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Asessment of desertification using of modify MEDALUS model in Sistan plain (The east of IRAN)

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ABSTRACT

Desertification is a complex phenomenon which reduces the soil fertility involving ecological and economic processes that characterise the environment at different geographic scale. The MEDALUS model identifies regions that are environmentally sensitive area (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. About 80% of IRAN is located in arid and semi-arid region and third of its area is exposed to the threat of desertification with attention turning to the increasing area of deserts on IRAN, it is necessary to first identify areas liable to desertification before identifying mitigation and control measures. For this purpose it is necessary to prepare a desertification map as a guide for planners. In this study to evaluate the desertification condition regarding to local conditions of the study area, six indices of water, climate, soil, vegitation, management and wind erosion erosion were selected and assessment of desertification condition was conducted Based on these indices, weightening and MEDALUS model. The results showed that climate with average of 1.9 and wind erosion with 1.68 have the highest effects. Soil with average of 1.28 and Water with average of 1.31 have the lowest effect on the desertification process in the study area. almost 32.86% of study area was located in the very high class, 65.9% was located in high class and 1.24% was located in moderate class of desertification.

Introduction

Desertification is a complex phenomenon which reduces the soil fertility involving ecological and economic processes that characterise the environment at different geographic scale (22). The most widely accepted definition of desertification is the one given by the United Nation Convention:. It defines desertification as 'land degradation in arid, semi arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities' (23). The term desertification was generally associated to geo-physical conditions (e.g. soil, slope, vegetation cover) coupled with drought features (12) and water availability (19), but in Mediterranean land the study of the interaction of physical patterns with population dynamics is necessary to better delineate areas at risk (6). In fact, desertification impacts on the social, economic, and agricultural activities, and it is perceived as an ensemble of disasters affecting drylands, without a clear understanding of the involved processes (15). The complexity of this phenomenon represents a limitation for the scientific approach and for the development of efficient action plans (11). However, the interest for these problems was renewed in the last years, also considering the role of man in the way which external forces such as market, demography, tourism, and agricultural policies, influence the society-resource system(5).

As a result of global and regional climate changes, **ME**diterranean **D**esertification **A**nd **L**and **US**e (MEDALUS) project is one of the largest project of the European Comission established in the environment program(4).

The MEDALUS model (Kosmas et al.1999) identifies regions that are environmentally sensitive area (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 in accordance with the developed algorithm which takes the geometric mean to compile maps of ESAs to desertification(15). About 80% of IRAN is located in arid and semi-arid region and third of its area is exposed to the threat of desertification(13). with attention turning to the increasing area of deserts on IRAN , it is necessary to first identify areas liable to desertification before identifying mitigation and control measures. For this purpose it is necessary to prepare a desertification map as a guide for planners.

The MEDALUS model has also been used in some middle Eastion countries. Forexmple, Basso et al(1969) have used it for defining ESA on the lesvos Island of Greece and Kosma et al(1999) applied this model in the Agri basin of Italy. The ministry of Agriculture of Lebanon(2001) used the model to prepare map of Lebanon showing areas where desertification was being combated. Jiardao et al (2002) used it to evaluate

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desertification in Sisil region of Italia and Ladisa et al (2002) considered six indexes for assessing desertification in Bari region, Italy. Salvati et al(2007) applied this model in a scheme for Mediterranean basin.

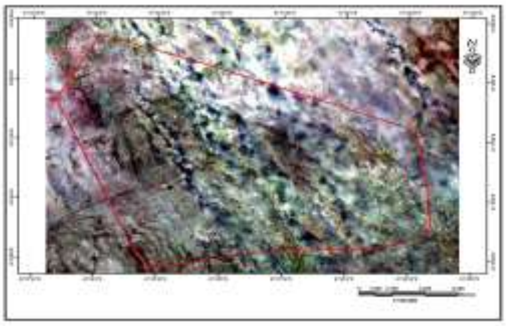
In IRAN, this model was used in varamin plain(Rafi Emam), the Kashan plain (Khosravi) and discussed by (Zehtabian et al), the Izad Khast plain(Farjzade2007) and the Fidoye-Garmosht plain(Sepher et al2007).

Materials and methods

Study area

The study area,(Sistan plain) is located in the Sistan&Balochestan, Iran (61 28 31- 61 44 0E and 31 12 0- 31 22 0N), has a comprises one geomorphologic main unit: a plain unit with 14 facieses that is a part of Sistan land with mean slop of 0/45(m/km) (Fig.1). the annual range of rainfall is 59.6 mm and the mean of annual evaporation4000(mm), mean of land height 450(m),mean of temperature 22c. Blowing of seasonal winds from the end of Ordibehesht started with average rate (30km/h)for 120days.

Fig. 1 The position of study area on image of ETM$^+$ (4-3-2), (2002)



Methodology

Desertification involves a complex set of factors, interacting in space and time leading to a decrease in land productivity. It is closely related to many environmental factors such as climate, soil, vegetation cover and morphology the character and intensity of which contribute to the evolution and characterization of different degradation levels. Desertification is also strongly linked to socio-economic factors, since man s behavior and this social and economic actions can greatly influence the evolution of numerous environmental characteristics. The following three main criteria were considered in the selection of the information layers in this study: (1) the relationship with desertification phenomena or environmentally critical situations; (2) the extent of data coverage; (3) the ease of updating the data quickly and economically.

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 Desertication 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 individual factors and their indicators are described in Tables 1.

In this study wind erosion status was investigated using the IRIFR method(Ekhtesasi and Ahmadi 1995) and for the evaluation water erosion, the PSIAC (1968) method was used.

The Days stormy index(DSI) calculated by using Eq.1.

DSI=(5)SD+MD+LD/20

SD= the number of day with horizontal sight less than 200 meter

MD= the number of day with horizontal sight less than 1000 meter

LD= the number of day with horizontal sight between 200-1500 meter

Information on soil, climate, vegetation, wind erosion, water and management was collected according to the study map. In the next step each of indicators weighted according to their relative impacts on desertification based on environmental condition in the area. After weighting, the map for each of the indicators can be calculated by using the following Eq2:

$Index_x=[(layer_1)\times(layer_2)\times(layer_3)\times\ldots\times(layer_n)]^{1/n}$ (2)

X: the six quality indices

N: the number of sub- indicators (layers) used to calculate each quality index

Finally six quality layers were combined to give a single desertification sensitivity layer. preparing creating desert situation maps according to Eq3, and categorized according to final categorization in 4 class of desertification.

$ESA=(SQI\times CQI\times VQI\times MQI)^{1/4}$

ESA= environmentally sensitive areas

SQI= soil quality indices

CQI= climate quality indices

VQI= vegetation quality indices

MQI= management quality indices

Although the original MEDALUS model was designed with reference to Mediterranean region it is necessary to make adjustments to the indicators with in the model according to the characteristics of each study area. These adjustments are focused here on the classification method and assigned weight used. An adjusted model was applied with some new indicators added together with related data layers.

Due to importance of intensity wind erosion, different faces of wind erosion, Percent of live and none live cover, Days stormy index, Percent of plant covered crown in growing season, Drainage matrix compression and Kind and compression of water erosion in land degradation, this factor were added to the modified MEDALUS model for study area. Therefore, Eq4 is modified as follows:

$ESA=(SQI\times CQI\times VQI\times MQI\times EQI\times WQI)^{1/6}$

Where the two new indices are: WQI(water quality index) and EQI(erosion quality index).

Then the finall map was classified into four classes (low, moderate, high and very high) as shown in table2.

Results:

Soil indices:

In the soil indices different characteristics such as texture, depth and slop were prepared. The most of area are usually dominated by coarse textured soils, with a shallow soil formed on a and formation. Therefore with average of 1/52 take the very high class of desertification. About total of study area has a slope less than 5%, and with average of 1 take the low class of desertification. the average of depth is 1.41 that take the high class . therefore the slope indicator has the lowest effect on the desertification quantity of desertification of the area. But texture and depth have an important role in desertification process.

At last the soil indices with a weighting mean of 1.28 take the moderate class.

Climate indices

Indicators that considered for the Climate indices are precipitation, evapotranspiration and day stormy. The annual range of rainfall is 59.6 mm and evaporation is 4820.54 mm. The wind is dry and strong, blowing at great velocity in Jul reaching more than 148 Km/h. the number of day stormy in year over than 60 days.

Factors of indices, precipitation with average of 2 , evapotranspiration with 2 and days dust stormy index with 1.72 have a very high class. At last climate indices with 1.9 (very high class), is the most effective factor at desertification over the study area.

Vegetation indices

High , form and intensity of Vegetation have remarkable effects on a value of erosion(16, 24). A value of erosion have a reversed relation with Percent of live and none live cover on ground land.(2)

Indicators of vegetation are as follow: Vegetation cover with average of 1.58, Percent of none live cover with average of 1.46 and Erosion protection with average of 1.58 take the class of very high and high. The vegetation indices with 1.54 take the very high class.

Water indices

This indices is derived from indicators of Electric conductivity, Groundwater table, Kind and compression of water erosion and Drainage matrix compression that these average of 1.5, 1.83, 1.01 and 1.06. and water indices with average of 1.31 take the moderate class.

Small compression of drainage and worthless of the rate of water erosion in the region, affect the dominant Electric conductivity and the Groundwater table and total water indices.

Wind erosion indices

Wind erosion indeces included Intensity wind erosion and Appearance of erosion faces(different faces of wind erosion) indictors. that the average of these indicators are 1.62 and1.74 that take the very high class . at last wind erosion indices with averge of 1.68 take the very high class.

Topography situation (deference of low height), lack of plant vegetation , blowing 120days winds of Sistan and inappropriate tissue and soil structure are effective in increasing of the rate of this criteria.

Management

Indicators of management are Landuse, Population density (person /Km^2) and Policy and management. land use with average of 1.59and Policy and management indicator with 1.67 take the very high class, and Population density with 1.02 take the low class of desertification. The management indices with 1.4 take the high class.

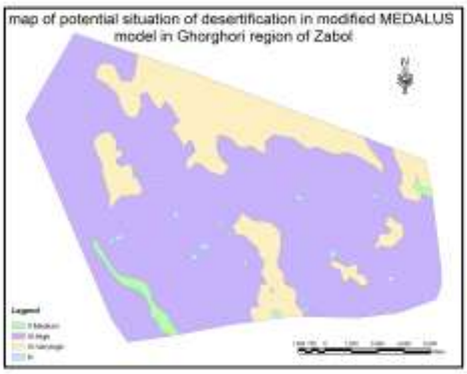
Results shows that texture, depth, precent of none live cover and Electric conductivity take the high class of desertification. Population density, Kind and compression of water erosion, slope and Drainage matrix compression take the low class. And groundwater, land use, precipitation, evapotranspiration, days dust stormy, Vegetation cover, Erosion protection, Intensity wind erosion , Appearance of erosion faces and Policy and management indicator take a very high class of desertification.

The table 3 shows the extent of each of the classes for six quality maps of considered indices associated with their computed mean of weights.

According to the table 3 Among main indices, climate with average of 1.9 and wind erosion with 1.68 have the highest effects. Soil with averge of 1.28 and Water with average of 1.31 have the lowest effect on the desertification process in the study area.

Finally based on six quality maps produced the Map of potential situation of desertification. Map1 show the potential situation of desertification in modified MEDALUS model in Ghorghori region of Zabol.

Fig 2: map of potential situation of desertification in modified MEDALUS model in Ghorghori region of Zabol.



According to map1, almost 32.86% of study area was located in the very high class, 65.9% was located in high class and 1.24% was located in moderate class of desertification .

According to the results of this investigation and comparing them with the condition which have been observed in the study area, the MEDALUS model is determined as the best model for evaluation of desertification condition in the arid and hyper arid land.

Discussion and conclusion

Natural environmental conditions of Iran and its geographical location that falls in the arid belt in one hand, and overuse of non renewable resources in the other hand, cause series of problems and conditions that brings the country into a rapid deterioration. So mapping of desertification condition is important and necessary matter. In this study, a modify MEDALUS model was used for mapping of desertification condition. The results showed that climate with average of 1.9 and wind erosion with 1.68 have the highest effects. Soil with average of 1.28 and Water with average of 1.31 have the lowest effect on the desertification process in the study area.

Based on the desertification map, almost 32.86% of study area was located in the very high class and 65.9% was located in high class of desertification . and 1.24% was located in moderate class of desertification .

Despite the fact that MEDALUS method has some advantages such as taking geometric mean, but eventually has its own deficiencies:

- Multiplying parameter classes under uneven conditions may results in overestimate or underestimating the scores which is likely far beyond the truth
- one of the deficiencies of this model is that the role of desert landscapes has been not considered and it is just relied on desertification severity class which is apparent in the criteria of water erosion. In the other words, the mean erosion rate of area is extracted from water erosion eaquation but the area-class graph shows that the most area is classified in low desertification severity.

According to the results of this investigation and comparing them with the condition which have been observed in the study area, the MEDALUS model is determined as the best model for evaluation of desertification condition in the arid and hyper arid land.

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Table1: indices used with related indicators and weight

indices	indicator	classes	weight
soil	texture	L, scl, sl, ls,cl	1
		Sc, sil, sicl	1.2
		Si, c, sic	1.6
		s	2
	Soil depth (cm)	>75	1
		30-75	1.2
		15-30	1.6
		<15	2
	Slope (%)	<6	1
		6-18	1.2
		18-35	1.5
		>35	2
climate	Precipitation (mm)	>300	1
		150-300	1.5
		<150	2
	Evapotranspiration (mm)	<1500	1
		1500-2000	1.5
		>2000	2
	Days stormy index (day)	<10	1
		10-30	1.3
		30-60	1.6
		>60	2
vegitation	Vegetation cover (%)	>35	1
		10-35	1.5
		<10	2
	Percent of none live cover (%)	>80	1
		40-80	1.3
		20-40	1.6
		<20	2
	Erosion protection	Gardens and orchards, evergreen rangelands	1
		Permanent grasslands and rangrlands	1.3
		Annual agricultural crops, cereals and annual grasslands	1.6
		Bare land	2
Wind erosion	Intensity wind erosion (IRIFR)	<25	1
		25-50	1.3
		50-80	1.6
		>80	2
	Appearance of erosion faces(different faces of wind erosion)	With out effects and problem in wind erosion and soil agitation during the year	1
		Having the effects of moving with wind limited in soil surface , divergence scattered surfaces and forming desert cobblestone	1.3
		Sand land, scattered sod, divergence compression and forming compression cobblestone	1.6
		Active sand hills , compression sod hill and next to each other	2
Water	Kind and compression of water erosion	Surface erosion accompanied by groove erosion by compression lower than 60 percent in each work unit	1
		Ditch erosion accompanied by scattered drainage with compression less than 50%	1.3
		Drainage erosion accompanied by ditch erosion , surface and mass erosion by compression less than 40%	1.6
		Dissolution erosion accompanied by mass erosion by high ditch erosion and thousand valley with compression less than20%	2
	Drainage matrix compression (km in km^2)	<10	1
		10-20	1.3
		2.-30	1.6
		>30	2
	Electrical conductivity (µmohs/cm)	<250	1
		250-750	1.2
		750-2250	1.5
		2250-5000	1.7
		>5000	2
	Groundwater table (cm)	>315	1
		315-285	1.5
		>285	2
Management	Landuse	Agricultural lands	1
		Rangelands	1.3
		Poor and degraded rangelands	1.6
		Bare lands	2
	Population density (person /Km^2)	<0.5	1
		0.5-1	1.3
		1-1.5	1.6
		>1.5	2
	Policy and management	>75% of the area under protection	1
		25-75% of the area under protection	1.5
		<25% of the area under protection	2

Table2: desertification senverity classes

type	Desertification severe classes			
Qualitative	Very high	high	moderate	Low
quantitative	1.54-2	1.38-1.53	1.23-1.37	1-1.22

Table 3: description, extent, perecent of area and meain of weight for each of indices

Indices	Description	Extent (Km^2)	Area (%)	Mean of weight
Soil	Very high quality	-	-	1.28
	High quality	3.48	1.24	
	Moderate quality	236.38	83.93	
	Low quality	41.78	14.83	
Climate	Very high quality	281.64	100	1.9
	High quality	-	-	
	Moderate quality	-	-	
	Low quality	-	-	
Vegetation	Very high quality	81.49	28.93	1.54
	High quality	145.97	51.83	
	Moderate quality	54.18	19.24	
	Low quality	-	-	
Wind erosion	Very high quality	225.84	80.2	1.68
	High quality	8.32	2.95	
	Moderate quality	41.42	14.7	
	Low quality	6.06	2.15	
Water	Very high quality	-	-	1.31
	High quality	3.48	1.24	
	Moderate quality	278.16	98.76	
	Low quality	-	-	
Management	Very high quality	-	-	1.4
	High quality	68.37	24.28	
	Moderate quality	192.03	68.18	
	Low quality	21.24	7.54	