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THE APPROACH OF DESERTIFICATION MAPPING USING MEDALUS METHODOLOGY IN IRAN

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ABSTRACT

Desertification process as a great problem affects most of the countries in the world specially developing countries. This process has a high rate in arid and semi-arid countries such as Iran. The main objective of this research was to investigate land degradation status and desertification mapping of Kashan area. Different studies have been carried out in the world in order to assess desertification resulted in production of different regional models for their application in another region the indices should be re-investigated and adjusted to local conditions. So in this study, the newest method for assessment and mapping of desertification was used. The method was carried out by European Commission (EC) at the MEDALUS project and booked as ESAs in 1999. All indices of the model were revised before using, and regarding to the region condition these indices for land degradation were defined as key indices which were: hydrological index, wind erosion and climate index, and each index has some layers getting from their geometric mean. Method were parameterized and tested for Kashan area (91383 ha) with dry climate. Thematic databases were integrated and elaborated by using a GIS and its spatial modeling function. Finally by means of all the above mentioned information land degradation mapping was provided. The area was presented as a present situation map of desertification on area. Among the total studying area about 29867 ha is, under average class, 3600 ha is high class and 24021 ha is under very high class desertification.

KEY WORDS: *Land Degradation, Desertification, GIS, Environmental Sensitive Area*

Introduction

Nowadays, desertification as a serious challenge, affects most of the countries especially developing ones. Desertification process occurs in different climatic conditions. According to the latest FAO definition, desertification is land degradation in arid, semi-arid and dry sub-humid regions due to the climatic and human factors.

In many regions of the world, especially in arid ones, studies have been done to assess the land degradation rate, degradation status and mapping. In this regard, several case studies have been conducted on land degradation which provided information for desertification conference held by the United Nations in Kenya (1977). After that conference, many studies were done to introduce land degradation assessment methods e.g. FAO-UNEP, Turkministan model, GLASOD, MEDALUS, LADA, etc. The researchers believe that applicable key benchmarks are necessary to evaluate desertification process.

At present, such applicable benchmarks have not been defined to be relied on at different global, regional, national and local level. On the other hand, defined benchmarks have not been accepted universally and their validity has not been ensured. However, the assessment methods of these models are utilized to assess desertification quantitatively and qualitatively.

Its seems that MEDALUS model introduced by European Commission (EC) in 1999 has apparent advantages compared to the other ones. All necessary data have been export to Geographic Information System (GIS) to be computed and the required indices and maps produced based on the available algorithms (Kosmas *et al*, 1999). An important feature of this model is the way of measuring of indicator and preparation of map using geometric mean of indicators. Other advantages include the possibility of integration of layers and algorithm measurement using GIS.

MEDALUS was tested in European countries such as Greece, Portugal and Italy, simultaneously. Since 1999, others such as Ladisa *et al.* and Giordano *et al.* (2002) applied the model in Ban and Sicily (Southern Italy) and rectified it based on the regional conditions. Another researcher (2001) also used the same model in Lebanon and Palestine. Due to the lack of comprehensive model for assessing desertification in Iran, MEDALUS model or ESAs, can be applied to evaluate desertification condition in Iran. The model has been applied and calibrated before in some case studies (e.g. Varamin region, Tehran province) and provided acceptable results (Rafiei *et al*, 2003).

2- Materials and Methods

2-1- Desertification mapping based on MEDALUS model

In this stage, four benchmarks were considered for desertification mapping and each includes some indicators have a weighted value in desertification. Finally, desertification map of the region was prepared using individual benchmark and geometric mean (Fig. 1).

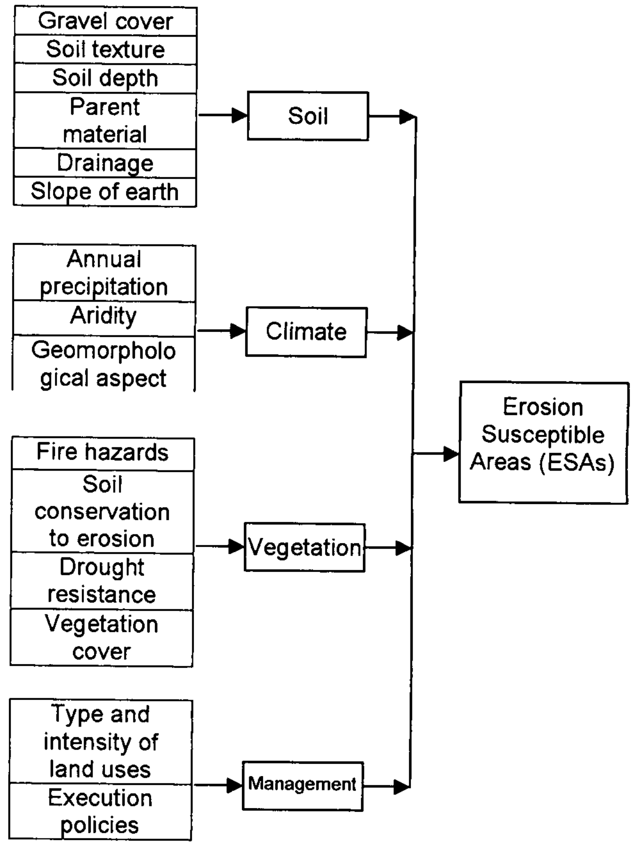

Figure 1: Parameters used in MEDALUS model

2-1-1- Soil benchmark

The role of soil benchmark in desertification process is related to the available water and soil erodibility. The soil properties such as texture, parent materials, depth, slope, drainage and gravel content can be defined as soil indicators. There are also various land conservation classes necessary to produce desertification map.

<u>- Soil texture indicator</u>

It is related to erodibility and water holding capacity of soil. Availability of water also depends on soil texture and structure. Soil texture classes are categorized based on water holding capacity as shown in Table 1.

- Parent materials indicator

It is obtained using geological map of region. Different types of them are classified based on lithological and mineralogical properties of rocks and their susceptibility to desertification (Table 1).

- Surface gravel

Surface gravels with diameter greater than 6 mm were classified into three groups based on the percentages of surface coverage and soil conservation against erosion process (Table 1).

- Soil depth indicator

It was categorized into four classes based on soil profile depth (Table 1).

- Slope indicator

It was categorized into four classes using topographic maps and its effect on soil erosion (Table 1).

- Soil drainage condition

Drainage condition is defined based on the hydromorphic processes related to Fe, Mn and also the depth of ground water. In this case, three classes of drainage were determined based on it's effected on soil salinization (Table 1).

Table 1: Classes and values of various parameters used for assessment of soil quality

1- Texture

Class	Description	Soil texture	Value
1	Good	Cl, Ls, Sl, Scl, L	1
2	Moderate	Sc, Sil, SiCl	1.2
3	Poor	Si, C, Sic	1.6
4	Very poor	S	2

2- Slope

Class	Description	Soil texture	Value
1	Very moderate to even	<6	1
2	Moderate	6-18	1.2
3	Steep	18-35	1.5
4	Very steep	>35	2

3- Parental materials

Class	Description	Parental materials	Value
1	Good	Sand, comglomera	1
2	Moderate	Limestone, Marl, Granite, Riolith, Silt stone	1.7
3	Poor	Marl, Pyroclassic	2

4- Gravel coverage

Class	Description	Gravel coverage (%)	Value
1	Very rocky	>20	1
2	Rocky	20-60	1.3
3	Bare land to very low rocky	<20	2

5- Soil depth

Class	Description	Soil depth (cm)	Value
1	Deep	>75	1
2	Moderate	30-75	2
3	Shallow	15-30	3
4	Very shallow	<15	2

6- Drainage

Class	Description	Value
1	Good drainage	1
2	Improper drainage	1.2
3	Poor drainage	2

7- Soil quality

Class	Description	Value
1	High quality	<213
2	Moderate quality	113-146
3	Low quality	>146

Then, Soil Quality Indicator (SQI) was measured by geometric mean of soil texture, parent materials, surface gravel, soil depth and drainage layers using the following algorithm:

Soil Indicator = (Soil texture × parent materials × surface gravel × soil depth × slope drainage)$^{1/6}$

2-1-2- Vegetation benchmark

This is assessed based on the type and coverage percentage of vegetation, fire hazard, revegetation capability and resistance to erosion and drought. Four dominant vegetation cover classes in Mediterranean region are determine according to fire hazard (Table 2). Based on soil conservation and resistance to drought and erosion, four and five classes are determined, respectively (Table 2). Finally coverage percentage of vegetation is categorized in three classes (Table 2). Vegetation Quality Indicator (VQI) is measured by a geometric mean of the mentioned vegetation features related to their sensitivity to desertification using the following algorithm and classified into three classes:

Vegetation cover quality = (Fire hazard × soil conservation × drought resistance × coverage percentage of vegetation)$^{1/4}$

Table 2: Classes and values of parameters used for evaluation of vegetation quality

1- Fire

Class	Description	Vegetation type	Value
1	Low	Bare lands, perennial crops. Annual crops (corn, tobacco)	1
2	Moderate	Annual crops (cereals, grasslands), nut trees, evergreen forests	1.2
3	High	N/A	1.6
4	Very high	Pine trees	2

2- Conservation of erosion

Class	Description	Vegetation type	Value
1	Very high	Evergreens	1
2	High	Pine trees, permanent grasslands	1.2
3	Moderate	Deciduous forests	1.6
4	Low	Deciduous trees (orchards)	1.8
5	Very low	Annual crops and grasslands	2

3- Drought management

Class	Description	Vegetation type	Value
1	Very high	Evergreens	1
2	High	Pine trees, olive	1.2
3	Moderate	Trees (orchards)	1.4
4	Low	Permanent grasslands	1.7
5	Very low	Annual crops	2

4- Vegetation cover percentage

Class	Description	Vegetation percentage	Value
1	High	>40	1
2	Low	10-40	1.8
3	Very low	<10	2

5- Quality of vegetation

Class	Description	Vegetation ranges	Value
1	High	<1.12	1
2	Moderate	1.12-1.28	2
3	low	>1.28	3

2-1-3- Climate benchmark

This is assessed based on factors affecting water availability for plants such as aridity, air temperature and precipitation as follows:

- Annual precipitation indicator is categorized into three classes (Table 3).

- Aridity index is measured by Goessen-Bagnolous index and classified into six classes (Table 3).
- Aspect index is classified in two classes.

Finally, climate quality indicator is measured through merging mentioned factors and using the following formula and table 3.

Climate index = $(\text{Precipitation} \times \text{aridity} \times \text{aspect})^{1/3}$

Table 3: Classes and values of layers used for evaluation of climate quality

1- Precipitation

Class	Precipitation (mm)	Value
1	650	1
2	280-650	2
3	280	3

2- Aridity

Class	BGI ranges	Value
1	50	1
2	50-75	1.1
3	75-100	1.2
4	100-125	1.4
5	125-150	1.8
6	150	2

3- Slope direction

Class	Description	Value
1	North west & North east	1
2	South west & south east	2

4- Climate quality

Class	Description	Value
1	High	1
2	Moderate	2
3	low	

2-1-4- Management or human stress indicator

Based on land use types, the following groups are determined in the study areas:

1- Agricultural lands including croplands and range lands.

2- Natural resources including forests, shrub lands and bare lands.

3- Mines.

4- Recreation sites including parks, tourism attractors, etc.

5- Infrastructure facilities such as roads, dams, etc.

Then, land use intensity and executive policies related to the environmental conservation are evaluated.

A. Landuse intensity

Agricultural lands-croplands

Landuse intensity for croplands is determined in three classes (low, medium, high) based on irrigation rotation, the extent of agricultural mechanization, application of fertilizer and other chemical substances; and plant varieties (Table 4).

Rangelands

Landuse intensity for rangelands is estimated using allowable live stock rate, current livestock rate and current rate/allowable rate for different grazing land areas (Table 4).

Natural resources

Landuse intensity in forests and shrublands is obtained on the basis of current and sustainable yield. Based on current/sustainable yield ratio, intensity is classified in three classes (Table 4).

Mines

Landuse for these lands is assessed based on the intensity of activities has been done for soil conservation including terracing, planting, etc.

Finally, landuse intensity is classified in three groups according to the degree of soil conservation activities.

Recreation sites

In these areas, landuse intensity is determined base on current and allowable visitor numbers. Based on current/allowable number ratio, intensity is classified into three classes (Table 4).

Executive policies

These are classified based on measures implemented for conservation of environment. The related data are gathered the extent of implementation is assessed. In this case, three classes are define (Table 4). Management quality indicator is also measured using mean of land use intensity and implementation of policies.

Management = (Type and intensity of land use × policy implementation)$^{1/2}$

Then, Management Quality Indicator is defined using Table 4.

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Table 4: Classes and values of parameters used for evaluation of management quality

1- Arable lands

Class	Description	Value
1	LLUI	1
2	MLUI	1.5
3	HLUI	2

* LUI: Land Use Intensity

2- Pasture

Class	Description	Domestic livestock	Value
1	Low	ASR<SSR	1
2	Moderate	ASR=1.5SSR - ASR=SSR	2
3	high	ASR>1.5*SSR	3

3- Natural sites

Class	Description	Managerial charateristics	Value
1	Low	A/S=0	1
2	Moderate	A/S<1	1.2
3	high	A/S>=1 or A/S=1	2

4- Mines

Class	Description	Presion control	Value
1	Low	Adequate	1
2	Moderate	Moderate	1.5
3	high	low	2

5- Recreation sites

Class	Description	A/P ratio	Value
1	Low	<1	1
2	Moderate	1-2.5	1.5
3	high	>2.5	2

6- Policy

Class	Description	Degree of implementation	Value
1	Low	Complete: more than 75% of the areas are conserved	1
2	Moderate	Incomplete: 25-75% of the areas are conserved	1.5
3	high	Partial: less than 25% of the areas are conserved	2

7- Management quality

Class	Description	Value ranges
1	Low	1-1.25
2	Moderate	1.26-1.5
3	high	>1.51

3- Results

Final stage of the research was to synthesis the physical qualities of environment (soil, climate and vegetation cover qualities) as well as Management Quality Indicator to determine different levels of susceptibility to desertification using the following algorithm:

Desertification map = (Soil benchmark × climate benchmark × vegetation benchmark × management benchmark)$^{1/4}$

The range of ESAI for each ESAs includes three sub-classes (Table 5) and the range of each ESAs type is between 2 (high) and 1 (low).

The map symbol of each ESAs type shows its class and sub-classes. Also, four abbreviations related to landuse quality (S for Soil, C for

Climate, V for vegetation cover and M for management) and four numbers indicating the level of limitation in each quality were considered to determine susceptible areas to desertification (Fig. 2). For example, formula of figure 2 illustrates that the study area has low level of susceptibility to desertification (F_1). In this regard, climate limitation is medium (C_2), soil limitation is low (S), vegetation cover is medium (V_2) and finally management Imitation is low (M_1).

Table 5: ESAs types and ranges

Class	Sign	ESAs range
Critical	C3	>1.53
Critical	C2	1.42-1.53
Critical	C1	1.38-1.41
Fragile	F3	1.33-1.37
Fragile	F2	1.27-1.32
Fragile	F1	1.23-1.26
Degradable	P	1.17-1.22
Non affected	N	<1.17

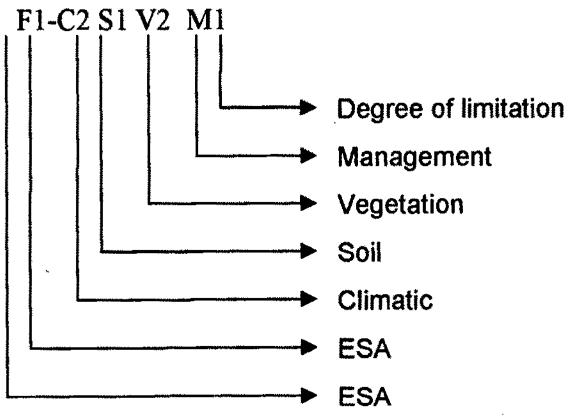

Figure 2: An example for symbols used for introducing studied areas vulnerable to desertification

2-2-The data used for desertification mapping (case study: Kashan region)

For this purpose, benchmarks and indicators of the original model were calibrated based on conditions and so, seven benchmark including ground waters, vegetation cover, soil, climate, water erosion, wind erosion and management were considered as key factors on desertification.

1- Ground water resources degradation benchmark:

This benchmark consists of some indicators as groundwater tables, Cl^-, EC, groundwater table depletion, water crisis and water resources deficiency necessary for livestock utilization.

2- Water erosion benchmark including indicators as damages caused by flooding, fluvial features and water erosion class.

3- Wind erosion benchmark includes some indicators such as stormy days, percentage of surface gravel, aeolian features, wind erosion class and frequency of winds with speed>6 m/s.

4- Vegetation benchmark: these are some indicators such as the amount of production and reproduction percentage of plant composition and coverage percentage.

5- Soil quality benchmark including indicators as SAR, EC, type of geologic formations, slope, drainage, soil depth and texture.

6- Climate benchmark including indicators as Transo aridity index, aspect and the amount of precipitation.

7- Management benchmark includes indicators as executive management and policy, type and intensity of land use.

To obtain mentioned benchmarks, several comprehensive studies on hydrology, landuse, soil, geomorphology, erosion and vegetation cover of the region were conducted. Each of that parameters were studied individually. Then, a value was assigned to each layer based on its effect on desertification as 1 and 2. The 1 indicates the best while 2 the worst value.

Some landuses such as pools and residential areas were assigned value "Zero". Consequently, a map was prepared based on the given values. Each benchmark is measured using the following formula for their indicators:

Index-X=[(Layer-1).(Layer-2)...(Layer-n)]$^{1/n}$

Where:

Index-α= The given benchmark

Layer= Indicator of each benchmark

n: Number of indicators for each benchmark.

Therefore, seven maps were obtained showing the status of benchmark. These maps can be used for studying the quality and effect of each indicator on desertification. The final map showing desertification condition of the region was prepared using geometric mean of all indicators.

4- Results

Analysis of desertification indicators in calibrated MEDALUS used for Kashan showed that water resources degradation is the main factor with value of 1.74 as very severe factor and climate having value of 1.55 is in the second order.

The results for other benchmarks are shown in Table 6. The conducted research showed that precipitation, water deficiency index and groundwater depletion having values 1.85, 1.83 and 1.79, respectively have the lowest effect on desertification. Figure 3 shows the susceptibility of Kashan to desertification based on the mentioned algorithm. The researches showed that in all Kashan area, desertification is occurred in different levels as shown in Table 7.

Table 6: Mean weight of quantitative value

Row	Benchmark	Quantitative value	Desertification class
1	Degradation of water resources	1.74	Very severe
2	Climate	1.557	Very severe
3	Management	1.409	Severe
4	Vegetation	1.369	Severe
5	Wind erosion	1.33	Severe
6	Soil	1.247	Moderate
7	Water erosion	1.097	low

Table 7: Frequency of desertification status clases

Qualitative classification	sign	Value rate	area	Studied area Total area (%)
Water pools & urban sites	U	0	8.91	0.97
Low	I	1-1.22	0	0
moderate	I I	1.23-1.32	298.67	32.68
Severe	I I I	1.33-1.41	366.04	40.07
Very severe	I V	1.42-2	240.21	26.28

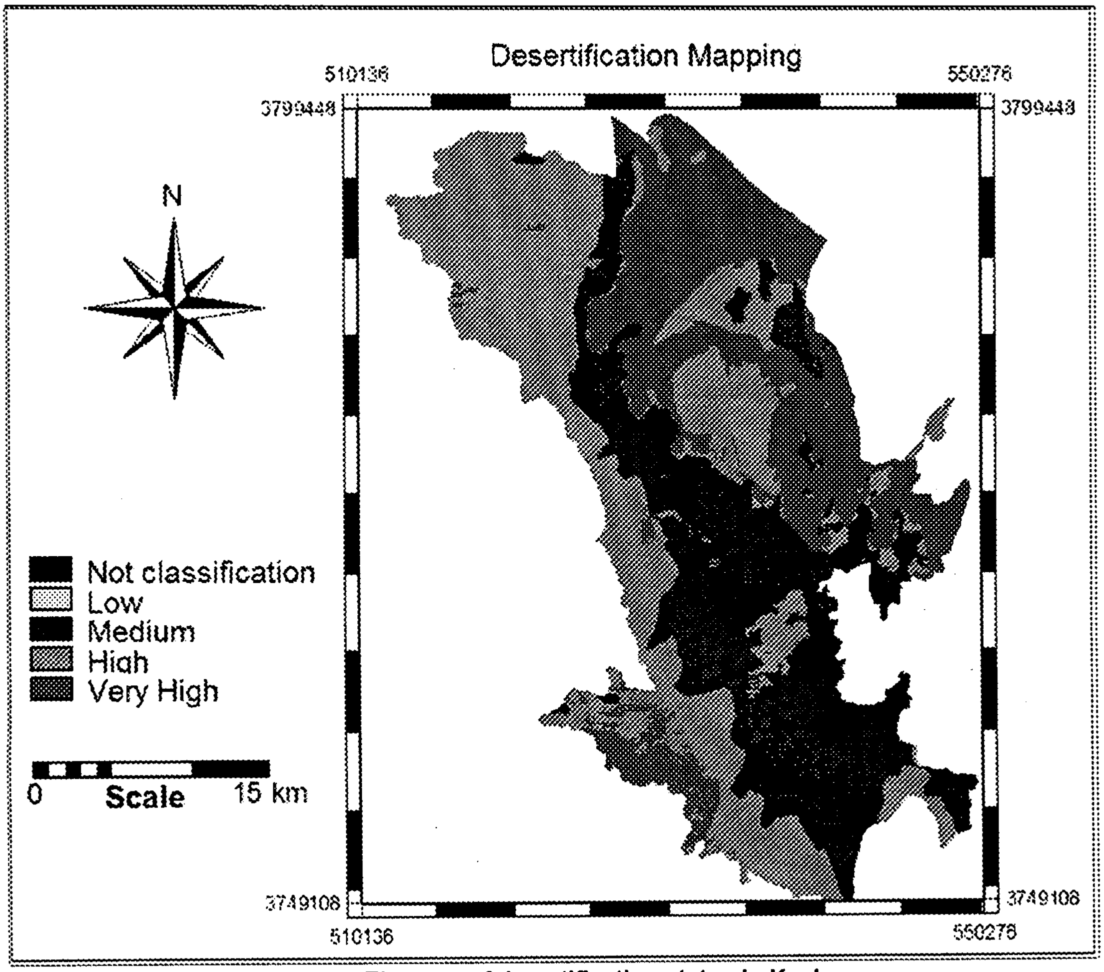

Figure 3: The map of desertification status in Kashan

5- Discussion and Conclusion

Based on the results of current research, calibrated MEDALUS model has high efficiency for desertification mapping in Kashan. This method has been used in other European and Middle Eastern countries and showed positive results.

The important issue for using MEDALUS model, declared by European Commission staff, is to adjust its benchmarks and indicators for desertification assessment based on the regional condition.

The method of value giving to each layer, using GIS as well as geometric mean instead of arithmetic as one are same of advantages of the model. Since different factors and their interaction play major role in desertification, it is necessary to consider all effective ones. The preliminary results of conducted research showed that both environmental and human factors affect desertification. In Iran which leads to degradation land, water and vegetation resources. In Kashan, environmental and human factors all together causes desertification and degradation of resources.

The soil salinity and vegetation cover removal are consequences of desertification. The case study in Kashan also showed that water resources degradation has the highest effect on desertification while climate benchmark stands in the second order.

Meanwhile, it is necessary to conduct numerous regional researches in different climates of Iran to calibrate benchmarks and indicators and obtain more accurate results. One of the problems of presented models is lack of ability to measure all effective indicators due to the extent of lands, expenditures, lack of data, etc.

In the current research, 45 indicators were considered but it is important to continuously update the data in order to obtain actual results on intensity and trend of desertification and introduce the most effective combating desertification measures.

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