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Assessment of desertification hazard, risk and development of management plans

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Abstract

About 80 percent of Iran is arid and semi-arid and about 35 percent of this area is susceptible to desertification hazard. Therefore desertification assessment and identification of the most important criteria for the assessment of risk and a basis for development of management plans is essential. This research was conducted in the semi-arid region of Agh-Band in the Golestan province, Iran with an area of 3062.5 km^2 aiming at preparation of the desertification hazard and risk maps and development of various management plans to control the desertification. In this study, the IMDPA model and geomorphologic facies were used to evaluate the desertification hazard. The work units (geomorphologic facies) were defined based on geology and land use maps, satellite images and field surveys. The risk map was developed with a combination of desertification hazard intensity and hazard elements and degree of vulnerability maps using the total risk equation. Desertification management plan was developed based on four management strategies including: no plan, maintains the status quo, avoid the risk and implement the control measures. The results indicated that soil and vegetation criteria with magnitudes of 2.67 and 2.54 fall into sever desertification category (III) and other criteria are within medium class (II). The average value of degree of desertification in the study area was 2.03 (class II).

***Keywords*:** Desertification hazard; Geomorphologic facies; Risk; Management plan; Agh-Band; Golestan

1. Introduction

Nowadays, risk has a widespread and multi-dimensional meaning which depends on safety, economic, social and environmental issues. Various meanings which are due to different application of different decision- making authorities have caused an indefinite definition of this word. One of the problems encountered is the technical definition of risk and extension of its application in different sciences. The best definition for the risk may be the correlation between parameter (element) and hazard (Messnerand Meyer, 2005). Desertification in arid, semi-arid, and dry sub-humid regions, is a global environmental problem (Yang *et al.*, 2005). Desertification sensitivity can be defined, in this context, as the response of the environment or part of it to a change in one or more external factors (Batterbury and Warren, 2001). Therefore, fighting against desertification and harnessing it in these areas is essential for development plans. Mapping desertification risk and damage is a reasonable basis for planning. Desertification in developing as well as developed countries is intensifying, so dealing with this phenomenon particularly in these countries will be very helpful and beneficial. So far desertification and land degradation has not been considered as a priority at local, national, regional, global levels (Melchiade, 2009), while its spreading and progression can be mitigated or reduced by providing appropriate management approaches. In this way, selecting influential criteria and indices in the form of a model capable of expressing desertification intensity is highly beneficial. The purpose of this research is mapping risk intensity and desertification

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damages as well as providing and developing various managerial plans for a semi-arid area named Agh-band. Evaluating the contribution of the most important criteria (soil, vegetation, etc.) involved in desertification is another objective of this study. A performed study by Yang *et al.* (2005) showed that there are two major problems facing the assessment of degradation in China including uncertainty of baseline assessments and indictor systems and the misuse of remotely sensed data sources. Ownegh (2009) developed a desertification risk management plan for Gorgan plain on the basis of physiographic units by including five key parameters (salinity, waterlogging, water erosion, wind erosion, and degradation of vegetation cover) based on AHP and subjective model. He also classified the risk of desertification in this region into four classes, and by applying different scenarios provided a managerial plan. From the major advantages of the model adopted in this study, the quick process of evaluation and the inclusion of expert judgments under the lack of reliable field and laboratory data sources could be mentioned. Bouabid *et al*. (2010) assessed desertification in Morocco's Souss river basin by means of MEDALUS with some modifications. Four main indicators including soil, vegetation, climate and management were used for the preparation of desertification sensitivity map. As given by the results, a large part of the area (72%) is highly vulnerable to desertification. The southern part of the state has a critical and fragile condition with weather as the crucial parameter which is per se exacerbated by the physical and human factors. Gad and Lotfi (2008) used remote sensing and GIS for mapping susceptible areas for desertification in Egypt and they understand that the Nile valley's soil quality is low and also showed that 86.1% of Egypt's soil is in the low quality class and is sensitive to erosion. Hosseini *et al.* (2012) studied desertification hazard using modified MEDALUS model in Niatak region of Sistan and indicated that of the whole studied region (comprising 4819.6 acres), 55% are located in medium desertification intensity class, 26.34% are positioned in severe desertification intensity class, and 18.64% are placed in vary severe desertification intensity class. All things considered, it appears that desertification is complex in nature and many factors are involved in this phenomenon. In spite of the facts that different methods have been used to assess the risk of desertification in different regions of the world, no single method has been identified for the assessment of desertification risk and damages and thus no management agenda thus far has been proposed. Therefore, in a systematic and sustainable attempt to reach a management plan for dealing with the risk of desertification in desert areas along a steep gradient from the foothills to the playa, preparing the maps of desertification risk and damage based on an appropriate model (IMDPA[a]) is inevitable. The model provides a procedure of weighted layers with GIS applications. Moreover, it insures accuracy, speed of assessing and mapping (Geeson *et al*., 2010). In this study, the simultaneous implementation of three stages of risk and damage assessment as well as development of the desert management plan is of high applicability as the consecutive circles of information chain in the comprehensive land management and management of environmental risks. this study assessed desertification risk by applying the general equation R = H. E. V. Ownegh (2009) in Ziarat watershed in Gorgan, Kenlong *et al*. (2007) in Yangjya, Yangf Zhyg province of China, Remondo *et al*. (2008) in Bajudba (northern Spain), Enrique *et al*. (2008) in Kuantamo, Cuba also used this equation to estimate damage. Roads, residential areas, springs, facilities, rangeland lands and agricultural lands were selected as elements at risk in this study. Ownegh (2009) in Ziarat watershed selected roads, electricity networks, residential areas, tourist complexes and water resources. Zezere *et al*. (2008) in north of Lisbon, Portugal have selected roads and buildings and Enrique *et al*. (2008) in Kvantamv Cuba have selected houses, schools, cemeteries and roads as in hazard elements. Desertification in semi-arid region of Agh-band is in its active state because of the special climate, edaphic and geomorphologic characteristics of the area. Hence, it is inevitable to assess the desertification risk and status based on the criteria and indices of utmost influence in the form of the IMDPA model in order to wisely develop a mitigating while harnessing managerial plan in line with national action plan (NAP) for desertification control.

2. Materials and Methods

This phase of the research involved collecting information from relevant agencies, acquiring maps, defining work units, risk mapping by means of the IMDPA model, preparing risk and damage maps and finally developing an

[a] Iranian Model of Desertification Potential Assessment

appropriate management plan to deal with the phenomenon.

2.1. Study area

The study area lies within 37° 7' 37” to 37° 37' 22” northern latitude and 54° 24' 03” to 54° 40' 07” eastern longitude with a total area of 3062.5 km^2 in Golestan province, Iran. The province, in terms of geomorphology, is divided into three sections of mountainous, foothills and lowlands. Fig. 1 shows the location of the study area in Golestan province.

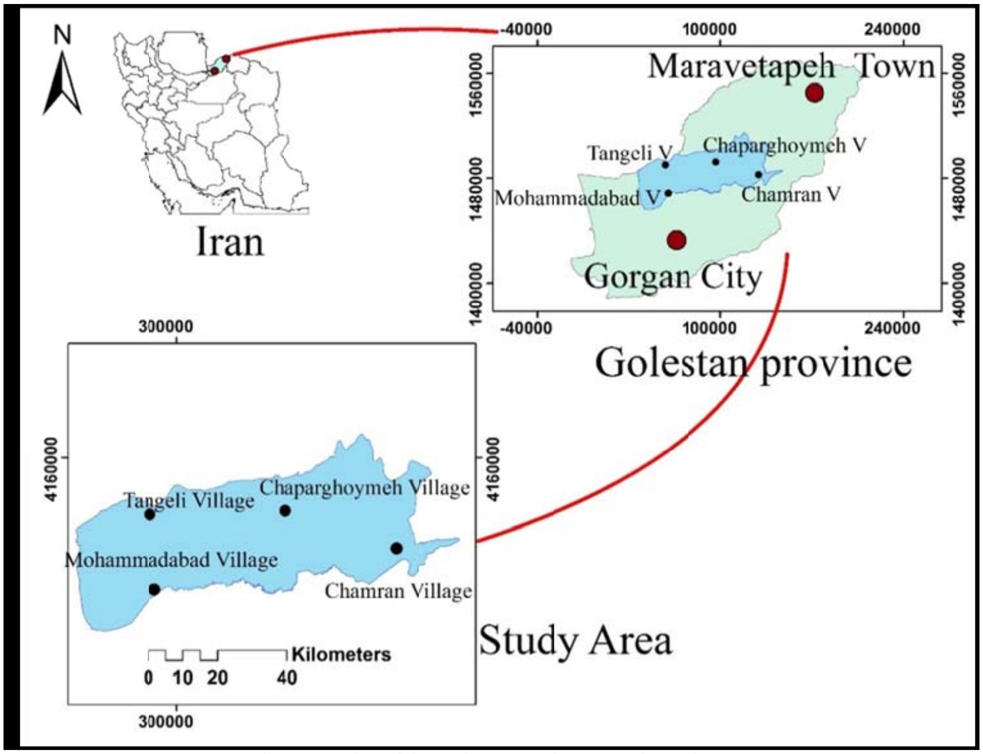

Fig. 1. Location of the study area, Golestan province of Iran

2.2. Mapping geomorphological facies (work units)

In this study, to evaluate the hazard of desertification and to provide risk management plan in accordance with the purpose of research, geomorphological facies has been separated into mountains and pediments.

2.3. Desertification hazard

In this study, for the purpose of investigating the status of desertification and providing desertification maps in Agh-band, Golestan province of Iran, IMDPA model was used. IMDPA is the latest tool for the assessment of desertification in Iran by taking account of 9 criteria for three climates of dry, semi-arid and semi-humid dry. The nine criteria are: climate, geology and geomorphology, soil, vegetation, water, erosion (water-air), agriculture, socio–economic conditions, urban and industrial development. Each of the parameters was separately considered and evaluated as a desertification criterion (Fig. 2).

As can be seen each criterion map is divided into four classes of slight, moderate, severe and very severe based on the assigned weights (Table 1).

Table 1. Classification of desertification classes in IMDPA model (Arami, 2012)

Class	value range	Symbol
Slight and negligible	0 – 1.5	I
Moderate	1.6 – 2.5	II
Severe	2.6 – 3.5	III
Very Severe	3.6 - 4	IV

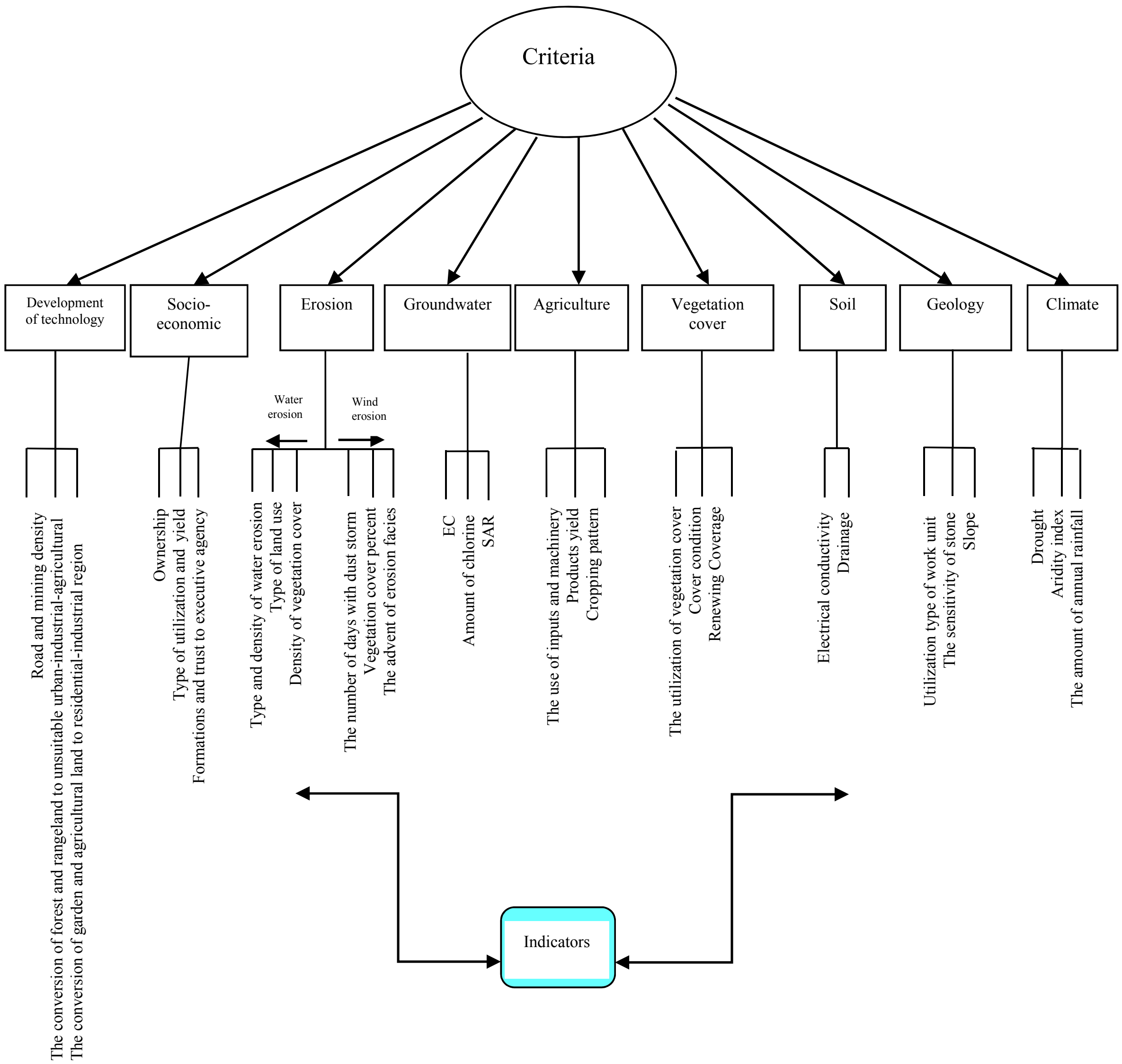

Fig. 2. Structural diagram of IMDPA model (assessed criteria and indices) (Ahmadi, 2006)

2.4. Assessment of Desertification Risk

Total Risk is estimated by the desertification risk equation as R = H.E.V (Ammann, 2016). Where, R is risk, H large hazard, E elements at stake and V vulnerability of the elements. Elements at risk studied in this research include buildings, roads, rangelands, residential areas and infrastructure.

2.5. Map of the elements at risk

Land use, topography and the inventory of elements at risk (agriculture, rangelands, villages, facilities, roads and springs) facilitate the identification and delineation of these elements in each unit of hazard classes (Ownegh, 2009).

Table 2. Classes of elements at risk in the semi-arid region of Agh-band (Ownegh, 2009)

No	Element Class	Qualitative Class	Number of Elements
1	I	Very Low	≤2
2	II	Low	3
3	III	Medium	4
4	IV	High	5
5	V	Very High	6

2.6. Elements Vulnerability Map

After determination of classes (Table 2) and identification of the elements in each unit of hazard map, elements vulnerability classes were determined by using table 3 (Nazari Nejad, 2010) and based on the related hazard intensity classes, expert judgments and Conditions of the study area. Elements at the higher classes are subjected to higher level of vulnerability.

Table 3. Classification Standards and vulnerability level of elements at hazard (Nazari Nejad, 2010)

Vulnerability Class	Qualitative Classes	Vulnerability Value
I	Very Low	< 7
II	Low	7 - 15
III	Moderate	15 - 35
IV	High	35 – 45
V	Very High	> 45

2.7. Risk Assessment

To calculate the risk value from the aforementioned equation R = H. E. V, numerical value of risk elements, vulnerability of the elements and risk severity are multiplied in order to demonstrate the priorities of different work units and management plans to combat desertification (Table 4) (Nazari Nejad, 2010).

2.8. Prioritization of desertification management plans

Based on management classes, prioritization of management plans to deal with the crisis of desertification was carried out in semi-arid region of Agh-band (Table 5).

Table 4. Classification Standards and risk value

Risk Class	Qualitative Classes	Risk Value
I	Very Low	0-10
II	Low	10-25
III	Moderate	25-40
IV	High	>40

Table 5. Guidelines for the setting priorities for management plans

Risk Class	Management Plan	Recommended Plans	Management Plan Classification
I	No Plan	No specific management plan is recommended	0
II	Maintaining Status quo	Prevention of land use change and destruction of vegetation or controlling grazing	I
III	Risk Avoidance	II-a: spaces at risk not to be occupied	II
		II-b: planting crops tolerant to salinity	
IV	Controlling measures	III-a: enrichment of grasslands, increasing vegetation, especially crops tolerant to salinity and drought	III
		III-b: the mechanical operation of constructing Open Drains	

3. Results

3.1. Work units (geomorphological facies)

3 study area was divided into 3 units, 5 types and 40 geomorphological facies (work unit) (Fig. 4 and 5 and Table 6). The scale all maps are 1/100000.

3.2. The hazard of desertification in the study area

To assess the current state of desertification, each of the indicators was evaluated and ranked in each work unit in order to determine desertification classes. After determining the numerical value of each of the facies, it was attempted to determine the current status of desertification and to map it (Fig. 3). The following results were obtained after the summarization of data sources form the IMDPA model (as the selective model) (Figs. 6 to 14).

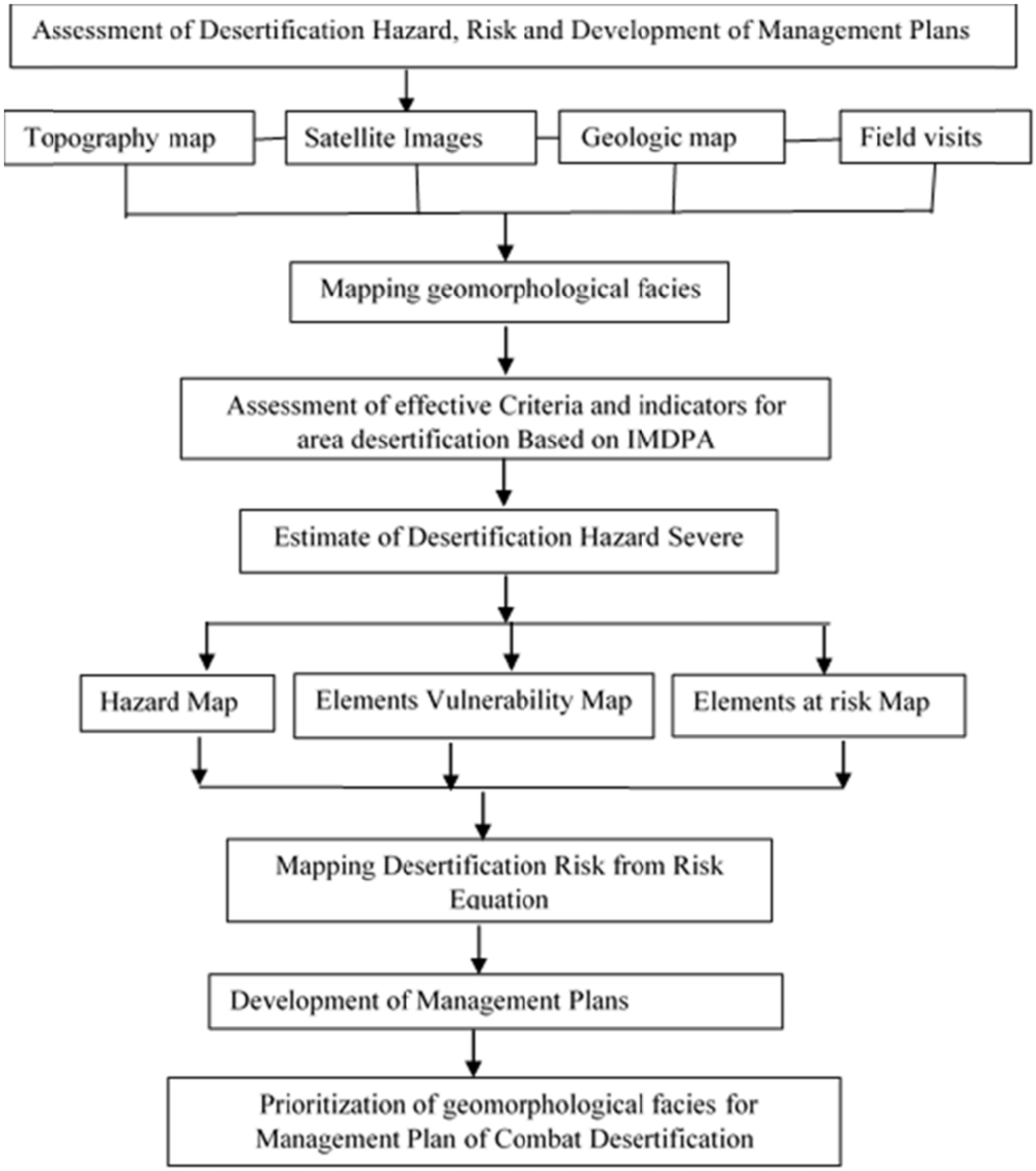

Fig. 3. Flowchart of the research methodology

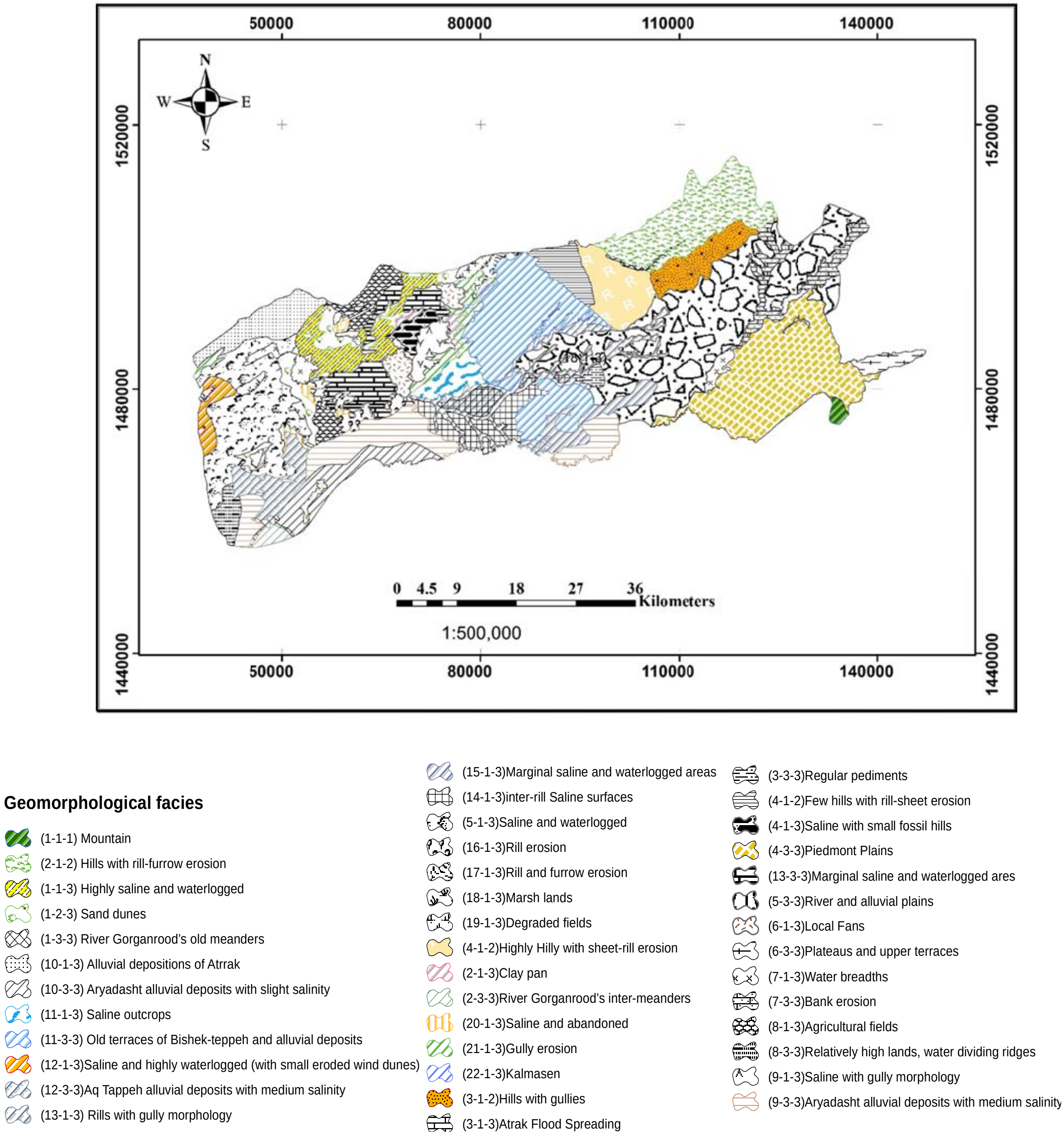

Fig. 4. Work-Unit map of Agh-band area, Golestan province (geomorphological facies)

Table 6. Distribution of geomorphological units of semiarid region of Agh-band

Unit	Type	Facies	Area (ha)	Percent	frequency
Mountain (0.26 %)	Relatively high mountains (0.26 %)	Mountain	808.1	0.26	1
Loess Hills (12.57 %)	Loess Hills (12.57 %)	Hills with rill-furrow erosion	18128.55	5.92	1
		Highly Hilly with sheet-rill erosion	8892.9	2.90	1
		Hills with gullies	6825.85	2.23	1
		Few hills with rill-sheet erosion	4650.6	1.52	1
Khazari covered pediment (87.17 %)	Atrak's New Flood Plain (34.49 %)	Highly saline and waterlogged	7978.9	2.60	2
		Clay pan	1374.98	0.45	3
		Atrak Flood Spreading	349.88	0.11	1
		Saline with small fossil hills	2160.21	0.70	1
		Marginal saline and waterlogged ares	9652.35	3.15	3
		Local Fans	3197.09	1.04	2
		water breadths	5092.58	1.66	11
		Agricultural fields	5652.23	1.85	3
		Saline with gully morphology	3143.3	1.03	1
		Alluvial depositions of Atrrak	7603.02	2.48	1
		Saline outcrops	4149.06	1.35	1
		Saline and highly waterlogged (with small eroded wind dunes)	2638.14	0.86	1
		Rills with gully morphology	13295.1	4.34	2
		inter-rill Saline surfaces	9940.73	3.25	7
		Saline and waterlogged	21687.03	7.08	1
		Rill erosion	1864.7	0.61	2
		Rill and furrow erosion	2386.69	0.78	3
		Marsh lands	1389.07	0.46	4
		Degraded fields	880.4	0.29	1
		Saline and abandoned	1350.47	0.44	4
		Gully erosion	4662.35	1.52	3
		Kalmasen	264.19	0.09	1
	Sand dunes (2.58 %)	Coastal fossil dunes	7894.49	2.58	15
	Gorganrood's New Flood Plain (50.1 %)	River Gorganrood's old meanders	636.97	0.21	1
		River Gorganrood's inter-meanders	1181.7	0.39	1
		Regular pediments	934.54	0.30	1
		Piedmont Plains	30584.06	9.97	1
		River and alluvial plains	49016.52	16.00	4
		Plateaus and upper terraces	2132.53	0.70	1
		Bank erosion	6153.47	2.01	2
		Relatively high lands, water dividing ridges (between Atrak and Gorganrood Basins)	2396.2	0.78	1
		Aryadasht alluvial deposits with medium salinity	15952.05	5.21	3
		Aryadasht alluvial deposits with slight salinity	7584.71	2.46	1
		Old terraces of Bishek-teppeh and alluvial deposits	25946.22	8.47	3
		Aq Tappeh alluvial deposits with medium salinity	6022.6	1.97	1
		Marginal saline and waterlogged areas	4888.13	1.60	1
		Total	306250.08	100	99

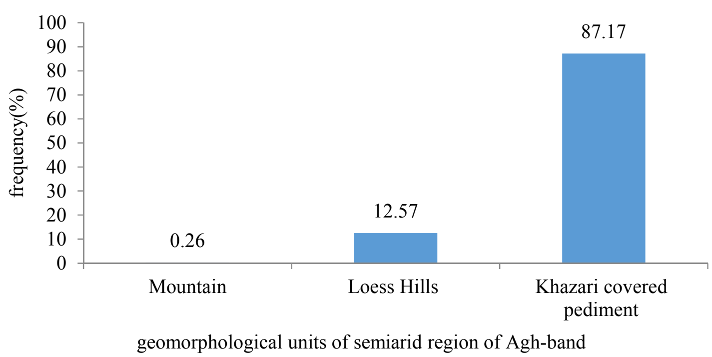

Fig. 5. Frequency distribution of geomorphological work-units in the study area

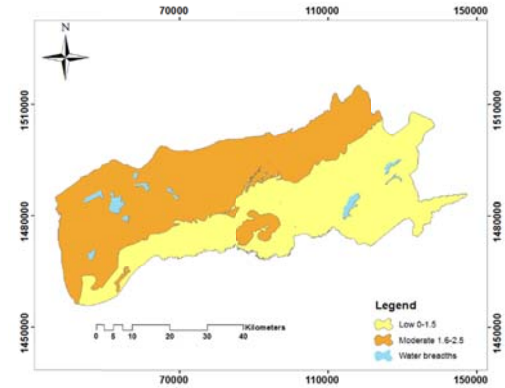

Fig. 7. Desertification sensitivity map of Agh-band region based on climate criterion

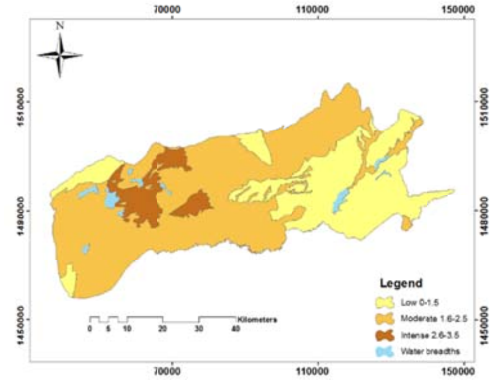

Fig. 6. Desertification sensitivity map of Agh-band region based on geology criterion

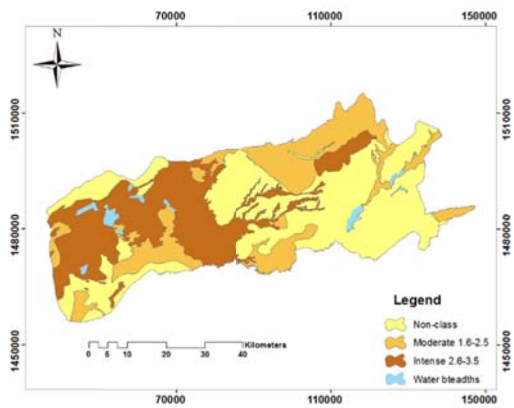

Fig. 9. Desertification sensitivity map of Agh-band region based on vegetation cover criterion

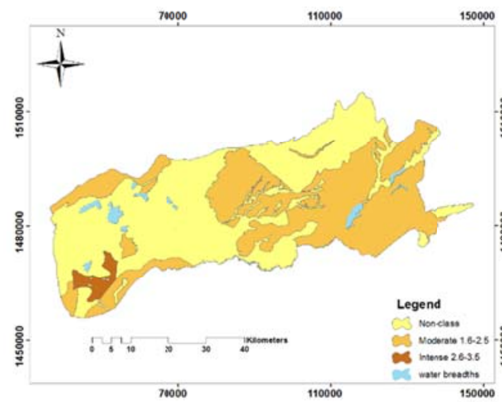

Fig. 8. Desertification sensitivity map of Agh-band region based on agriculture criterion

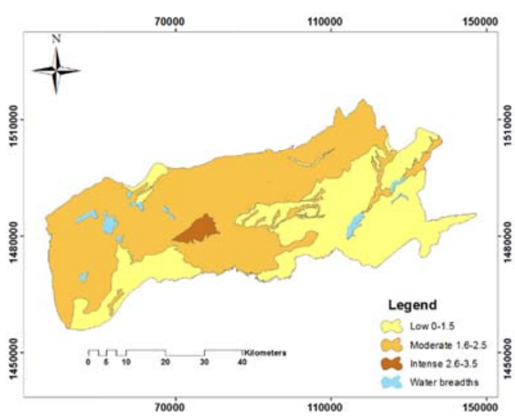

Fig. 11. Desertification sensitivity map of Agh-band region based on erosion criterion

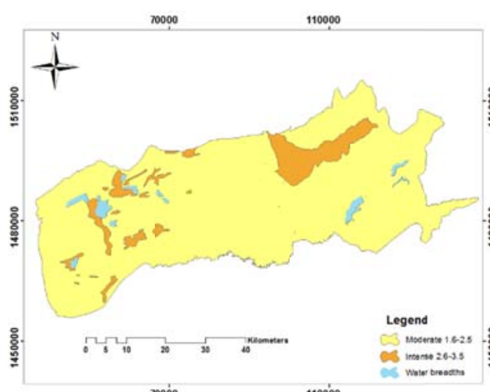

Fig. 10. Desertification sensitivity map of Agh-band region based on socio-economic criterion

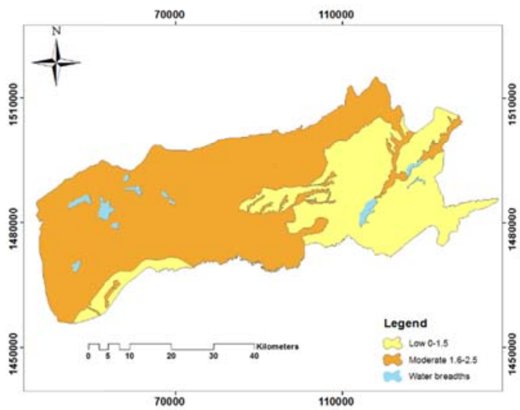

Fig. 13. Desertification sensitivity map of Agh-band region based on groundwater criterion

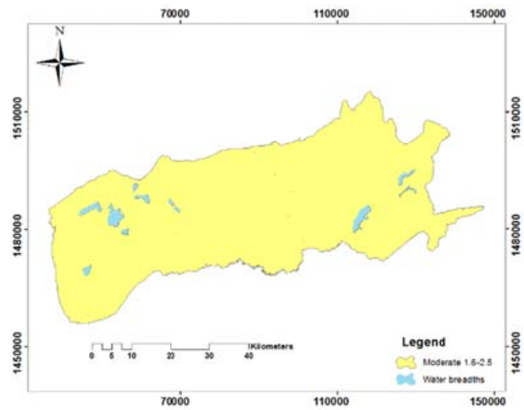

Fig. 12. Desertification sensitivity map of Agh-band region based on development of technology criterion

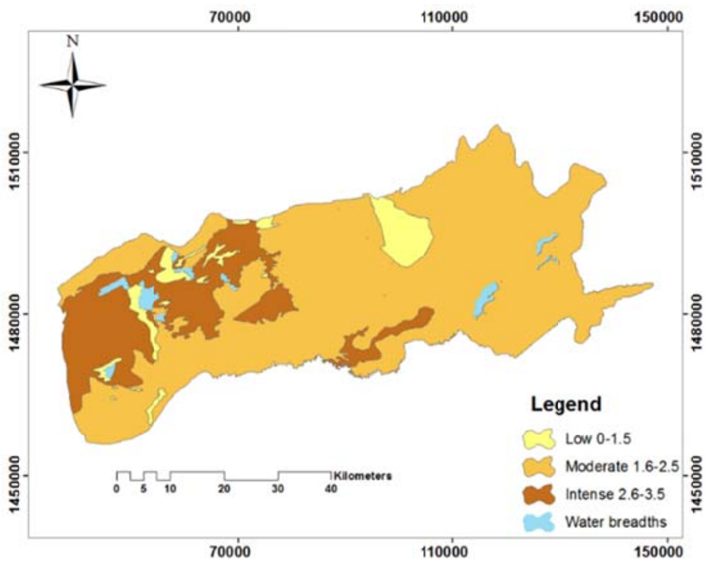

Fig. 14. Desertification sensitivity map of Agh-band region based on soil criterion

3.3. Analysis of criteria and indicators of desertification in Agh-band area

3.3.1. Desertification criteria

Criteria of desertification in the region, in order of importance include: vegetation cover (2.67), soil (2.54), development of technology (2.42), socio-economic (2.21), agriculture (2.08), climate (1.72), erosion (1.7), geology (1.65) and groundwater (1.6) (Figs. 15 and 16).

3.3.2. The severity of desertification

According to calculations made using the ArcGIS desktop 9.3 software, the value of desertification intensity in semi-arid region of Agh-band in Golestan province was measured 1.95. In the current classification scheme of the IMDPA model, desertification class (II) was assigned as the average status to the whole region.

In terms of frequency, 31.32% of the total area fell into the desertification slight to negligible desertification class, 50.88% into the moderate and 17.80% into the severe classes (Table 7).

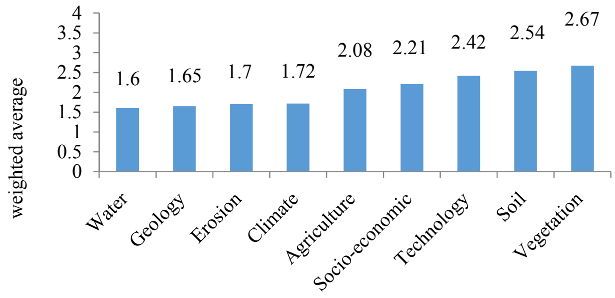

Fig. 15. The analysis of the weighted average of desertification in Agh-band area

Table 7. Frequency distribution of desertification hazard classes in Agh -band region

Class cod	Hazard class	Weight range	Area(ha)	Frequency percent
I	Low	0-1.5	95925.92	31.32
II	Moderate	1.6-2.5	155811.59	50.88
III	sever	2.6-3.5	54512.5	17.80
Total			302800	100

According to the following formula it can be found that:

$$DM = (QC \times QW \times QS \times QG \times QA \times QT \times QE \times Q(S - E) \times QV)^{\frac{1}{n}}$$

$$DM = (1.72 \times 1.6 \times 2.54 \times 1.65 \times 2.08 \times 2.42 \times 1.7 \times 2.21 \times 2.67)^{\frac{1}{9}} = 2.03$$

Evaluations taken place on the weighted average of quantitative values of the IMDPA model's criteria showed that in the semi-arid region of Agh-band, vegetation criterion with 2.67 and intense class (III) is the main factor in intensifying desertification.

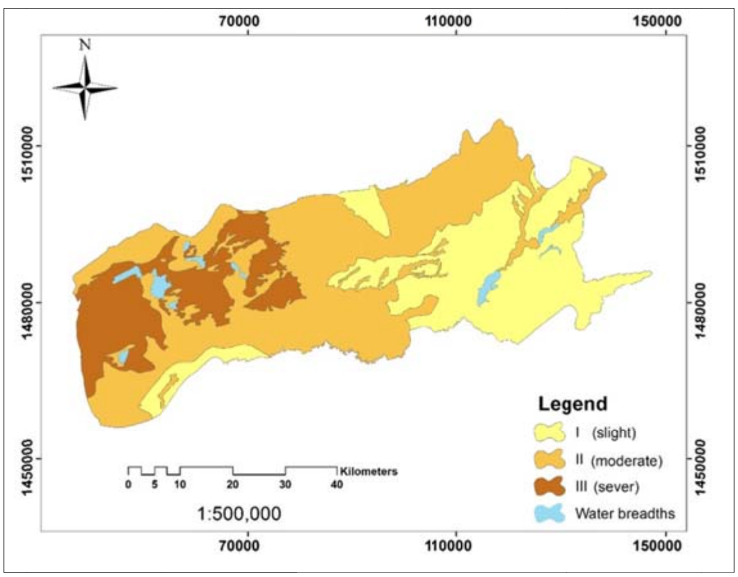

Fig. 16. The final Map of desertification intensity in the semi-arid region of Agh-band based on IMDPA

3.4. Risk Assessment

In order to map the desertification risk, it was firstly attempted to identify and classify the elements at risk and then by applying the degree of vulnerability of each element and by the consideration of the hazard intensity map, the desertification risk classes were assigned in four classes based on the general risk equation.

3.4.1. Map of the desertification elements at risk

Fig. 17 and 18 illustrates frequency distribution of classes of components at hazard of desertification in the study area. Sensitive areas in terms of the number of elements are located in the east and south-east.

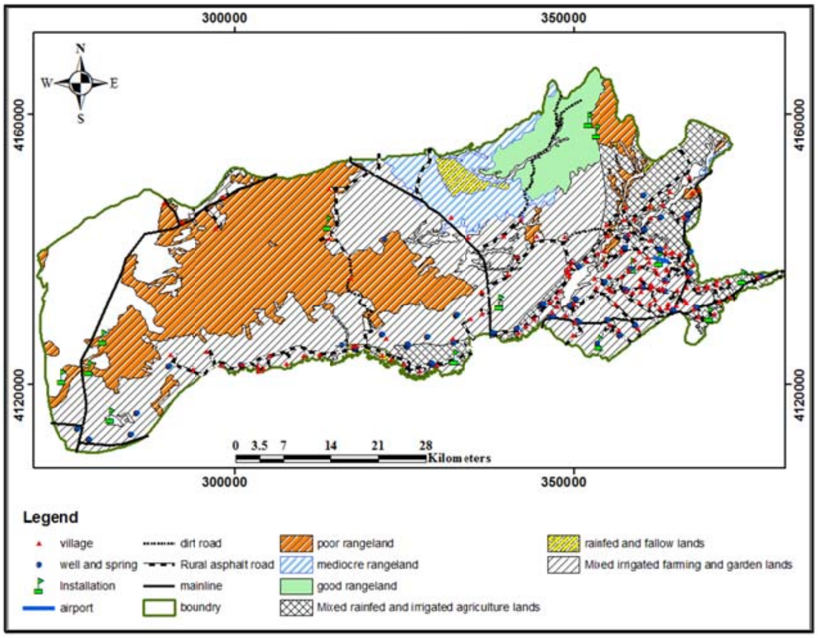

Fig. 17. Desertification risk elements map in Agh-band area

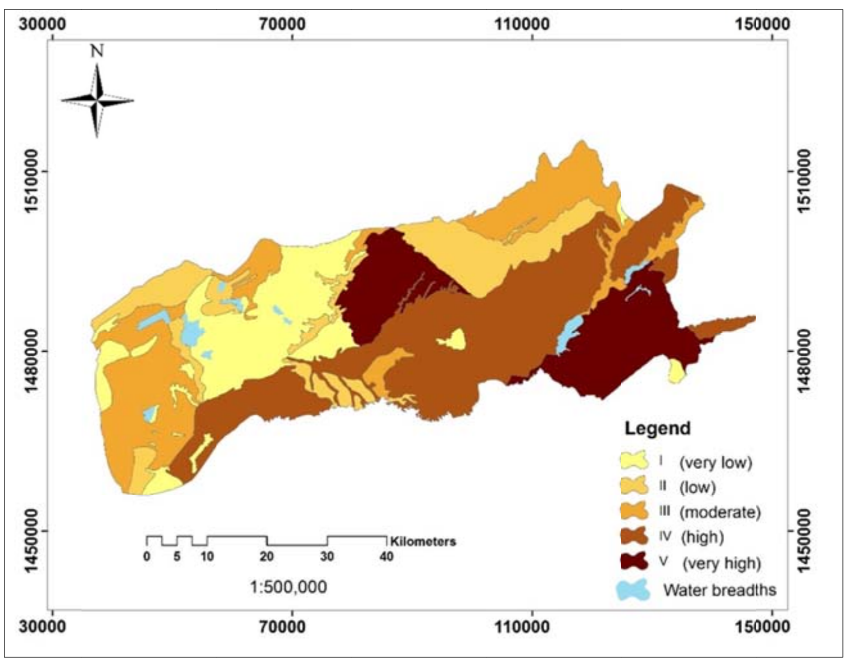

Fig. 18. The classes of elements at desertification risk

3.4.2 The vulnerability of elements at risk

The expert judgment scores were used for each of the elements at risk in order to determine the degree of vulnerability. The study area lacks major industrial facilities and irrigation canals with a high degree of sensitivity. Roads, rangelands and residential properties are more important than the listed elements. Roads in the area are important for the passage of vehicles and communication of villagers with the surrounding cities such as Gorgan, Gonbad-e-Qabus, Minoodasht and Maravetappe.

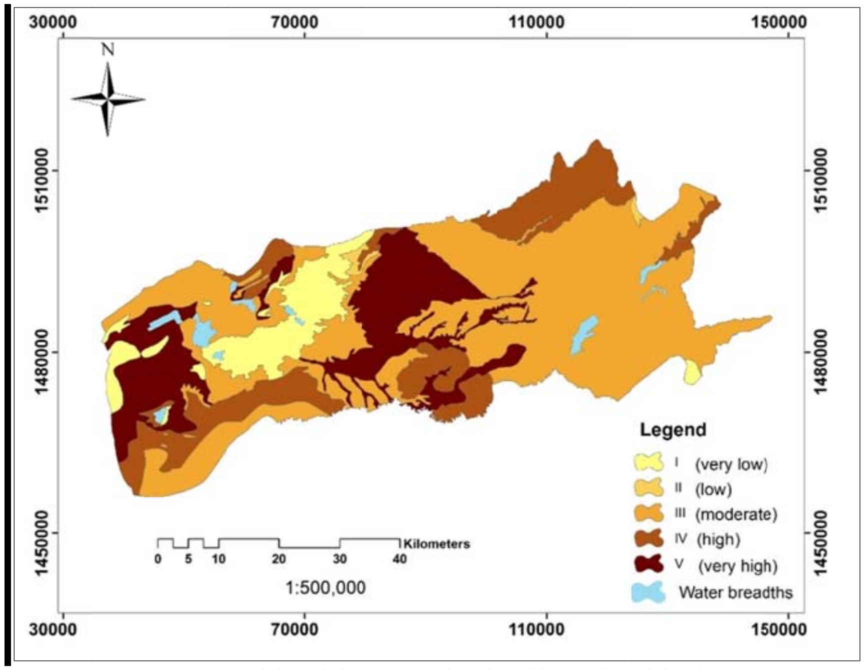

Fig. 19. Vulnerability of elements at risk to desertification in Agh-band area

3.4.3. Risk of desertification

Using the general equation (R = H. E. V), risk value was calculated and classified based on the turning points of the cumulative frequency curves of pixels in 4 classes of low, medium, high and very high (Fig. 20). The results showed that ultimately, 30.03% of the region was occurred at high and very high class.

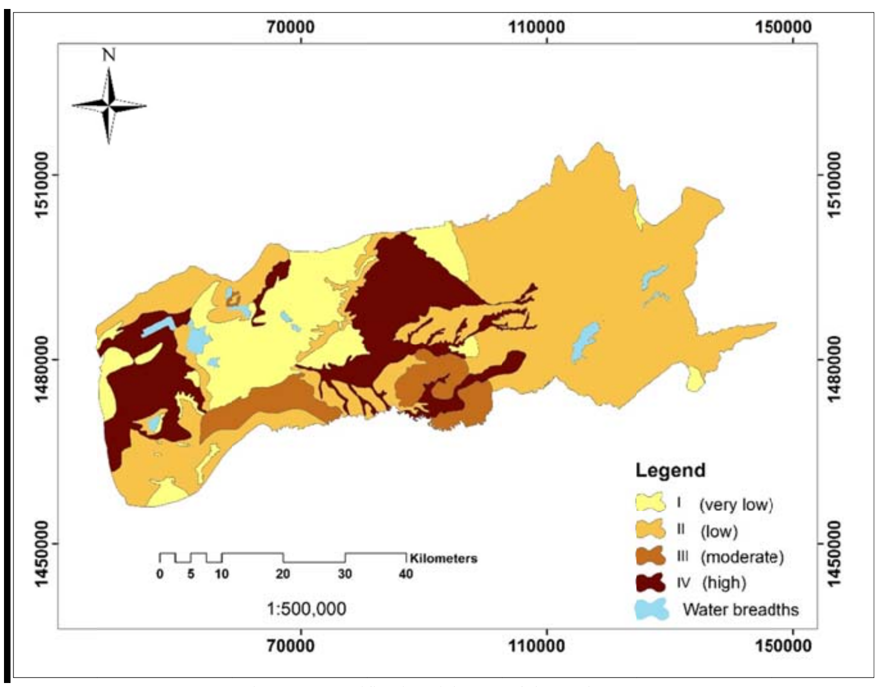

Fig. 20. Desertification risk map of the study area

3.5. Policies and managerial plans for desertification risk

Management plans and solutions were devised on the basis of the risk classes in four activities to achieve sustainable development and to mitigate environmental conditions. Then the map of management plan was prepared accordingly (Table 8) (Ownegh, 2009).

3.6. The proposed management plans

3.6.1. Taking no plans

Areas that are included within this management plan embrace 14.43% of the total area including 5266.8 ha of agricultural fields, 33147.83 ha of rangelands, 7.7 km of main road, 10.23 km of rural blacktop and dirt road. For this reason, in these areas no particular program other than adapting to the traditional methods is recommended.

Table 8. The priority of desertification management plans

Work unit cod	hazard class	Elements class	Vulnerability class	Risk class	Management plan
(1-1-1)	I	I	I	I	Non class
(1-1-2)	II	III	IV	II	IIb
(2-1-2)	II	II	III	II	I
(3-1-2)	II	II	III	II	I
(4-1-2)	I	II	III	I	Non class
(1-1-3)	III	I	III	I	I
(2-1-3)	III	I	I	I	Non class
(3-1-3)	II	II	III	II	I
(4-1-3)	II	I	I	I	Non class
(5-1-3)	III	III	V	IV	Non class
(6-1-3)	II	I	I	I	Non class
(8-1-3)	II	III	IV	II	IIb
(9-1-3)	III	I	I	I	Non class
(10-1-3)	II	II	III	II	I
(11-1-3)	III	I	III	I	I
(12-1-3)	III	I	I	I	Non class
(13-1-3)	II	IV	V	IV	IIIb
(14-1-3)	II	III	III	II	IIa
(15-1-3)	III	III	V	IV	IIIb
(16-1-3)	II	I	III	I	Non class
(17-1-3)	II	III	IV	II	IIb
(18-1-3)	III	I	I	I	Non class
(19-1-3)	II	I	I	I	Non class
(20-1-3)	III	II	V	III	IIIa
(21-1-3)	II	II	III	II	I
(22-1-3)	II	II	III	II	I
(1-2-3)	II	III	III	II	I
(1-3-3)	II	I	III	I	Non class
(2-3-3)	II	I	III	I	Non class
(3-3-3)	II	I	III	I	Non class
(4-3-3)	I	V	III	II	IIa
(5-3-3)	I	IV	III	II	I
(6-3-3)	I	IV	III	II	I
(7-3-3)	II	III	IV	II	IIa
(8-3-3)	II	III	IV	II	IIb
(9-3-3)	II	IV	IV	III	IIIa
(10-3-3)	I	IV	III	II	I
(11-3-3)	II	IV	V	IV	IIIb
(12-3-3)	II	III	IV	II	IIb
(13-3-3)	II	IV	V	IV	IIIb

Table 9. Distribution of management activities in the study area

Management plan	Management class	Area (ha)		Area (percent)
No Plan	Non class	44193.57		14.43
Maintaining Status quo	I	110667.7		36.14
Hazard Avoidance	II	IIa	36934.84	12.06
		IIb:	34129.04	11.14
Controlling measures	III	IIIa:	20252.6	6.61
		IIIb:	60072.19	19.62
Total		306250		100

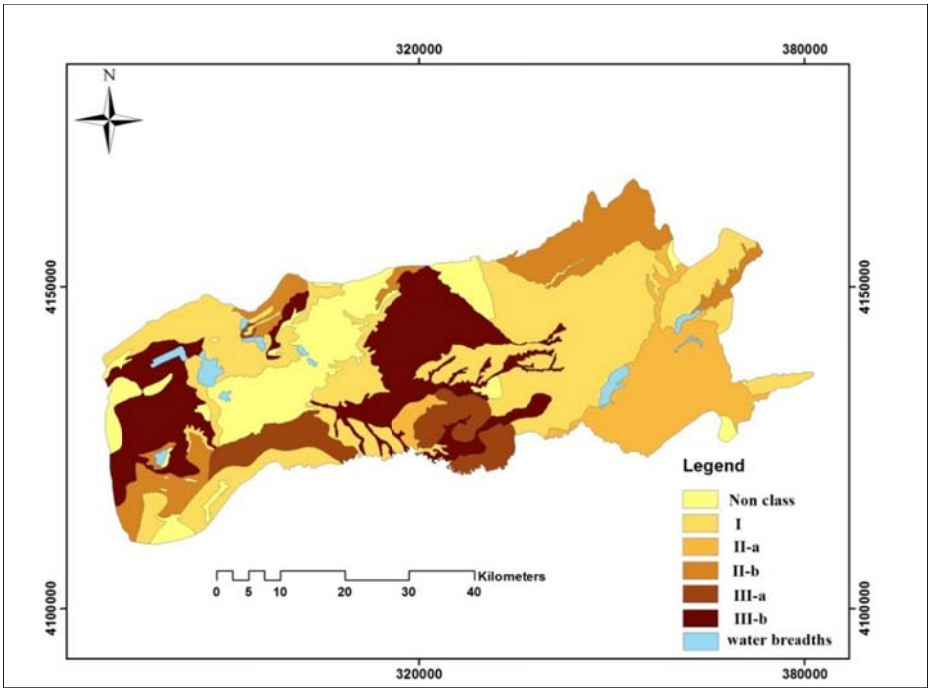

Fig. 21. Management plans map in the semi-arid region of Agh-band

3.6.2. Maintain the status quo I

Maintaining the status quo was recommended for parts of the area comprised of 63572.13 ha agricultural lands, 34124.12 ha of rangeland, 1 facility, 16 wells and springs, 53.53 km of main roads, 19.81 km rural dirt road, 125.73 km rural blacktop and dirt roads and 46 villages. Important villages here are Amman Qoli Teppeh, Chaparghoeime, Tengel and Aq Qamish covering 36.14% of total area. The risk of desertification in these areas is controlled by maintaining the status quo and taking the necessary measures to prevent land use change, degradation of vegetation covers and grazing.

3.6.3. Hazard avoidance II

a: This class encloses 32737.66 ha of agricultural lands, 2640.76 ha of rangelands, 29 springs and wells, 43.45 km of main roads, 12.17 km of rural dirt road, 147.3 km rural paved and graveled road and 4 facilities and 71 villages and Kalaleh Town. Important villages are: Dykcheh, Sarli Makhtoom and Barbar Qale which account for 12.6 percent of the region. Management and prevention of desertification in these areas is accomplished by planting resistant plants and prevention of occupying spaces at hazard.
b: This class has 9139.39 ha of agricultural lands, 22825.17 ha of rangelands, 1 springs and wells, 20.7 km of main roads, 17.16 km of rural dirt road, 4.48 km rural paved and 6 villages which account for 11.14 percent of the region. Desertification management in these areas is recommended by using resistant plants and prevention of occupying spaces at hazard.

Due to the sensitivity of the regions, increase in vegetation cover in these areas is a priority that it is essential to use halophyte species due to edaphic conditions of region.

3.6.4. Control measures III

a: This class encloses 16663.7 ha of agricultural lands, 3405.18 ha of rangelands, 6 springs and wells, 0.37 km of main roads, 1.17 km of rural dirt road, 31.3 km rural paved and graveled road, 1 facilities and 8 villages. This class includes 6.61 percent of studied region.
b: This class has 25202.8 ha of agricultural lands, 16712.14 ha of rangelands, 4 facilities, 5 springs and wells, 45.62 km main roads, 10 kilometers of backtop roads, 28.3 km of paved and graveled rural roads and 9 villages. Important villages are: Okhi-teppeh Qazzaqli, Bahram Abad and Okhi-teppeh covering about 19.62% of the area.

Due to the high sensitivity of these regions, the following measures could be considered: increasing vegetation by planting species resistant to salinity and drought, the use of control measures such as the construction of roads and drainage. Poor and deflected drainage leads to the reduction of the depth of the aquifer and waterlogging and due to the low quality of water, the evaporation of salty water and leaving alkaline soils behind the region will encounter a further qualitative and quantitative lack of vegetation in the region.

4. Discussion and Conclusion

Considering a three-step assessment process including hazard and risk assessment as well as developing management plans in semi-arid areas is of high practicality for the comprehensive management of land and environmental hazards management. Therefore, in this study, desertification risk and hazard was assessed in a semi-arid region (Agh-band, Golestan province) with a total area of 3062.5 km^2 followed by the development of management plan.

The geomorphological investigation is the basis for other studies on the subject of renewable natural resources, and since the field of natural resources studies is vast and various sciences are included in it such as, botany, climatology, geology, hydrology, ecology, geology, etc. it is necessary for all other studies to be built on a similar basis that meets all of the basic requirements. This similar basis is the working unit map which is undeniably important to control and coordinate all efforts in investigating natural resources and desertification and developing managerial plans (Rezaei Rad, 2008). Building on the facts provided, desertification studies are no exception to other natural resources studies. Similarly, because of different standards used in the process and the need to evaluate each of these factors, the necessity of a comparable ground for all studies is felt more than ever that. Here, if facies can be defined according to the influential factors and can be adopted as the foundation, desertification studies will be led to a common goal and also errors caused by the lack of coordination between different standards will be avoided (Rezaei Rad, 2008). In this study, 9 criteria including climate, geology and geomorphology, vegetation, agriculture, erosion (water and wind), socioeconomic, groundwater, soil, urban and industrial development and technology were assessed to evaluate the desertification status of the semi-arid region of Agh-band by means of the IMDPA model. According to assessments made, between the criteria of desertification in the study area, the effect of vegetation is quite dominant; as a weighted average of 2.67 denotes a severe desertification class. The dominance of natural vegetation criterion can be justified by physical limitations such as high soil salinity, waterlogging, excessive grazing and conversion of rangeland lands to agriculture. According to previous researches and the results of weighted average, prioritized effects of desertification criteria are as follows: vegetation, soil, technology development, socio-economic, agriculture, climate, erosion, geology and groundwater with average values of 2.67, 2.54, 2.42, 2.21, 2.08, 1.72 and 1.7, respectively. The results suggest that the criteria having the strongest direct links to human, environment and resources had the greatest impact on the severity of desertification, which can be due to excessive use, particularly in grasslands (overgrazing and uprooting) and in agricultural land (improper land conversions and over cultivation). Quantitative value of desertification (the current state of desertification) for the entire study area based on 9 criteria obtained 2.03. This value also was obtained 1.62 for Abuzzied region in Esfahan province and shows similarities with the results of this study. (Abdi, 2007). It should be noted that most studies only assessed some of the criteria of this method and less studied considered all nine criteria, so we cannot compare the two areas. Dolatshahi (2007) in south of Garmsar and Jafarizadeh (2010) in Mollasani region of Ahvaz were acquired Desertification value in class (II) for all studied regions. When comparing this value with the current classification method in IMDPA, Agh-band falls into the moderate class and it is due to the heavy soil texture and waterlogging during the flood events. The results showed that the areal cover percentage and the classes of vulnerability of elements at risk in the area were low, medium, high and very high by, 5.28, 51.31, 18.51 and 24.9 % respectively. According to the classes of vulnerability in the region, low classes do not exist due to the absence of elements. After multiplying desertification risk map by the elements at risk and vulnerability of elements, desertification damage map was prepared. Finally, 30.03% of the area was in high and very high class. Providing strategies and management plans to reduce the hazard of desertification in order to improve the environmental condition and to establish sustainable development in the study area was done in four hazard management programs to offer the best management model and to make necessary decisions which provided relatively similar results with

Mohammadi (2000) and Fallah Mehneh (2004) due to the applied management programs.

References

Abdi, Z.H., 2007. Investigation and Preparation of in desertification intensity map using IMDPA method with emphasis on water and soil Criteria in Abuzeid abad Region. M.Sc. thesis, Desert Region Management Dept., International Desert Research Center (IDRC), University of Tehran, Tehran, Iran.

Abella, E.A., C.J. Van Westen, 2008. Qualitative landslide susceptibility assessment by multicriteria analysis: a case study from San Antonio del Sur, Guantánamo, Cuba. Geomorphology, 94; 453-66.

Ahmadi, H., 2006. Calibration of measurement and standards of desertification in Iran, IMDPA model, Client: Department of Pasture and Soil of Forest, Rangeland and Watershed Management.

Ammann, W., 2016. Early Warning in Disaster Risk Reduction Needs and Potential. 7th International Conference on Integrated Natural Disaster Management-INDM 15-16 Feb, Tehran, Iran, pp. 9.

Batterbury, S.P.J., A. Warren, 2001. Desertification in: Smelser N, Baltes P (Eds.). International Encyclopedia of the Social and Behavioral Sciences, Elsevier Press, pp. 3526–3529.

Bouabid, R., M. Rouchdi, M. Badraoui, A. Diab, S. Louafi, 2010. Assessment of land desertification based on the MEDALUS approach and elaboration of an action plan: the case study of the Souss River Basin, Morocco. Land Degradation and Desertification: Assessment, Mitigation and Remediation. Springer, Netherlands. pp. 131-145.

Dolatshahi, R., 2007. Preparation of in desertification intensity map using IMDPA method with emphasis on vegetation, water and soil Criteria (Case study: South of Garmsar). M.Sc. thesis, Desert Region Management Dept., International Desert Research Center (IDRC), University of Tehran, Tehran, Iran.

Fallah Mehneh, S., 2004. A Comparison of different methods of FAO-UNEP and Ekhtesasi-Mohajeri in desertification hazard zonation in order to Torbat Heidariye plain manage. M.Sc. thesis, Arid Zone Management Dept., Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Farajzadeh, M., M.N. Egbal, 2007. Evaluation of MEDALUS Model for Desertification Hazard Zonation using GIS; Study Area: IyzadKhast Plain, Iran. Pakistan Journal of Biological Sciences, 10; 2622-30.

Gad, A., I. Lotfy, 2008. Use of Remote Sensing and Gis in Mapping the Environmental Sensitivity Areas for Desertification of Egyptian Territory. Earth Discuss, 3; 41-85.

Geeson, N.A., C.J. Brandt, J.B. Thornes, 2003. Mediterranean Desertification: A Mosaic of Processes and Responses. John Wiley & Sons, pp 456.

Hosseini, S.M., S. Sadrafshari, M. Fayzolahpour, 2012. Desertification Hazard Zoning in Sistan Region, Iran. Journal of Geographical Sciences, 22; 885-94.

Jafarizadeh, M., 2010. Application of IMDPA Model to assess desertification intensity (Case Study: Mollasani-Ahvaz). M.Sc. thesis, Combating Desertification Dept., University of Tehran, Tehran, Iran.

Kunlong, Y.I., C.H .Lixia, G. Zhang, 2007. Regional Landslide Hazard Warning and Risk Assessment. Earth Science Frontiers, 14; 85-93.

Melchiade, B., 2009. Secretariat of the Convention to Combat Desertification. CSD-17 Intergovernmental Preparatory Meeting Panel on Desertification, New York. pp 150.

Mohammadi, M., 2000. A Comparison of the Efficiency of two Quantitative Methods of Desertification Hazard Zonation (Ekhtessassi-Mohajeri and Turkmenistan Desert Institute) for the Management of Bajestan Desert Area. M.Sc. theses, Arid Zone Management Dept., Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Nazarinajad, M., 2010. Assessing ESAs and ICD Models for Desertification Hazard Mapping and Management Plans (Case study: Reza-Abad Region, Khartoran, Semnan Province). M.Sc. thesis, Arid Zone Management Dept., Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Ownegh, M., 2009. Assessing Land Degradation Hazard Intensity and Management Plans Using Subjective Models and the Analytical Hierarchy Process in Gorgan, Iran. International Journal of Sustainable Development and Planning, 4; 35-45.

Remondo, J., J. Bonachea, A. Cendrero, 2008. Quantitative Landslide Risk Assessment and Mapping on the Basis of Recent Occurrences. Geomorphology, 94; 496-507.

Rezaee Rad, N., 2008. The Study of Desertification Potential Cheshme Khan Basin by IMDPA Method. M.Sc. thesis, Combating Desertification Dept., University of Tehran, Tehran, Iran.

Yang, X., K. Zhang, B. Jia, L. Ci, 2005. Desertification Assessment in China: An Overview. Journal of Arid Environments, 63; 517-31.

Zezere, J.L., R.A. Garcia, S.C. Oliveira, E. Reis, 2008. Probabilistic Landslide Risk Analysis Considering Direct Costs in the Area North of Lisbon (Portugal). Geomorphology, 94; 467-95.