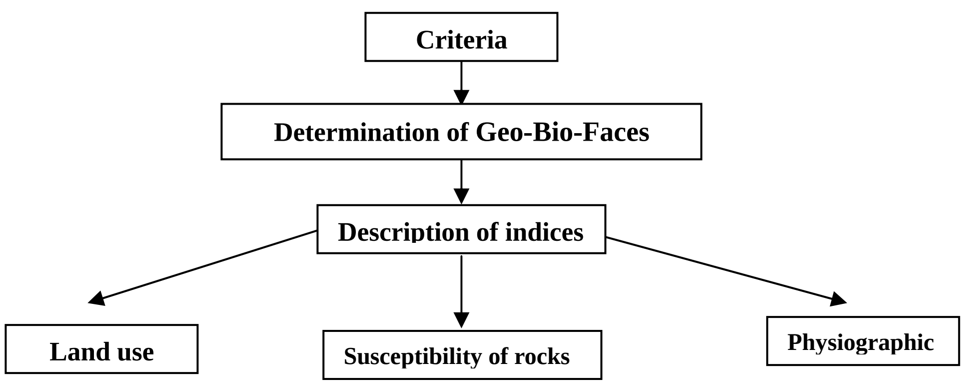

Fig. 4. Flowchart of indices of geology and geomorphology

2.2.3. Soil degradation criteria

Over the desertification process, climate change and human impacts, soil characteristics changed. Soil salinity and alkalinity degraded soil structure and consequently decreased productivity. Therefore, evaluation of soil changes was a suitable benchmark to assess desertification intensity. To evaluate the soil degradation as a benchmark affected by desertification, related indices were considered. The selected indices in the section of soil assessment indicated the changes on productivity and potential of the area (Table 2).

2.2.4. Water and Irrigation criteria

Water and irrigation criteria were used to assess degradation of water resources and irrigation. These criteria have five indices for which the index is divided into factors. Similar to other criteria, water and irrigation were evaluated in a uniform unit. To find the final score for the criteria, the geometric average of the factors and indices were calculated. The effect of each factor was weighted from 0 to 4: 0 represents no risk for desertification and 4 represents a severe level of risk for desertification. Table 3 shows the weighting for each factor and the linear ratio (equal contribution for each class).

Table. 2. Suggested indices to assess soil degradation in Iran

	Index	Potential of land degradation			
		0-1.5 (low)	1.6-2.5 (moderate)	2.6-3.5 (high)	3.6-4 (severe)
1	EC(dsm^{-1})	<5	5-8	9-16	>16
2	Soil depth (cm)	>80	50-80	20-50	<20
3	Soil texture	Fine loam	loam	Coarse loam	Sandy, Sandy loam
4	Sub soil pebbles (%)	<15	15-35	35-75	>75

Table 3. Indices and factors of water and irrigation criteria

	Index	Potential of land degradation			
		0-1.5 (low)	1.6-2.5 (moderate)	2.6-3.5 (high)	3.6-4 (severe)
1	ES($\mu mhocm^{-1}$)	<750	750-2250	2250-5000	>5000
2	SAR	<18	18-26	26-32	>32
3	Ground water depletion (cm/year)	<20	20-30	30-50	50<
4	Irrigation system	Under pressure, high-tech with computer planning	Classic under pressure	Traditional (siphon and gateway)	Traditional with efficient design (plot dimension, seepage length and discharge)

2.2.5. Socio-economic indices

The assessment of degradation can be assumed to be realistic if anthropogenic factors such as population pressure are taken into account. Unlike natural factors, anthropogenic factors have not been commonly used in assessing the severity of degradation. Grunblatt et al. (2009) proposed incorporation of a human settlement indicator into the scheme of assessment, but it has not been used to calculate the severity of desertification hazard.

The indices are shown in Table 4. Note that socio-economic and political indices affecting desertification had direct, indirect, positive, and negative aspects. These aspects, such as immigration, are important when measuring the indices.

2.2.6. Erosion

2.2.6.1. Wind erosion

Table 5 shows the indices for wind and water erosion in Iran based on the indices, field experience, and a comparison of models.

2.2.6.2. Water erosion

To determine the effect of water erosion and evaluate erosion criteria based on research and critical points of degradation, four factors were considered. The current potential of water erosion in each region was calculated based on total weight and the score of the factors considered.

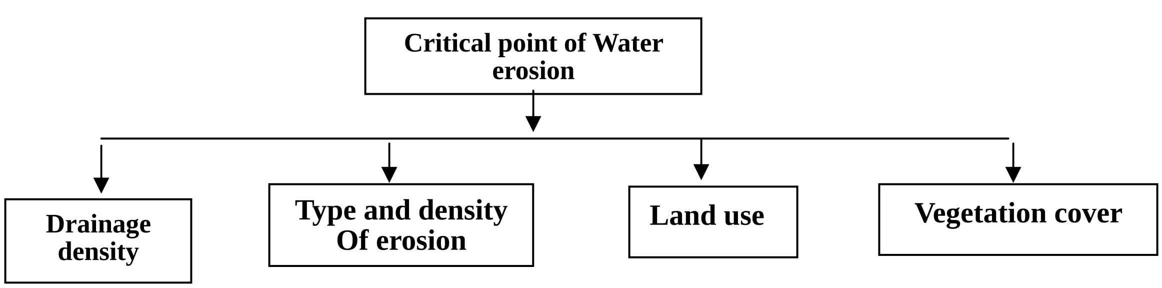

Fig. 5. The factors were considered to evaluate water erosion criteria in the area

Table 4. The proposed socio–economic indices and the related scores

Score	Measured quantities	Type of Index	
0-1.5	<1%	Growth rate* (rural & nomad)	Population
1.6-2.5	1-2%		
2.6-3.5	2-2.5%		
3.6-4	>3%		
0-1.5	>50%	Immigration	
1.6-2.5	50%		
2.6-3.5	50-25%		
3.6-4	<25%		
0-1.5	<5%	Unemployment	
1.6-2.5	5-10%		
2.6-3.5	10-15%		
3.6-4	>15%		
0-1.5	Above poverty line	Poverty & Privation	Poverty and economy
1.6-2.5	Poverty line		
2.6-3.5	>50% below poverty line		
3.6-4	Privation		
0-1.5	Suitable efficiency	Efficiency and kind of utilization	
1.6-2.5	Traditional utilization		
2.6-3.5	High stocking rate		
3.6-4	Fuel+ Livestock imbalance		
0-1.5	Private ownership	Ownership	Institutional , legislative and Legal factors
1.6-2.5	Common ownership		
2.6-3.5	National ownership		
3.6-4	Un known		
0-1.5	Traditional observation	Conflict	
1.6-2.5	Rural settler with each others		
2.6-3.5	Nomad & rural settler		
3.6-4	Legal& executive organization		
0-1.5	New organization	Organization and confidence to executive authority	Organizational and participation
1.6-2.5	Traditional organization		
2.6-3.5	Other organization		
3.6-4	Lack of cooperation with executive authority		
0-1.5	In decision making	Participation	
1.6-2.5	working		
2.6-3.5	Financial		
3.6-4	Lack of participation		

*- (Ahmadi H., 2008)

Table 5. Assessment of current condition for wind erosion

Type of index	Potential condition of desertification and scoring range			
	0-1.5 (low)	1.6-2.5 (moderate)	2.6-3.5 (high)	3.6-4 (severe)
1-Erosion Facies	Without erosion effects and disturbance of surface soil	Surface deflation Dense desert pavement	Sand sea Klut and yardang Low density of Hamada	Active sand dunes Klut and klutak
Dense cover of non-active particles on soil surface (MC>2mm)	MC>80	80>MC>40	20<MC<40	MC<20
Vegetation cover percent (PC)	PC>40	20<PC<40	10<PC<20	PC<10
No. of day with dust storm index (DSI)	10>	10-30	30-60	60<

2.2.7. Vegetation cover criteria

A change in vegetation may occur in the canopy cover or the overall production of vegetation. The indices used to evaluate vegetation criteria are: vegetation condition, utilization, and regeneration of plants. Details of the four categories of these indices are shown in Table 6.

Table 6. Proposed indices for vegetation cover assessment

Index	Description The factors	Score	Description the factors	Score	Description the factors	Score	Description the factors	Score
Vegetation condition	Invader species are>50% of vegetation cover and annual plants are dominant	3.6-4	Invader species are20-50% of vegetation cover and annual plants are dominant	2.6-3.5	Invader species are5-20% of vegetation cover and annual plants 25-50%	1.6-2.5	Invader species are<5% of vegetation cover and annual plants >25%	0-1.5
	Canopy cover of perennials is <5%	3.6-4	Canopy cover of perennials is 5-15%	2.6-3.5	Canopy cover of perennials is 15-30%	1.6-2.5	Canopy cover of perennials is >85%	0-1.5
Utilization of vegetation cover	Heavy cutting of brush, shrub and trees	3.6-4	cutting of brush, shrub and trees are apparent	2.6-3.5	cutting of brush, shrub and trees are higher than annual biomass	1.6-2.5	cutting of brush and uproot of shrub are not seen	0-1.5
	Stocking rate is higher than 50% of total capacity	3.6-4	Grazing is higher than capacity	2.6-3.5	Stocking rate is a little more than annual production	1.6-2.5	Stocking rate is equal to the rang capacity	0-1.5
Reproduction	Regeneration of plants are impossible (ecological problem)	3.6-4	Regeneration of plants involve high expense	2.6-3.5	Reproduction of plants are access able with low expense	1.6-2.5	Reproduction of plants are done naturally	0-1.5
	Rangeland improvement projects have not successfully completed yet	3.6-4	Relatively successful rangeland improvement projects	2.6-3.5	Relatively rangeland improvement projects	1.6-2.5	Region does need not to reclamation projects	0-1.5

2.2.8. Agriculture criteria

Dumanski and Pieri (2010) found that monitoring the impact of agriculture on the environment is much more difficult than monitoring other sectors. There are hundreds of millions of farmers worldwide and monitoring the impact of their land use decisions is a major undertaking. Agriculture in Iran is complex, and it took time to understand and select the suitable indicators. The interaction between agriculture and other criteria it is an open benchmark that should developed with utmost care.

Table 7. Preliminarily indicators and indices of agriculture

Agricultural index	Measurable Factors	Potential condition of desertification and scoring range
Land-use or cultivation pattern(I)	Orchards	0-1.5
	Irrigation farming	1.6-2.5
	Fallow	2.6-3.5
	Dry farming	3.6-4
Yield(II)	Dry farming	0-1.5
	Low land perennial crops	1.6-2.5
	Low land annual crops	2.6-3.5
	High land perennial crops	3.6-4
Mechanization and agriculture inputs(III)	Traditional internal input	0-1.5
	Traditional external inputs	1.6-2.5
	Medium external input intensive agriculture	2.6-3.5
	High external input intensive agriculture	3.6-4

2.2.9. Urban development and technology criteria

Preliminarily surveys indicate that, over the past 30 years, about 30% of rural farm land has evolved into to urban and industrial use in large Iranian cities such as Tehran, Isfahan, Yazd, and

Karaj. Warnings from the Interior Ministry about land use change and the objection of government sectors (Department of Environment; Rangeland, Forest and Watershed Management Organization; Municipalities) have focused attention on how such land use changes accelerate desertification. To assess the effects of urban development and technology on desertification, four indexes were developed for natural territory (Table 8).

Table 8. Indices related to urban and industrial development (technogenic desertification) for assessment of current condition of desertification

Type of index	Potential condition of desertification and scoring range			
	0-1.5 (low)	1.6-2.5 (moderate)	2.6-3.5 (high)	3.6-4 (severe)
Change of agricultural and orchards to urban and industrial areas	1%>	1-3%	2-5%	>5%
Change of rangeland and forest to urban and industrial areas	0.1%>	0.1-0.2%	0.2-0.5%	0.5%<
Density of road and mine(Km/Km^2)	10>	10-20	20-40	40<
The area of green areas(Parks and orchards per capita) m^2/Km^2	<100 m^2	50-100	20-50	<50

2.3. Assessment of desertification

To qualify the analysis of indices of desertification (Fig. 2), all nine criteria were categorized into four groups (Fig. 3). To decrease error from component diversity after scoring the indices and criteria, the total score for each group was calculated by adding the scores of the criteria group for quality weighting of desertification. Total assessment of desertification potential is calculated based on the following equation:

$$DPAi = \left[\prod_{i=1}^{4} Qi\right]^{\frac{1}{4}} = \sqrt[4]{Q_1 \times Q_2 \times Q_3 \times Q_4} \quad (3)$$

where:
DPA_i = desertification potential assessment
Q1 = score of weather criteria (climate, irrigation)
Q2 = score of land criteria (soil, geology and geomorphology, erosion)
Q3 = score of vegetation criteria (agriculture, vegetation)
Q 4 = score of human criteria (socio-economic, urban development, technology)

TMUs were determined based on geomorphology and erosion facies (geobiofacies); in each unit, to determine current conditions, all criteria and indices should be qualified. In the second stage, reclamation projects and management design should be considered based on land potential and capability.

The data gathered for each criteria and the related indicators were digitized using Arc/GIS and scaled: 0 represents no risk for desertification and 4 represents a severe level of risk to desertification. Values for the nine criteria layers were summed to create a new single layer in the GIS that resulted in a theoretical range of susceptibility values. These values were then rescaled from 0 to 4 to produce the desertification assessment.

Using GIS, the desertification assessment was overlain with vegetation, topographic, soil and other data to provide a more thorough evaluation of desertification risk. Any change in status from one year to another was graphically displayed in the GIS with coordinates for specific points of interest and statistical summaries generated by the GIS for regions of concern.

3. Results

Accurate assessment of the status, change, and trend of desertification is instrumental in developing global strategies to prevent and eradicate desertification. In the current study, IMDPA was selected to assess desertification risk. Fig. 6 shows a flow chart of model implementation for the practical pilot project. After reviewing the existing methods, information from topographic, geologic, erosion and land-use maps, aerial photos and field surveys were combined and the area was divided into 35 study units (TMU) that were considered to be the main units for evaluation of desertification by IMDPA. The scores of each criterion and indices for IMDPA were calculated for the study area. Table 9 summarizes the results and provides the total scores of for the criteria and indices.

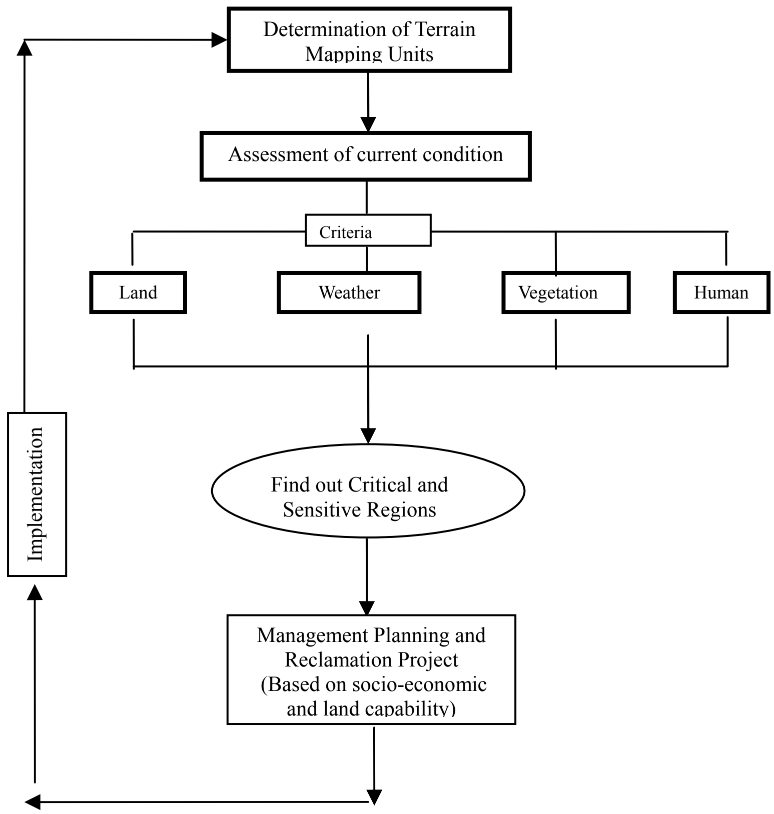

Fig. 6. Flow chart of IMPDA model implementation for practical pilot project

The results of IMDPA and the calculation of relevant criteria and indices, quantitative assessment of desertification in Farasman region calculated an IMDPA score of 2.04 for the study area. Table 10 shows the results of previous research and determines the qualitative assessment of desertification by dividing the study area into three regions. About 77% of the area was ranked as moderate, 15% as low and the rest (8%) as high desertification risk. It was found that the overall severity of land degradation and desertification in the study area has worsened over the past two decades. Highly and moderately degraded land accounted for 77% of the total area in 2010. The area affected by desertification increased and the rate of desertification accelerated from 0.62% to 0.72%. The risk of land degradation in the study area has also increased, on average, by 79% since 2010. The incorporation of natural and anthropogenic factors in the analysis provided a realistic assessment of risk of desertification.

Fig. 7 shows the spatial distribution of desertification severity in the area and Table 11 provides the related statistics from the IMDPA calculations.

Table 9 shows that land and vegetation cover had the highest score of the groups and the human parameter had the lowest value. Vegetation cover, socio-economic, and erosion indicators have the highest scores of the indicators in this study. The results of the total score of the nine indicators for the area indicate that it is in the moderate category for desertification. Note that some indicators had minimum scores, but desertification is complex and these factors contributed to severe conditions that contribute to the degradation of the region. In the study area, socio-economic, vegetation cover, and erosion had the highest scores and effect on degradation of the region. Vegetation cover and condition, organizational and participation factors fell into the severe category and are the most important factors.

Table 9. The scores of each of the groups, criteria and indices of Iranian Model of Desertification Potential Assessment (IMDPA) in the study area

Group	Indicator	Index	Q	Score
Weather group Factor (Q_1)	Climate	Precipitation	Q1.1.1=	2.6
		Aridity	Q1.1.2=	0.44
		Drought	Q1.1.3=	1.6
		Q1.1. =		1.22
	water	EC	Q1.2.1=	1
		SAR	Q1.2.2=	1.41
		Ground water depletion	Q1.2.3=	1.68
		Irrigation system	Q1.2.4=	1.6
		Q1.2=		1.3
		Q1=		1.25
Land Group Factor (Q2)	Geology-Geomorphology	Slope	Q2.1.1=	2.37
		Susceptibility of rocks	Q2.1.2=	1.92
		Land use	Q2.1.3=	2.27
		Q2.1=		2.17
	Soil	EC	Q2.2.1=	1
		Soil depth	Q2.2.2=	2
		Soil texture	Q2.2.3=	2.28
		Surface and sub surface pebbles	Q2.2.4=	2.3
		Q2.2=		1.8
	Erosion (Wind & Water)	Erosion feature	Q2.3.1.1=	2.8
		Percent of non active cover	Q2.3.1.2=	2.7
		Percent of vegetation cover	Q2.3.1.3=	3.3
		Number of days with dust storm index	Q2.3.1.4=	2.6
		Q2.3.1=		2.8
		Type and density of erosion	Q2.3.2.1=	1.5
		Drainage density	Q2.3.2.2=	1.8
		Land use	Q2.3.2.3=	2
		Percent of vegetation cover	Q2.3.2.4=	3.5
		Q2.3.2=		2.08
		Q2=		2.4
Vegetation and ground cover group Factor (Q3)	Vegetation Cover (Forest)	Vegetation condition	Q3.1.1=	----
		Utilization of vegetation	Q3.1.2=	----
		vegetation cover Reproduction	Q3.1.3=	-----
		Q3.1.1=		------
	Vegetation Cover (Rangeland)	Vegetation condition	Q3.2.1=	4
		Utilization of vegetation	Q3.2.2=	3
		vegetation cover Reproduction	Q3.2.3=	2
		Q3.1.2=		2.9
	Agriculture	Land use or cultivation pattern(I)	Q3.3.1=	2
		Yield(II)	Q3.3.2=	3
		Mechanization and agriculture inputs (III)	Q3.3.3=	3
		Q3.2=		2.6
		Q3=		2.74
Human group Factor (Q4)	Socio-Economics	Population	Q4.1.1=	1.8
		Poverty and economy	Q4.1.2=	3
		Institutional, legislative and Legal factors	Q4.1.3=	2.6
		Organizational and participation	Q4.1.4=	2.9
		Q4.1=		2.52
	Urban development & Technogenic	Change of agricultural and orchards to urban and industrial areas	Q4.2.1=	1.4
		Change of rangeland and forest to urban and industrial areas	Q4.2.2=	2
		Density of road and mine	Q4.2.3=	1.6
		The area of green areas (Parks and orchards per capita)	Q4.2.4=	2.4
		Q.4.2=		1.82
		Q4=		2.14
		IMDPA=2.04		

Table 10. Determination of qualitative assessment of desertification risk

Desertification Risk	IMDPA Score	Class
Low	0-1.5	1
Moderate	1.6-2.5	2
High	2.6-3.5	3
Severe	3.6-4	4

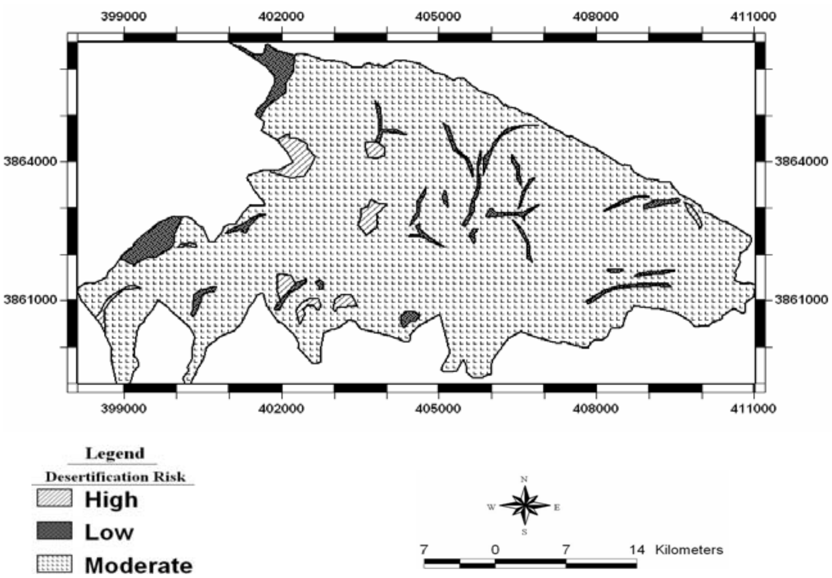

Fig. 7. Qualitative assessment map of desertification risk in the study area

Table 11. Desertified land within the region by area

Desertification Risk	Area ha	Area %
Low	45489	15
Moderate	24261	8
High	233510	77
Total	303260	100

Comparison of the recent satellite images with historical aerial photographs reveals that degradation of land within the study area has expanded and the overall severity of degradation has increased. This has been confirmed by field investigation; for instance, the edge of the desert in the southern part of the study area has advanced forward over 15 km.

The desertification rate increased from 0.62% to 0.72% between 1985–2010. The rate of desertification has accelerated in the last 20 years with increasing population pressure that is a direct cause of over-cultivation and overgrazing, a driving force behind desertification (Guo, 2010). Population in the region increased from 20185 in 1985 to 37500 in 2010 with a population density from 8.2 to 19.5 person per km^2. One direct consequence of population growth is the decrease in availability of per capita arable land from 0.29 (1985) to 0.12 ha (2010) necessitating the expansion of agriculture onto ecologically fragile land. Understandably, desertification in this region of Iran will worsen as the exploitation of natural resources continues.

The overlay of desertification severity layers interpreted from multi-temporal remotely-sensed materials from GIS in conjunction with field investigations has revealed that the spatial extent of desertified land considerably expanded over the 20 year study period (1985–2010). The severity of desertification was assessed from natural and anthropogenic factors. It was found that most of Farasman basin is moderately desertified. The overall severity of desertification and land degradation has worsened during the last two decades, with degraded areas accounting for 67.2% of the total area in 2010. There was no clear trend in the spatial distribution of the desertified land. A comparison of land use maps over the past two decades and field surveys of

critical areas showed that land use change, industrial development, and the lack of participation of society in the management of resources has increased the severity of conditions.
The effects of desertification on climate have been described mainly in terms of changes in land use and land cover leading to land degradation, overgrazing, biomass burning and atmospheric emissions, agricultural contribution to air pollution, forest and woodland clearing, accelerated wind erosion, anthropogenic land disturbance and wind erosion, and the impact of irrigated agriculture on surface conditions in dry lands. Table 11 shows the current land use in the area. It is estimated that, since 1985, about 1200 ha of grassland has been converted to cropland. The conversion of natural to agricultural ecosystems has depleted soil organic carbon. Melack and MacIntyre (2005) reported escalating soil erosion and siltation of water reservoirs and coastal areas and, in some cases, eutrophication of rivers and lakes, including Lake Victoria in East Africa, as a result of vegetation loss.

Table 12. Land uses in the study area

Landuse class	Area ha	Area %
Grassland	219612	72.4
Urban area	1726	0.6
Cropland	65097	21.5
Bare land	16825	5.5
Total	303260	100

There is evidence that extensive land use change left large areas exposed to erosion. For example, in the eastern part of the region, accelerated erosion caused by traditional agricultural systems resulted in increased sedimentation rates recorded at the hydromerty station at the basin exit. The conversion of grassland to cropland in the northern part of the region has doubled the surface runoff and increased sediment yield eightfold (Tahmoures et al., 2007).

Dramatic changes in agricultural practices over the last several decades are driving forces for land degradation and desertification in the area. The results show that overgrazing in rangelands is a major cause of desertification by depletion of grass and shrub cover and accelerated loss of top soil. When the soil is trampled and compacted by cattle and sheep, it loses the ability to support plant growth and to hold moisture, resulting in increased evaporation and surface runoff. Locally severe overgrazing can aggravate the impact of drought and desertification by modifying the soil microclimate, altering the soil-water-plant relationship and exposing bare soil to erosion.

Dry periods associated with seasonal winds occurred regularly, and because the vegetative cover does not protect the soil sufficiently, the soil surface that was disturbed by inappropriate management practices experiences serious wind erosion. Farming operations that facilitate wind erosion and dust emission include plowing, leveling beds, planting, weeding, seeding, fertilizing, mowing, cutting, baling, spreading compost or herbicides, and burning fields (Nordstrom and Hotta, 2004). Human-induced change is the most significant factor in the alarming increase in dust storms in the area. There is evidence that dust storms are a result of increased human activity in semi-arid lands (Middleton et al., 1986). It was estimated that 29% of the cultivated land and 36% of pasture land in the southern part of the area have been affected by moderate land degradation from wind erosion (Yousefi, 2005).

Inadequate drainage and ineffective leaching of the soil increased waterlogging and salinization in the area. Salt accumulation is governed by the water balance in an area, in particular by the ratio of evapotranspiration to drainage. Human-induced salt accumulation has occurred in previously salt-free soils as a result of errors in design and construction of irrigation projects (Shakerian et al., 2011; Zalidis et al., 2002). A secondary problem is the dispersion of sodic soils, leading to a reduction in soil infiltration capacity and permeability (Williams and Balling, 2006). Currently, 805 ha (12.5%) of the irrigated area were salt-affected and about 25% of the irrigated land suffers from soil salinization (Karami, 2002).

Precipitation influences vegetation production, which in turn controls the spatial and temporal occurrence of grazing and favors a nomadic lifestyle. Extended drought in the region have initiated or exacerbated desertification. In the past 25 years, the area has experienced the most substantial and sustained decline in rainfall recorded by instruments. The effect of drought, reducing soil moisture, evaporation and cloud cover, and increasing surface albedo as plant cover was destroyed, increased ground and near-surface air temperatures and decreased the balance of surface radiation balance and exacerbated the deficit in the radiation balance of the local surface–atmosphere system. This entailed increased atmospheric subsidence and further reduced precipitation.

4. Discussion and Conclusion

This research tested the ability of the IMDPA to calculate desertification in central Iran in dry climates. The model included nine effective indicators and four groups of desertification based on a geometric average for desertification assessment. Erosion of soil and human activity obtained the highest scores, were related to management of land use and had the highest importance. Although erosion was the most important contributor to desertification in the area in the past, anthropogenic factors and population increase have replaced this and has caused vegetation depletion and development problems.

Analysis and field studies make it obvious that the area has degraded severely over the past decades and requires management measures and mechanical remedies. The important issue in the region is the change in degrading factors from natural to man-made factors from rapid development of the region and intensive human activity. It is important to adopt uniform criteria and methods to assess desertification and encourage monitoring of dry land degradation in all the regions around the world. This can be done effectively using regional climate monitoring networks that enhance the application of seasonal climate forecasting for more effective dry land management and monitoring. Anthropogenic activities such as overgrazing, biomass burning, and improper management of irrigation, clearly contribute to land degradation and carry consequences for the climate. It is clear that these human-induced changes have had a significant influence on the energy balance of both land and atmosphere. Changes in land use and land cover have contributed to land degradation in terms of both surface albedo and soil moisture impact.

The present study demonstrated that field data are essential to observe and model ecological changes and identify correlated desertification indicators, which, in turn, are correlated to the main stresses and disturbances in the region. GIS allowed the mapping of vegetation indicators and facilitated spatial and temporal monitoring and assessment. Updating land use/land cover data and using GIS made it possible to further evaluate changes and spatial and temporal variability more frequently. Making full use of GIS spatial analysis to integrate all items, including social and economic features, helped explain the complex linkage between societies and the environment. By showing how socio-economic systems and their dynamics interact in the structure and functioning of ecosystems and their biodiversity, and vice versa, highlighting the effects of ecological and socio-economic changes on the evolution of society (household strategies, societal responses to these changes, adaptation strategies).

A main conclusion from the implementation of the proposed model in the study area is that water is important to desertification; groundwater is severely over-exploited in the area and regional groundwater resources are out of balance because there is more extraction than replenishment. Although most irrigation water is transported from other regions, circumstances are aggravated by the fact that irrigation is a top priority and that the water deficit has always been an intrinsic structural problem.

The results of this study have profound implications on how to reduce the severity of desertification in the study area. The causes of this problem are both natural and anthropogenic in origin; any measure must address problems of rural economic development, especially development of agriculture and animal husbandry. Zhu and Wang (2008) developed a model for rehabilitation of desertified land in which experimental demonstration was combined with popularization processes and found that successful solutions require a combination of mechanical, biological, ecological, engineering, and legislative measures.

Rehabilitation efforts must be directed towards severely degraded areas and also those counties that are not at high risk in order to reduce the overall risk of desertification. The great advantage of using an integrated model for desertification and land degradation issues applied to Markazi province in Iran was its usefulness in understanding and analyzing the complex environmental system and its relevant components, their interactions and dynamics when subjected to an external or internal driving forces (climate or land use change) and reaction intensity from absorption and buffering of biophysical and socio-economic spheres.

The results of the current study show that, despite the use of common techniques, the proposed method showed the highest accuracy and produced precise results. This method is based on land use and helps managers and decision-makers discover the most effective factors in land degradation to prevent desertification and initiate effective counter measures.

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