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Assessing Desertification Sensitivity in the Northern Part of Gorgan Plain, Southeast of the Caspian Sea, Iran

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ABSTRACT

This study was carried out to assess the desertification severity and sensitivity in the Northern part of the Gorgan plain, Southeast of the Caspian Sea. Desertification is a global environmental hazard, but it is the most urgent ecological problem in the Gorgan plain, Iran, Southeast of the Caspian Sea. Success in combating desertification requires assessment and mapping of desertification sensitivity in arid and semi arid environment. Considering the environmental condition of the study area, in the current research the regional model of MEDALUS has been modified. The key indicators for defining environmentally sensitive areas in the original MEDALUS model area divided into four broad categories including soil, climate, vegetation and management quality indices. In this research, two other categories of erosion and waterlogging indicators have been incorporated into the modified MEDALUS model. For each key indicator several sub-indicators affecting their index quality were identified. Based on the MEDALUS approach, each sub-indicator was quantified and a weight between 1.0 and 2.0 was given. Using ArcGIS 9, layers or maps of subindicators's weight for each main indicator have been prepared and their geometric mean has been calculated as the quality index of the main indicator. In turn the geometric mean of all six quality indices was used to generate a desertification severity index map. Results showed that 52.94, 44.27 and 2.79% of the area is severely, moderately and slightly affected by desertification, respectively. In addition the soil and waterlogging indicators were the most important factors affecting desertification process in the study area.

Key words: MEDALUS, hazard, assessment, waterlogging, quality index

INTRODUCTION

Desertification, land degradation in arid, semi arid and dry sub humid regions, is a global environmental hazard problem, but it is the most urgent ecological problem the Gorgan plain, Iran, Southeast of the Caspian Sea. According to National Forest, Range and Watershed Management Organization (2004) about 80% of Iran is located in arid and semi-arid environment and one third of its area is prone to desertification (Farajzadeh and Egbal, 2007). Some studies indicated that the salinization of soil and water resources, climate, wind erosion, inappropriate land management and destruction of vegetation were the most important factors affecting desertification process in the dry land ecosystems of Iran (Ahmadi *et al.*, 2003; Zehtabian and Rafiei, 2003; Honardoust and Azarmdel, 2005; Farajzadeh and Egbal, 2007; Sepehr *et al.*, 2007). Success in combating desertification requires assessment and mapping of desertification in the arid and semi arid environment. Different methods for assessment and mapping of desertification process such as FAO/UNEP (1984) and Turkmenistan Academy of Science (Babaev, 1985) have been presented. Although, these models are now used for local and regional assessment of desertification (Yang *et al*., 2005; Meshkat *et al*., 2006), both FAO/UNEP (1984) and Turkmenistan Academy of Science (Babaev, 1985) have practical problems. For example, in the FAO/UNEP (1984) method, the quantitative climax theory is used to determine the baseline for vegetation degradation assessment. However, in arid ecosystems with climate variability, non-equilibrium ecosystems based on state-and-transition models are more predominant than equilibrium ecosystems based on the Clementsian succession model. It is impractical for researchers to determine an assessment based only on vegetation growth and changes because there are multiple stable states for vegetation in arid ecosystems (Yang *et al*., 2005). Also some studies showed that application of FAO/UNEP (1984) method is unsuitable in Iran. Because, the criteria used in this model are non quantitative and non measurable (Zehtabian *et al*., 2002; Meshkat *et al*., 2006).

ICD (Iranian Classification Deserts) is another method which has been proposed by Ekhtesasi and Ahmadi (1995) for identification and classification of areas prone to desertification in Iran.According to this method, various types of areas prone to desertification can be identified and mapped by using certain indicators or factors for assessing the land capability to withstand further degradation, or the land suitability for supporting specific types of land use. The key indicators for classification of deserts are divided into two broad categories of environmental and anthropogenic factors. According to the study carried out by Ekhtesasi and Ahmadi (1995), the most pronounced result of application of ICD in the central part of Iran indicated that 75% of the area was affected by anthropogenic factors, particularly mismanagement.

An assessment carried out by FAO, based on data collected under the project Global Assessment of Soil Degradation-GLASOD indicated that 19.5% of dry lands of the world have been affected by soil degradation (Kosmas *et al*., 2003). However, it should be mentioned that the GLASOD estimates are mainly based on expert judgments that are necessarily subjective (Oldeman *et al*., 1991; Oldeman, 1994; UNEP, 1997).

The MEDALUS method (Kosmas *et al*., 2003) is able to identify Environmentally Sensitive Areas (ESAs). In this model, different types of ESAs to desertification can be analyzed in terms of various parameters such as landforms, soil, geology, vegetation, climate and human actions. Each of these parameters is grouped into various uniform classes and a weighting factor is assigned to each class. Then four layers are evaluated: soil quality, climate quality, vegetation quality and management quality. After determining indices for each layer, the ESAs to desertification are defined by combining the four quality layers. All the data defining the four main layers are introduced in a regional Geographical Information System (GIS) and overlain according to the developed algorithm which takes the geometric mean to compile maps of ESAs to desertification (Sepehr *et al*., 2007).

The successful implementation of assessing severity of desertification requires the integration of all identified indicators, which are readily manipulated in Geographic Information System (GIS). For example, Rangzan *et al*. (2008) by integrating all data layers into a GIS, identified landscapes having varying degrees of desertification hazard.

The specific objectives of this study were assessment and mapping of desertification sensitivity in the Agh-Ghala-Gomishan plain in Northern part of Golestan province wherein desertification process does not seem to be induced by the main indicators mentioned in the original MEDALUS model. In fact the desertification process in this area is mainly controlled by waterlogging due to shallow saline water table. Therefore, in this study the original MEDALUS model has been modified in order to incorporate the effects of such deteriorating factor.

MATERIALS AND METHODS

Study area: Study area, hereafter called the Agh-Ghala-Gomishan plain, is located in the Northwest of the Golestan province in North East of Iran. It is geographically located between 36° 58' 43"-37° 27' 34"N and 54° 1' 15"-54° 35' 27" E just at the Southeastern coastal area of the Caspian Sea (Fig. 1A, B). The elevation ranges from-23 to 35 m a.s.l. This region has a typical semi arid climate: dry and hot in summer, cool in winter, plenty of sunshine, mean annual precipitation of 300 mm, mean annual temperature of about 17.5°C, an mean annual wind velocity of 2.7 m sec^{-1} with prevailing direction in West and Northwest. These conditions make the potential evapotranspiration rate becomes as high as 5.5 times of annual precipitation. The main soil type is saline and alkaline with loose structure and low organic matter content which make them very susceptible to wind erosion (Biroudian *et al*., 2006). The natural vegetation at the study area is combination of *Halocnemum strobilaseum*, *Aeluropus litoralis*, *Tamarix rosmosissima*, *Suaad maritime*, *Puccinelia distance* and *Salsola rigida*. The staple crops are winter barley and wheat in the study area.

Methods: The Environmental Sensitivity Index (ESI) of an area to desertification can be seen as the result of the interactions among elementary factors (information layers) that are differently linked to direct and indirect degradation or desertification phenomena. In the original MEDALUS approach 4 main indicators have been used to assess the desertification intensity of an area. As can be seen in the first column of Table 1, these main four indicators are soil, climate, vegetation and management. Each main factor includes some sub-indicators which have been presented in the second column of the table. However, as mentioned in the Introduction, in the Agh-Ghala-Gomishan plain the environmental condition is such that the main deteriorating factor is waterlogging and soil erosion processes which are not directly used in the original MEDALUS model. Therefore, in this study the MEDALUS model has been modified by incorporating these

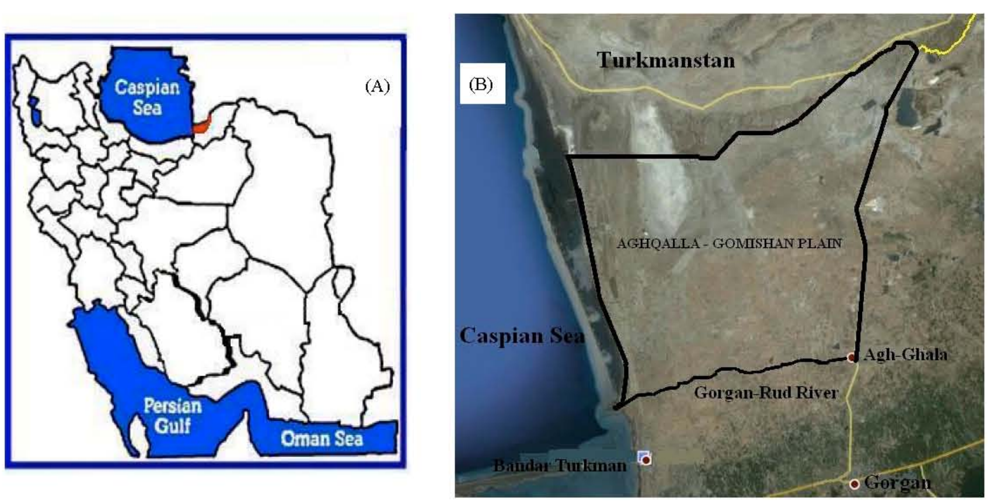

Fig. 1: Location of the study area (a) in country scale and (b) in regional scale

model. Therefore, in this study the MEDALUS model has been modified by incorporating these factors as new information layers. The following five main criteria were considered in the selection of the new information layers: (1) the clear relationship with desertification phenomena or environmentally critical situations, (2) simple in concept and accessible to both specialists and land managers, (3) the ease of availability of data, (4) objectively and scientifically measurable and (5) the ease of updating the data quickly and economically.

According to these criteria two new main indicators of waterlogging and erosion as well as their sub-indicators have been defined and added to modify the original MEDALUS model. Table 1 compares the original and modified MEDALUS models from the indicators point of view and Table 2 shows the classes and weights assigned to each of the indicator.

A quantitative classification scheme with values ranging from 1 to 2 has been applied throughout the model for individual indices as well as the final classification of Desertification Sensitive Areas (DSAs). The value 1 was assigned to areas of least sensitivity and the value 2 was assigned to areas with the most. Values between 1 and 2 reflect relative vulnerability. The geomorphological facieses were used as the analysis and computation units for distinguishing severity of desertification. Based on the morphological, topographical and lithological studies, a total of 16 facieses were identified in the study area (Fig. 2). Each facieses was treated as a separate study unit and the assessment of desertification was made in all of them. Information on soil, climate, plant cover, erosion and other factors were collected for the study area.

The quality indices were calculated for each study unit using Eq. 1:

Table 1: Indicators and sub-indicators in the original and modified MEDALUS models

Original MEDALUS (Kosmas *et al*., 2003)		Modified MEDALUS	
Indicator	Sub-indicator	Indicator	Sub-indicator
Soil	Texture	Soil	Texture
	Parent material		Rock fragment
	Rock fragment		Drainage
	Slope		Organic matter content*
	Soil depth		Electrical conductivity *
	Drainage		Sodium absorption ratio*
Climate	Rainfall	Climate	Rainfall
	Aridity		Aridity
	Aspect		Evapotranspiration*
Vegetation	Fire risk	Vegetation	Fire risk
	Erosion protection		Erosion protection
	Drought resistance		Drought resistance
	Plant cover		Plant cover
Management		Management	Land use*
	Land use intensity		Grazing intensity*
	Policy enforcement		Improper construction*
			Policy enforcement
-	-	Erosion*	Wind erosion*
			Water erosion*
-	-	Waterlogging*	Waterlogging depth*
			Waterlogging duration*
			Mean water table*

*Indicators and sub-indicators added in the modified MEDALUS method

Table 2: Classes and weights of indicators in the original and modified MEDALUS

Indicators	Class	Description	Original MEDALUS range	Modified MEDALUS range
Soil	1	High quality	1.00-1.13	1.00-1.13
	2	Moderate quality	1.13-1.45	1.13-1.45
	3	Low quality	1.46-2.00	1.46-2.00
Climate	1	High quality	1.00-1.15	1.00-1.15
	2	Moderate quality	1.15-1.81	1.15-1.81
	3	Low quality	1.82-2.00	1.82-2.00
Vegetation	1	High quality	1.00-1.13	1.00-1.13
	2	Moderate quality	1.13-1.38	1.13-1.38
	3	Low quality	1.39-2.00	1.39-2.00
Management	1	High quality	1.00-1.25	1.00-1.30
	2	Moderate quality	1.25-1.50	1.31-1.50
	3	Low quality	1.51-2.00	1.51-2.00
Erosion	1	High quality	-	1.00
	2	Moderate quality	-	1.10-1.40
	3	Low quality	-	1.41-2.00
Waterlogging	1	High quality	-	1.00
	2	Moderate quality	-	1.10-1.40
	3	Low quality	-	1.41-2.00

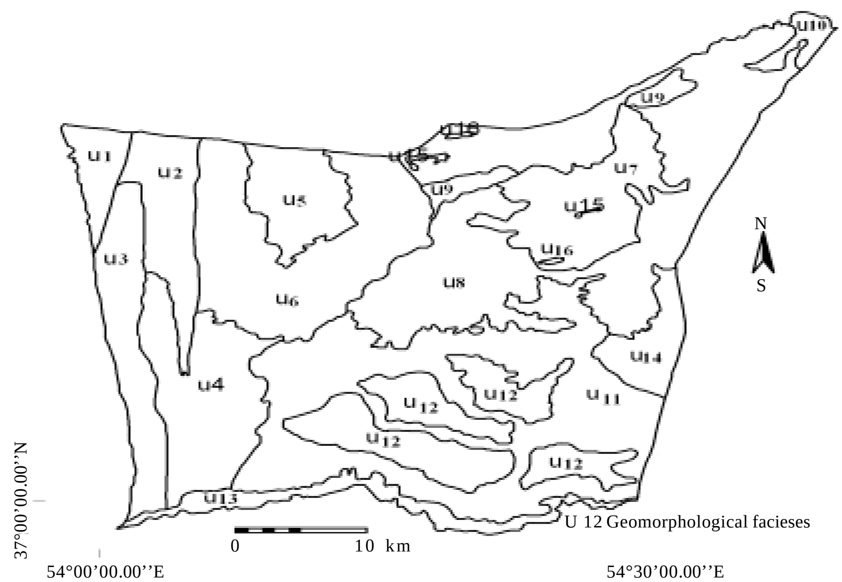

Fig. 2: Geomorphological facieses of the study area

$$\text{Index}_x = [(\text{Layer}_1)^* (\text{layer}_2)^* (\text{layer}_3)^* \ldots\ ^* (\text{layer}_n)]^{1/n} \tag{1}$$

where, X represents the main indicator (quality index); n represents the number of sub-indicators (layers) used to calculate each quality index.

As mentioned earlier, in modified MEDALUS method, two new indicators of erosion and waterlogging were added considering the environmental condition of the study area. The erosion indicator is assessed depending upon the wind and water erosion. Wind erosion status was investigated using the IRIFR method (Ekhtesasi and Ahmadi, 1995). In this method, nine parameters affecting wind erosion process including: lithology, morphology and relief, wind velocity, soil characteristics, type and plant cover percentage, wind erosion features, soil moisture, type and distribution of sand dune, land use and land management were considered as information layers of wind erosion. For the evaluation of water erosion index, the PSIAC method was used in which several parameters such as lithology, soil, climate, runoff, morphology, vegetation cover and land use are considered.

The waterlogging indicator is assessed from sub-indicators that are affecting on plant cover reduction. These sub-indicators are waterlogging depth, waterlogging duration (spell) and mean water table. After calculation of all the six main quality indices, the final desertification severity index was calculated as the geometric average of them using Eq. 2:

$$DS = (SQI * CQI * EQI * VQI * MQI * WLQI)^{1/6} \quad (2)$$

Where:
DS = Desertification severity
SQI = Soil quality index
CQI = Climate quality index
VQI = Vegetation quality index
EQI = Erosion quality index
MQI = Management quality index
WLQI = Waterlogging quality index

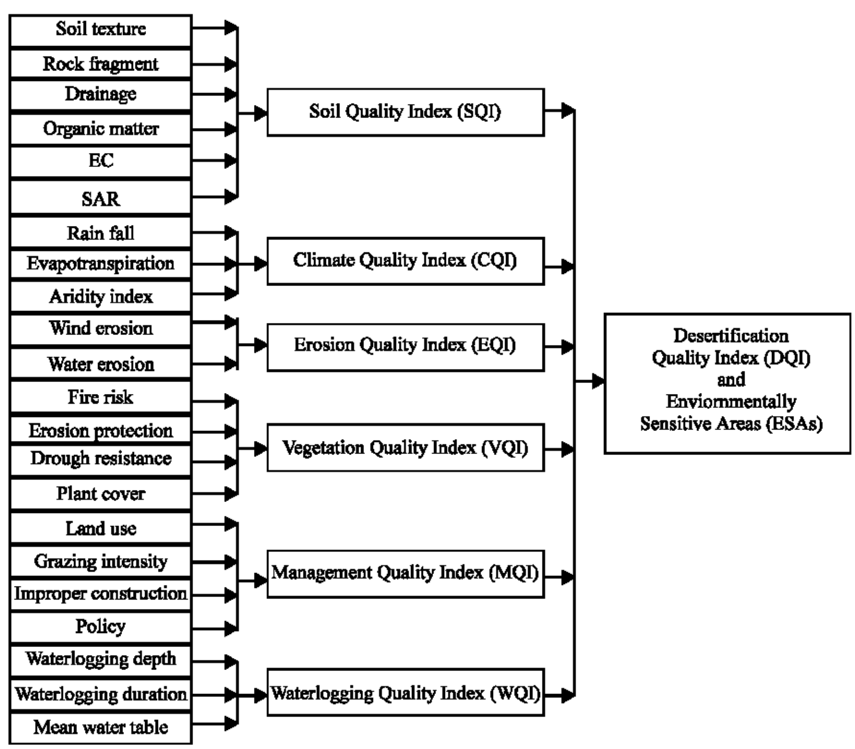

Fig. 3: Flow chart showing the process of research

Table 3: Desertification severity classes

Type	-- Desertification severe classes			------------------------------------
Qualitative	High severe	Severe	Moderate	Low
Quantitative	1.54-2	1.38-1.53	1.23-1.37	1-1.22

The following flow chart (Fig. 3) visualizes the regional model based on MEDALUS approach, which was used for the designation of ESAs to desertification in the study area.

Severity of desertification was classified as highly severe, severe, moderate and low according to the ranges of values in Table 3.

RESULTS AND DISCUSSION

Six layers including soil, climate, erosion, vegetation, management, waterlogging quality indexes were used to assess desertification sensitivity index (DSI) and for mapping the environmentally sensitive areas (ESA,s) in the studied area. Table 1 compares the original and modified MEDALUS models from the indicators point of view and Table 2 shows the classes and weights assigned to each of the indicator. In Table 4 the quantitative scores and their equivalent qualitative class of desertification severity for each indicator have been presented per each work unit in the study area. Also in Table 5 the area covered by each desertification severity class related to each indicator has been shown.

The Soil Quality Index (SQI) was evaluated depending upon soil texture class, rock fragments, drainage condition, Organic Matter (OM), Electrical Conductivity (EC), Sodium Absorption Ratio (SAR). Figure 4 represents the layer of soil quality index of the study area. The results indicate that the areas of moderate soil quality index (value = 1.13-1.45) represent 30% of the total area (i.e., 536.07 km^2) and the areas of low soil quality index (value >1.46) represents 70% of the total area (i.e., 1235.05 km^2). The low soil quality dominates the areas characterized by high electrical conductivity, poor drainage and poor organic matter content. The causes of stressed systems (Virmani *et al.*, 1994) are numerous and include development of salinization, alkalization, destruction of soil structure, accelerated wind and water erosion and loss of organic matter. Soil salinity prevents establishment of enough vegetation cover which thus leads to soil erosion. Jafari *et al.* (2004) and Biroudian *et al.* (2006) have reported the soil salinity and water table were the most important factors affecting on distribution and establishment of vegetation in the study area.

Climate Quality Index (CQI) is assessed based on the amount of rainfall, evapotranspiration and aridity index parameters. The layer of climatic quality index of the area is represented in Fig. 5. It is clear that area is dominated only by semi arid (Value1.15-1.81) climate class.

Rainfall amount and distribution are the major determinants of biomass production under semi arid climatic conditions. Decreasing amounts of rainfall combined with high rates of evapotranspiration reduce the soil moisture content available for plant growth. Reduced biomass production, in turn, directly affects the organic matter content of the soil and the aggregation and stability of the surface horizon against erosion (Kosmas *et al.*, 2003). In the study area the high potential evapotranspiration rate which far exceeds precipitation leads to accumulation of salts on soil surface.

Soil erosion (wind erosion and water erosion) is one of the most important processes leading to desertification, especially in arid and semi arid zones (Kosmas *et al.*, 2003). The wind erosion and water erosion parameters were used for assessing the Erosion Quality Index (EQI). Figure 6

Table 4: Quantitative scores and qualitative classes of considered indicators

	Soil		Climate		Vegetation		Management		Erosion		Waterlogging	
Unit No.	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class
1	1.67	L	1.16	M	1.46	L	1.32	M	1.15	M	1.89	L
2	1.67	L	1.16	M	1.52	L	1.27	H	1.30	M	1.40	M
3	1.44	M	1.16	M	1.46	L	1.24	H	1.28	M	1.36	M
4	1.46	L	1.13	M	1.55	L	1.24	H	1.30	M	1.30	M
5	1.77	L	1.26	M	1.51	L	1.41	M	1.28	M	1.77	L
6	1.70	L	1.20	M	1.47	L	1.30	H	1.43	L	1.49	L
7	1.70	L	1.30	M	1.42	L	1.52	L	1.41	L	1.63	L
8	1.64	L	1.26	M	1.42	L	1.52	L	1.33	M	1.53	L
9	1.64	L	1.30	M	1.42	L	1.49	M	1.50	L	1.53	L
10	1.59	L	1.30	M	1.49	L	1.30	H	1.25	M	1.46	L
11	1.39	M	1.13	M	1.36	M	1.19	H	1.25	M	1.10	M
12	1.59	L	1.13	M	1.46	L	1.19	H	1.25	M	1.20	M
13	1.28	M	1.10	M	1.43	L	1.14	H	1.25	M	1.10	M
14	1.38	M	1.13	M	1.46	L	1.24	H	1.25	M	1.10	M
15	1.52	L	1.30	M	1.49	L	1.37	M	1.50	L	1.00	H
16	1.52	L	1.30	M	1.49	L	1.37	M	1.50	L	1.00	H

L = Low quality, M = Moderate quality, H = High quality

Table 5: Frequency distribution of the qualitative classes of indicators

Indicator	Qualitative class	Area (km^2)	Percent of area
Soil	H	-	-
	M	536.07	30
	L	1235.05	70
Climate	H	-	-
	M	1771.12	100
	L	-	-
Vegetation	H	-	-
	M	348.63	20
	L	1422.49	80
Management	H	1132.85	64
	M	127.97	7
	L	510.30	29
Erosion	H	-	-
	M	1419.24	80
	L	351.88	20
Waterlogging	H	3.68	0.22
	M	907.76	51.25
	L	859.68	48.53

L = Low quality, M = Moderate quality, H = High quality

represents the layer of erosion quality index of the area. It is clear that area is dominated by moderate (Value 1.1-1.4) erosion class. In the Agh-Ghala-Gomishan plain, overgrazing in rangelands, shifting rangelands into croplands with long fallow periods. These croplands are extensively cultivated with barley and wheat dry farming mainly on saline soils with loose structure and low organic matter which make them very sensitive to soil erosion by wind (Honardoust and Azarmdel, 2005; Onweremadu, 2007).

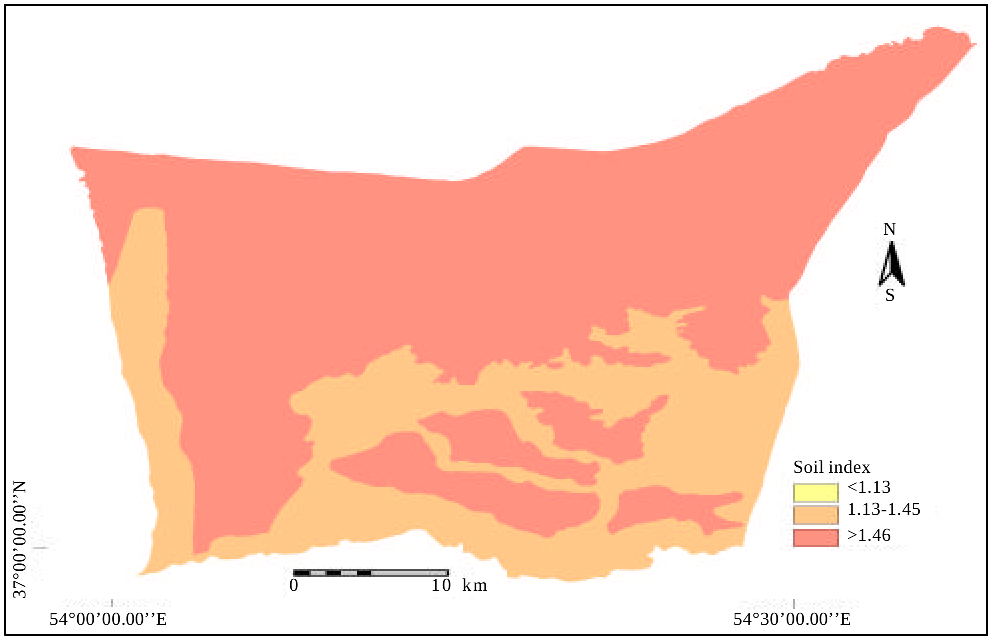

Fig. 4: Soil Quality Index (SQI) map of the Agh-Ghala-Ghomishan plain

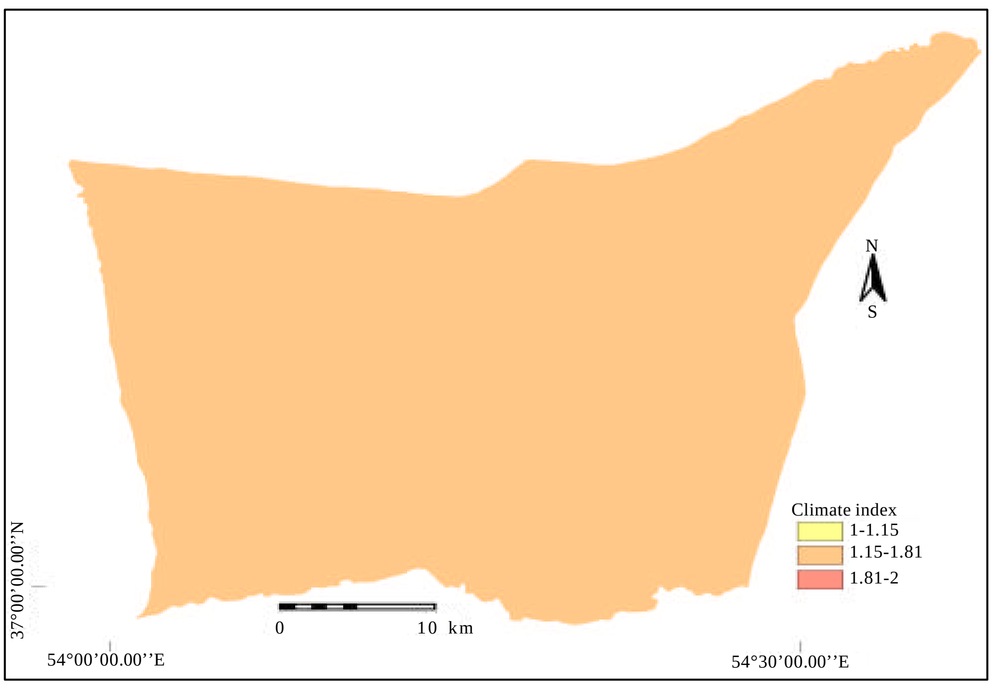

Fig. 5: Climate Quality Index (CQI) layer of the Agh-Ghala-Gomishan plain

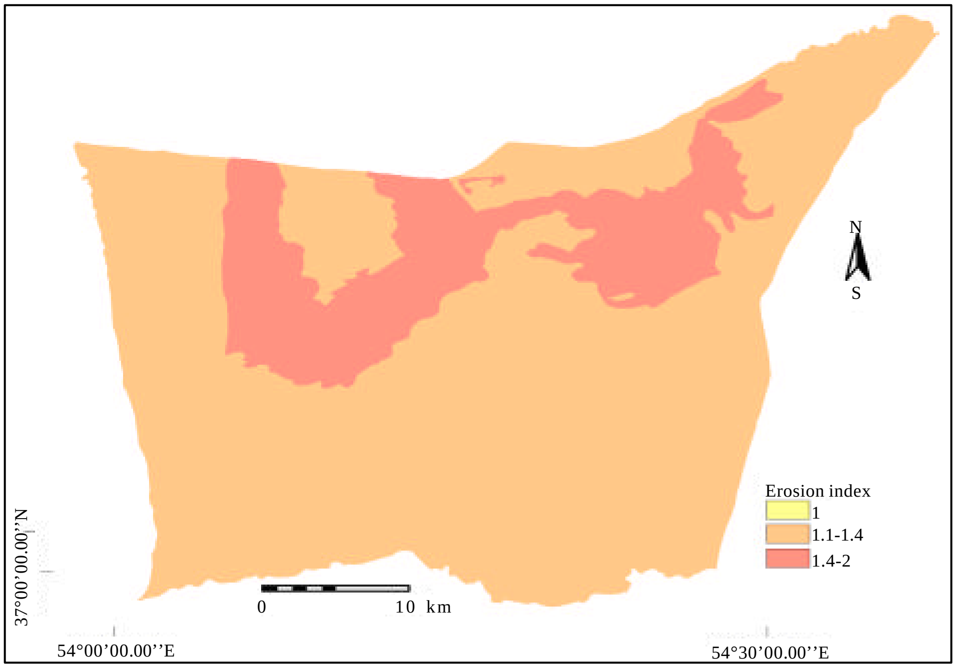

Fig. 6: Erosion Quality Index (EQI) map of the Agh-Ghala-Gomishan plain

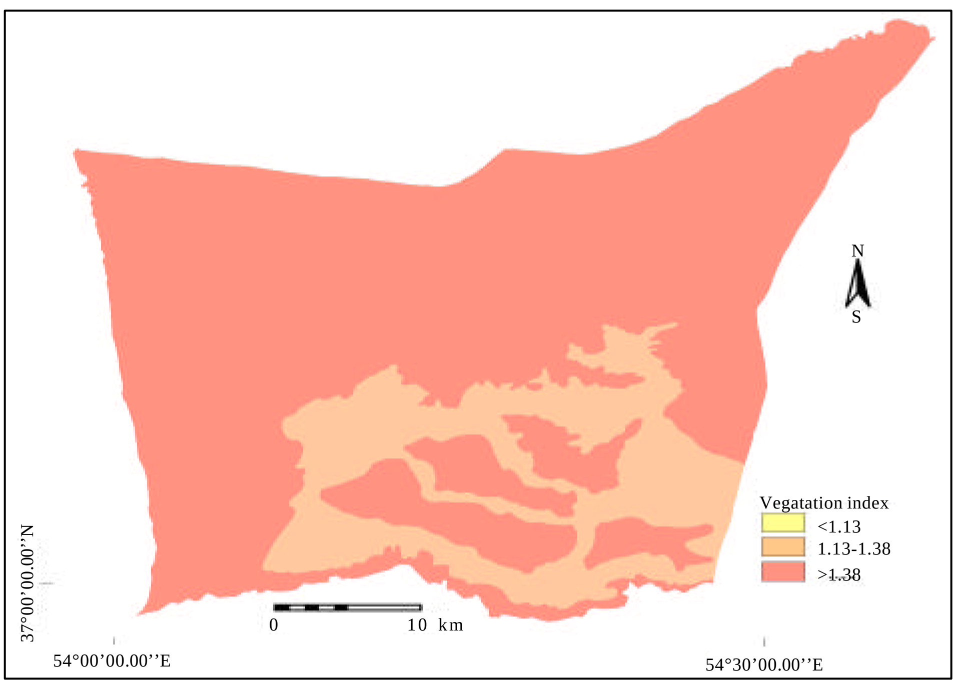

Fig. 7: Vegetation Quality Index (VQI) map of the Agh-Ghala-Gomishan plain

Vegetation plays an important role in mitigating the effects of desertification. The fire risk, erosion protection, drought resistance and plant cover (%) parameters were used for assessing the Vegetation Quality Index (VQI). Figure 7 represents the layer of vegetation quality index of the area. The data indicate that the areas of moderate vegetation quality index (value 1.13-1.38) dominate the Southern parts of the study area, covering 19.68% (348.63 Km^2) of the total area. While, the low quality index (value >1.38) dominates the rest of the study area representing 80.32 of the total area. The low vegetation index is due to high electrical conductivity of soil which results in low density of plant cover. The high electrical conductivity leads to decrease in plant cover due to reduced soil aggregate stability and reduced organic matter (Biroudian *et al*., 2006; Imanparast and Hassanpanah, 2010).

The land use, grazing intensity, improper implementation of construction works and policy enforcement were used for assessing the Management Quality Index (MQI). Figure 8 represents the layer of management quality index of Agh-Ghala-Gomishan plain. The results reveal that the areas of high quality management index are found in the Southern parts of the area which represents 63.96% (1132.85 km^2) of the total area. The areas of moderate and low management quality represent 7.23 and 28.81% of the total area respectively. The low values of the management quality index are due to overgrazing, improper construction and the lack of the policy enforcement. Figure 9A and B show some locations in the study area that have been highly degraded due to incomplete drainage design. Furthermore, these areas are generally used for rangeland activities that are usually affected by overgrazing and hence they are susceptible to degradation. A similar condition in the Fidoye-Garmosht plain in Southeast of Iran has been reported by Sepehr *et al.* (2007).

Waterlogging is an important environmental stress that severely reduces plant coverage due to salinity stress to plants (Kosmas *et al*., 2003). It is a major problem in Northern parts of the Golestan province, especially in the Agh-Ghala-Gomishan plain. The waterlogging depth,

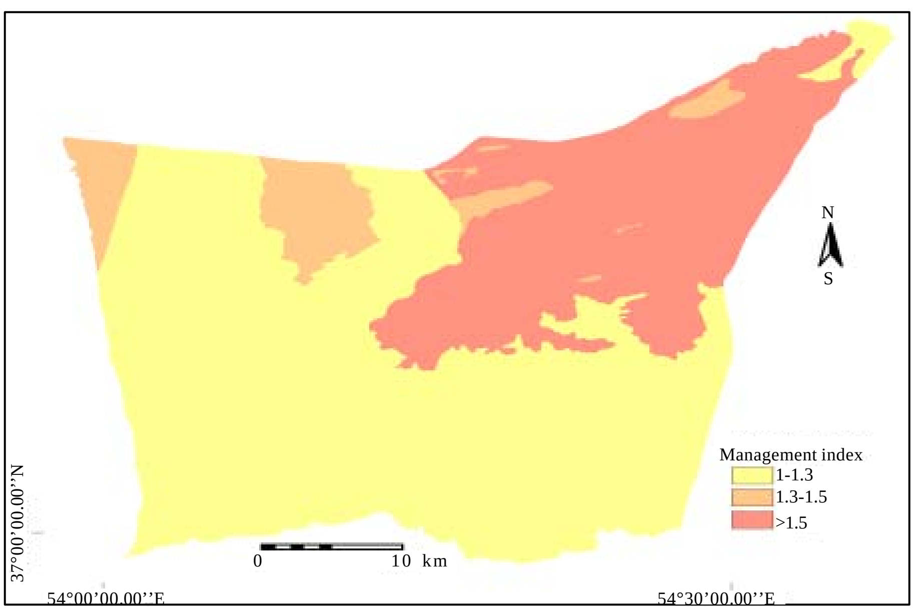

Fig. 8: Management Quality Index (MQI) map of the Agh-Ghala-Gomishan plain

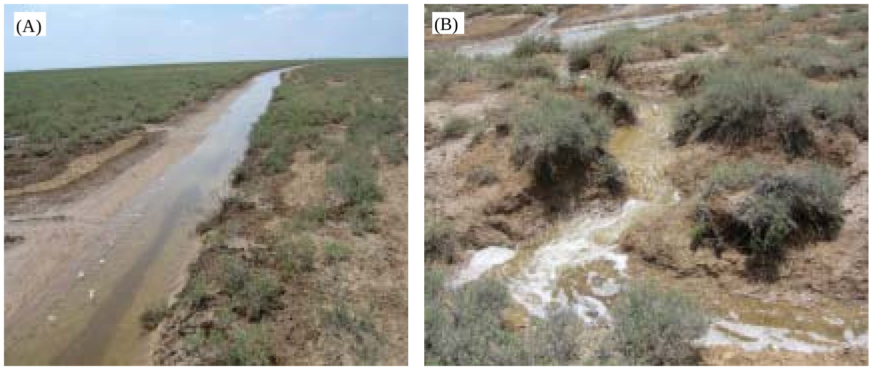

Fig. 9: Areas highly deteriorated under mismanagement (A, B) Sofekam rangeland in Northeastern of the study area

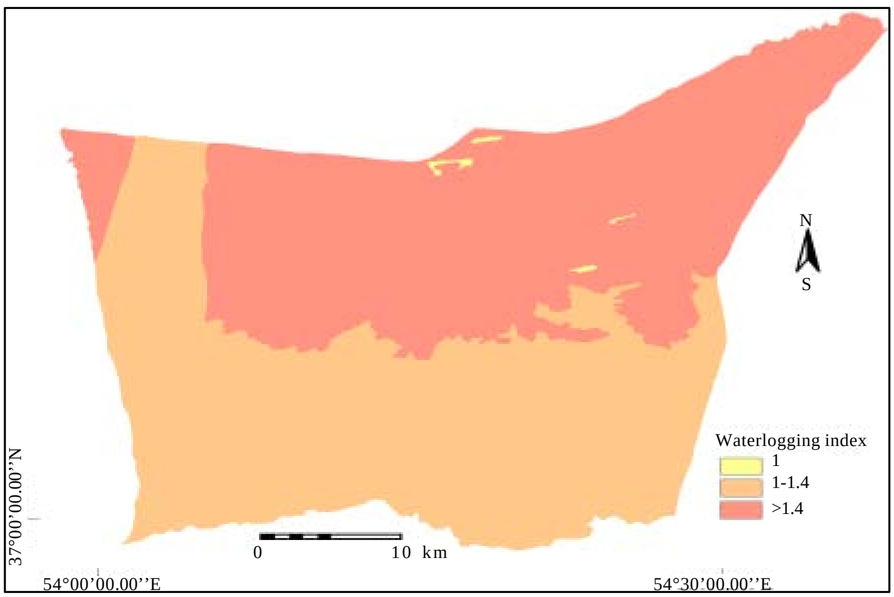

Fig. 10: Waterlogging Quality Index (WLQI) map of the Agh-Ghala-Gomishan plain

waterlogging duration and mean water table were used for assessing the Waterlogging Quality Index (WLQI). Figure 10 represents the layer of waterlogging quality index of Aghqalla-Gomishan plain. The results indicate that the areas of high waterlogging quality index (value >1.4) represent 48.54% of the total area (i.e., 859.68 km^2), the areas of moderate quality index (value = 1.1-1.4) represents 51.25% of the total area (i.e., 907.76 km^2) and the areas of low soil quality index (value <1) represents less then 1% of the total area (i.e., 3.68 km^2). The factors of waterlogging in study area include canals leakage, inadequate draining of agricultural fields, incomplete drainage networks in rangelands and shallow water table in the study area (2.5 m below the land surface). When a water table rises up to 2 m of the soil surface, the root zone available to plants becomes restricted, salts ascend to the surface by capillary rise and the resulting salinization can limit land suitable for agriculture (Wichelns, 1999).

Table 6: Scores and classes of desertification hazard in the Agh-Ghala-Gomishan plain

Unite No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Score	1.42	1.50	1.32	1.32	1.49	1.42	1.49	1.44	1.48	1.39	1.23	1.29	1.21	1.25	1.35	1.35
Class	III	III	II	II	III	III	III	III	III	III	II	II	I	II	II	II

I = Low, II = Moderate, III = Severe

Table 7: Area of desertification hazard classes in the Agh-Ghala-Gomishan plain

Class of hazard desertification	Symbol	Score	Area (km^2)	Percent of area
Low	I	1.00-1.22	49.47	2.79
Moderate	II	1.23-1.37	784.06	44.27
Severe	III	1.38-1.53	937.59	52.94
High severe	IV	1.54-2.00	-	-

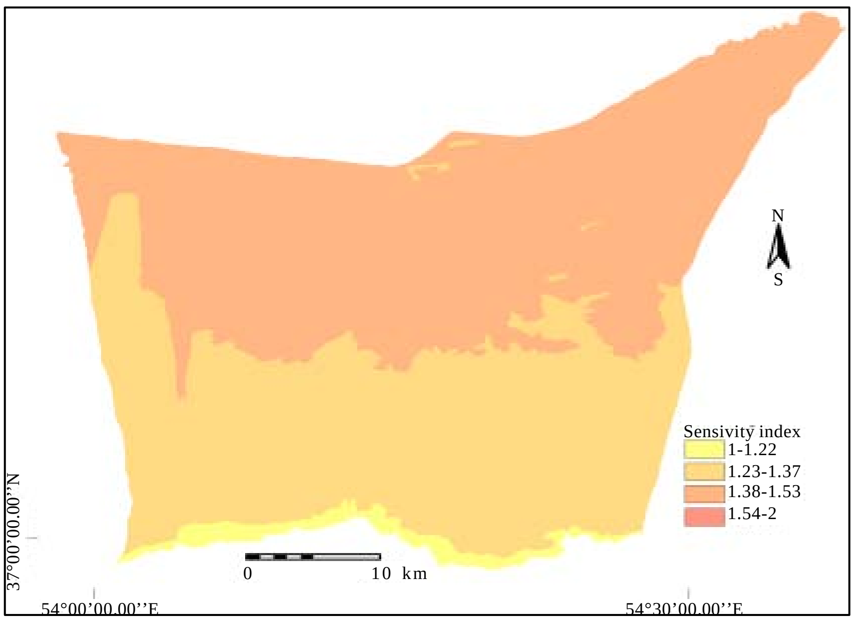

Fig. 11: Desertification Quality Index (DQI) of the Agh-Ghala-Gomishan plain

The six previous layers were superimposed for determination of environmentally sensitive areas (ESA's) to desertification, on the basis of the calculated Desertification Sensitivity Indices (DSI). Table 6 indicates the quantitative scores and their equivalent qualitative desertification hazard classes per each work unit. Moreover, in Table 7 the area coverage of each desertification hazard class in the whole study area has been presented. Figure 11 shows the distribution of environmentally sensitive areas (ESA's) in the Agh-Ghala-Gomishan plain. According to Table 6 and Figure 11, It is clear that the highly sensitive areas to desertification in the Agh-Ghala-Gomishan plain are found in the Northern parts, where the soil quality, waterlogging and vegetation quality are low; these areas in total represent 52.94% (937.59 km^2) of the study area (Table 7). The areas of moderately sensitive to desertification are located in the central of parts of the Agh-Ghala-Gomishan plain which represent 44.27% (784.06 km^2) of the total area. The Southern parts of the Agh-Ghala-Gomishan plain are characterized by low sensitivity to desertification with a limited area of about 2.79% (Table 7). The high sensitivity to desertification

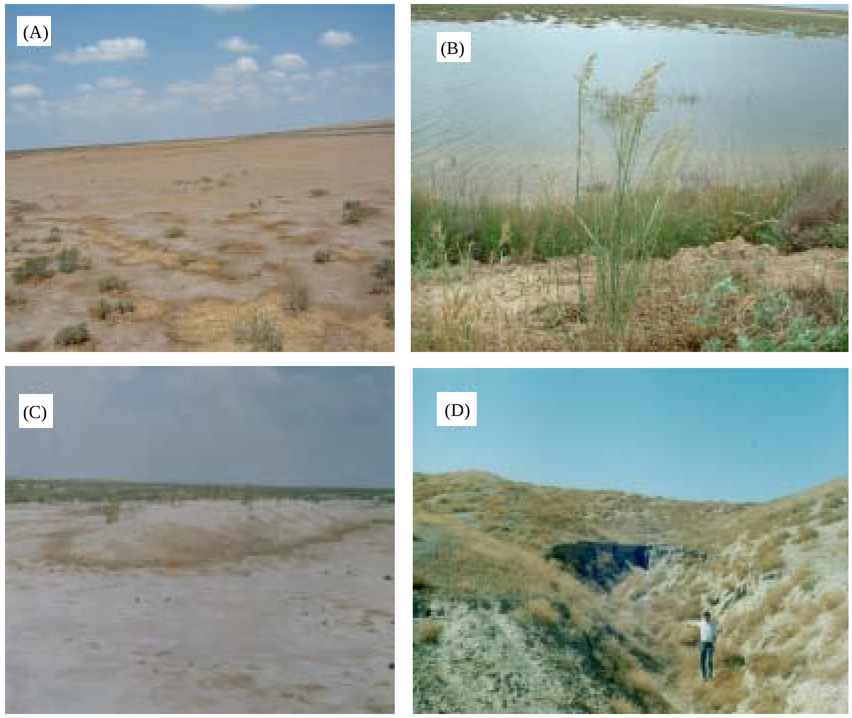

Fig. 12: (A, B, C, D) typical photographs of study area showing plant cover degradation; (A) soil salinity, (B) waterlogging, (C) wind erosion and (D) water erosion

is due to the low soil quality, high possibility of waterlogging and low vegetation quality (Fig. 12A-D).

The results of the assessment and mapping of desertification sensitivity by modifying the MEDALUS model highlight the extension and intensity of desertification threat in the Aghqalla-Gomishan plain. Based on the desertification map, almost 97.21% of study area is sensitive to desertification. This result reflects the particular geo-morphological characteristics of the inland areas of the Agh-Ghala-Gomishan plain: low lands and saline soils with loose structure and sensitive to wind erosion. Furthermore, the human activities such as overexploitation of natural resources and destruction of the scanty vegetation of the areas intensify this condition. Similar findings have been reported by Ahmadi *et al.* (2003), Honardoust and Azarmdel (2005), Farajzadeh and Egbal (2007) and Sepehr *et al.* (2007). According to the results of this investigation, modified MEDALUS model is a suitable tool for assessment and mapping of desertification sensitivity in the Agh-Ghala-Gomishan plain. Because, in comparison to the other traditional mapping methods such as FAO/UNEP (1984) and ICD (Ekhtesasi and Ahmadi, 1995), this approach utilize GIS for overlaying of maps and apply the geometric mean instead of arithmetic mean to compute the indices.

CONCLUSIONS

Desertification is land degradation in arid, semi arid and dry sub humid regions. It is the most urgent ecological problem in Iran. In Iran about 80% of the country is located in arid and semi arid environment and one third of its area is prone to desertification. Although, in the recent years the government had planed to execute many projects to combat desertification, it seems that due to the extent of arid area they are not adequate and need much more attention together with long-term effective national and international cooperation. In this study the original MEDALUS model was modified for assessment and mapping of the environmentally sensitive areas of the Agh-Ghala-Ghomishan plain to desertification. Based on desertification map and filed studies, more than 97% of the study area was moderately to high sensitive to desertification. Vegetation, soil and waterlogging were the most important factors in desertification process. Although, soil salinity and waterlogging are considered as the most important factors of desertification in the area but anthropogenic factors such as overgrazing, improper implementation construction works and shifting of rangelands into croplands practiced with long fallow periods has caused vegetation destruction and development problems in recent years. Management plans are essential for intended sustainable agricultural projects in the Agh-Ghala-Gomishan plain especially in the Southern parts which are moderately sensitive to desertification.

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