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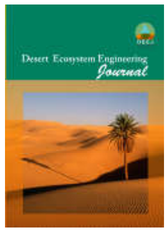

Assessing and mapping desertification hazard using desertification indicator system for Mediterranean Europe (Case study: Miandoab Plain of West Azerbaijan Province, Iran)

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Abstract

There are many hazards putting human life in danger; they are also influenced by human activities. Desertification in the natural environment and agricultural lands is one of the most critical threats for human life in drylands. In this research, the Desertification Indicator System for Mediterranean Europe (DIS4ME) was applied to evaluate the current status of desertification in the Miandoab plain, West Azerbaijan Province, Iran. In this model, there are four main indicators of climate, vegetation, soil, and land management; each of them was divided into measurable parameters used to calculate the severity of desertification. The study findings show that the desertification severity is due to vegetation and land management quality, whose low-quality levels cover 96.7%, and 76.6.4% of the study area, respectively. Desertification status also indicates that 97% of the study area has a severe critical class. Considering the anthropological induced hazard of desertification, it is necessary to apply proper land management.

Keywords: Hazard, Desertification, Indicator, Land Degradation, Miandoab Plain.

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1. Introduction

Considering interactions between the human and the environment, any community might be in danger of some hazards, which be induced from natural hazards or human activities. The human activities might either induce or accelerate the natural hazards such as flood, erosion, desertification, and global warming (Reuveny, 2007; Quansah et al., 2010; Warner & van der Geest, 2013); among them, the measured desertification according to the Life Cycle Assessment (LCA) shows that arid regions, 38 % of the Earth, are at risk of various levels of desertification severity (Núñez et al., 2010). Undoubtedly, nowadays, deterioration of natural resources jeopardizes sustainable development, particularly in the developing countries (Daniels, 1992; Amiraslani & Dragovich, 2011). In managerial programs, if their risks are not involved in the initial stages, this would eventually cause serious failure. Since land degradation decreases the quality of land, it hinders socioeconomic development. Furthermore, it explicitly changes land utilization type (LUT), as well as the structures and process of the nature (Helming et al., 2008). Land cover/use change is an indicator through which human impacts the nature; in other words, land use changes affect environmental sustainability (Mosavi et al., 2011). As land use changes over time, land quality and ecosystem diversity decrease, especially in arid and semi-arid areas. Therefore, to combat the disaster, it necessities to recognize and understand the effective factors and processes (Honardoust et al., 2011).

Land degradation refers to any reduction in the capability and product of any land on which the community depends. In general, land degradation is defined by UNEP (1997) experts as follows: any reduction of the biological productivity of any ecosystem, including pastureland, grassland, forestland, and cropland, caused by hydro-physiochemical agents (Soleimani Sardoo et al., 2015). According to the United Nations Convention to Combat Desertification (UNCCD), desertification is also defined as "land degradation in arid, semi-humid, and dry sub-humid areas results from various factors such as climatic variations and human activities" (Adger et al., 2007; UN, 1995). However, recent studies have shown existence of methodological weakness in desertification models (Verón et al., 2006) such as difficulty of data collection (Sepehr et al., 2007), lack of reliable measurement to represent the human activities in land use change (Núñez et al., 2010), and lack of methods to discriminate the contribution of climate change and human activity in land degradation (Jahelnabi et al., 2016), especially in the coincidence of desertification with drought event. Nonetheless, desertification assessment models are the most suitable methods to recognize effective factors of land degradation (Zehtabian et al., 2010). Additionally, novel tools such as remotely-sensed data have versatile utility in the identification of these factors (Jurio & van Zuidam, 1998).

Nowadays, to manage arid and semi-arid regions appropriately, accurate knowledge about desertification factors and its mechanisms is needed. Thus far, many desertification models have been evaluated in Iran. For instance, the IMDPA (Iranian model of desertification Potential Assessment) model is designed to assess desertification in the central drylands of Iran (Nateghi et al., 2009). However, in Miandoab plain, even in any part of the province of West Azarbaijan, few desertification models have not been applied. This research aims to implement the Desertification Indicator System for Mediterranean Europe (DIS4ME) model to assess desertification status within the watershed of Lake Urmia, particularly in Miandoab plain; four main indicators (climate, soil, vegetation and land management criteria) will be considered to estimate the severity of desertification.

It should be mentioned that after three phases of MEDALUS projects, the DESERTLINKS project was implemented in 2001 to assess land degradation and desertification indicators and to prepare sensitive environmental maps (ESAs) in Mediterranean countries (DIS4ME, 2004) with 150 indicators, especially main focus on Portugal, Spain, Italy and Greece. The DESERTLINKS project has provided researchers with an online resource to access affective desertification indicators easily (Bakhshi et al., 2016). The MEDALUS was applied in many countries. For instance, Giordano et al. (2003, 2002) assessed the desertification of the Italian Sicilian region by the MEDALUS method in which four indicators of soil, climate, vegetation and land management were considered the key parameters of desertification, showing that more than 50% of the region is subjected to severe to moderate intensity of desertification. In addition, Zehtabian et al. (2010) evaluated the desertification severity using the MEDALUS model in the Hable Roud region. Mosavi et al. (2011) studied the current status of desertification in the plains of Arak using the MEDALUS method; for this purpose, the work units were determined based on geomorphology facies, and then they were evaluated using four MEDALUS criteria of climate, soil, vegetation and management indices; the findings indicated that approximately 10.43% of the total area was considered critical desertification, 87.58% was in a fragile class, and 97.9% was in a potential class of desertification.

There is the severe land degradation in the Lake Urmia watershed where it caused many socio-economic problems (Eimanifar & Mohebbi, 2007; Delju et al., 2013; Lake Restoration National Committee (ULRNC), 2015), particularly in the southern part of the province of West Azerbaijan. The objective of this research is to assess desertification criteria in the Miandoab plain; in fact, it will help us to find the effective factors of desertification. In other words, this study aims to identify desertification areas, and to indicate the impact of natural and human desertification processes using DIS4ME, the modified project of MEDALUS III (Kosmas et al., 1999). In this study, most of parameters are extracted via remote sensing processing, so that such an indicator-based model of land degradation has not been applied to assess and monitor the quality of desertification in the Miandoab plain, West Azerbaijan Province, Iran.

2. Material and Methods

The study area, Miandoab plain (or Qushachay), is in the province of West Azerbaijan, the southeast of Lake Urmia; its extent, with an area of 1015 km^2, ranges from the longitude of 45˚ 15'E to 45˚ 53'E and the latitude of 36˚ 52'N to 37˚ 15N (Figure 1). As the study area is located in a delta region of the two rivers of Zarrinehroud and Siminehroud, the soil of this region is fertile, and land and groundwater are also not extremely saline and alkaline (Amari & Ghaemian, 2003; Kolahdouzan et al., 2015). Agriculture is the main activity of the rural population, so that it is considered as one of main plains of Iran in agriculture and livestock production (Kazemi et al., 2017).

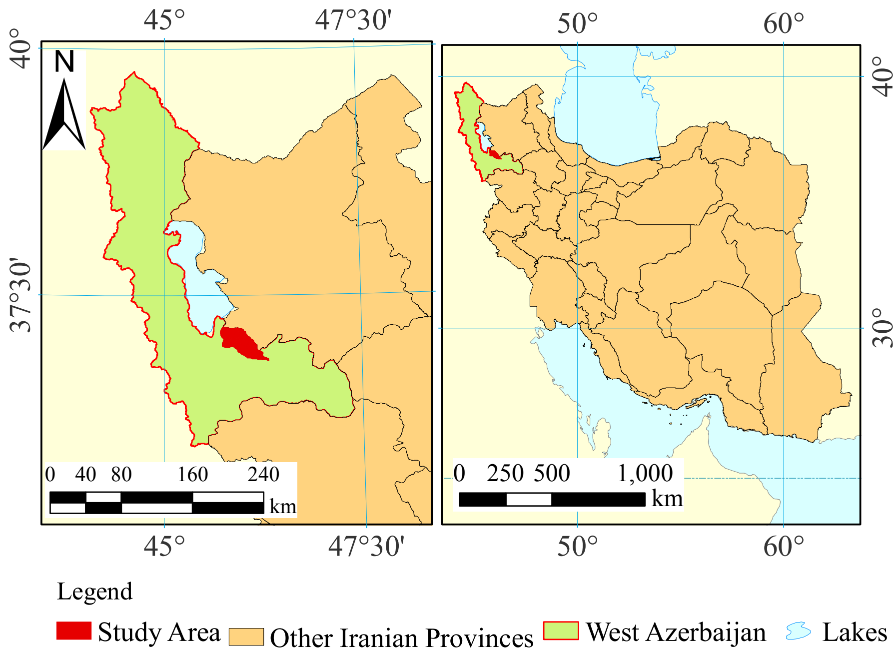

Figure (1): Location of the study area (red colored) in the Miandoab plain in Iran. The second map (top left) shows the Miandoab plain watershed in West Azerbaijan province

According to the Miandoab synoptic station report (1985-2015), the main rainfall seasons are winter and spring, and starts from October to July when around 256 mm of rain falls on average. However, rain distribution varies spatially and temporally; the mean annual temperature (2006–2015) is 16.35°C. Precipitation in the study area (1951-1980) on average is 130 cm annually (Niknam et al., 2018). Therefore, De Martonne aridity index is approximately 10.33; therefore, the study area is classified as semiarid region.

In this study, indicators and parameters (adapted from Ferrara, 2005) were used to recognize the areas sensitive to desertification (SAD) in the Miandoab plain, West Azerbaijan, Iran. Additionally, to implement the modeling desertification sensitivity in the study area, the following four biophysical indices are computed;

(i) Climate Quality Index (rainfall, aspect, aridity index),
(ii) Soil Quality Index (soil depth, texture, parent material, rock fragment, slope, and drainage),
(iii) Vegetation Quality Index (plant cover, erosion protection, drought resistance and fire risk),
(iv) Management Quality Index (land use intensity and policy enforcement).
(v) Additionally, Landsat 8 imagery of OLI (acquired on June 27, 2014) was used to classify the land use in the Miandoab plain; after atmospheric correction (using the QGIS software), for each land use in the study area, approximately 171 pixels were randomly selected as samples; then, they were identified by Google earth and field survey. Approximately 70% of samples were selected as training samples for supervised image classification (with a maximum likelihood classifier), and the rest of samples (as test samples) were also used to evaluate the accuracy of the classified land use map (Congedo, 2017).

2.1. Climate Quality Index (CQI)

The parameters of climate quality (Table 1) include a) rainfall, b) aridity, and c) the effective topographic factor (aspect of slope) on evapotranspiration and the water availability for plants. The annual precipitation of 280 mm is considered a crucial value for erosion as well as plant growth; therefore, as a hostile condition, it gets a severe desertification.

Table (1): The classes and weights of the Climate Quality Index (adopted from Kosmas et al., 1999)

Parameters	Description	Range	Weight index
Rainfall (mm/year)	High Moderate Low	Rain > 650 280 ≤ Rain ≤ 650 x < 280	1 $1+\frac{650-\text{Rain}}{650-280}$ 4
BGI	High Moderate Low	GI < 50 50 ≤ BGI ≤ 150 BGI > 150	1 $1+\frac{\text{BGI}-50}{150-50}$ 2
Aspect (degree)	High Moderate Low	x < 90 90 ≤ x ≤ 270 x > 270	1 2 1

Soil water content is calculated by precipitation minus evapotranspiration potential and runoff. Considering the water balance model, they need extensive data (Thapa et al., 2017). Although, the meteorological data are easily available, conceptually, instead of potential evapotranspiration, the Bagnouls-Gaussen bioclimatic index (BGI) is applied to determine aridity index (Marini & Talbi, 2008, p. 120), as the following equation;

$$\text{BGI} = \sum_{i=1}^{n}(2\text{T}_i - \text{P}_i) \times k \qquad (1)$$

where T_i is the mean air temperature in °C, and P_i represents the mean rainfall in mm for month i; k shows the proportion of the month when 2Ti-Pi is higher than zero.

According to the solar irradiance in northern hemisphere, slope aspect is grouped into two classes (a) NW and NE and (b) SW and SE; they are given the weight index of 1 and 2, respectively. Finally, the climate quality index is calculated by the geometric mean of the indices (rainfall, aspect, and aridity index), as shown below.

$$CQI = \sqrt[3]{\text{Rainfall} * \text{Aspect} * \text{BGI}} \qquad (2)$$

Then, the CQI is classified into very favorable (<1.15), favorable (1.15 -1.81), unfavorable (>1.81) class (Zdruli et al., 2010, p. 86).

2.2. Vegetation Quality Index (VQI)

To extract dominant types of vegetation and land use/cover, the Landsat 8 imagery is classified by the supervised maximum likelihood classification technique (Lillesand & Kiefer, 1987; Alavipanah, 2009). The main land use in the study area includes bare land (including salty lands), perennial agricultural crops (the irrigated croplands), annual agricultural crops (rain-fed croplands), perennial grasslands (and pasture) and orchards (Figure 2). The overall accuracy of the classified map was approximately 87 percent.

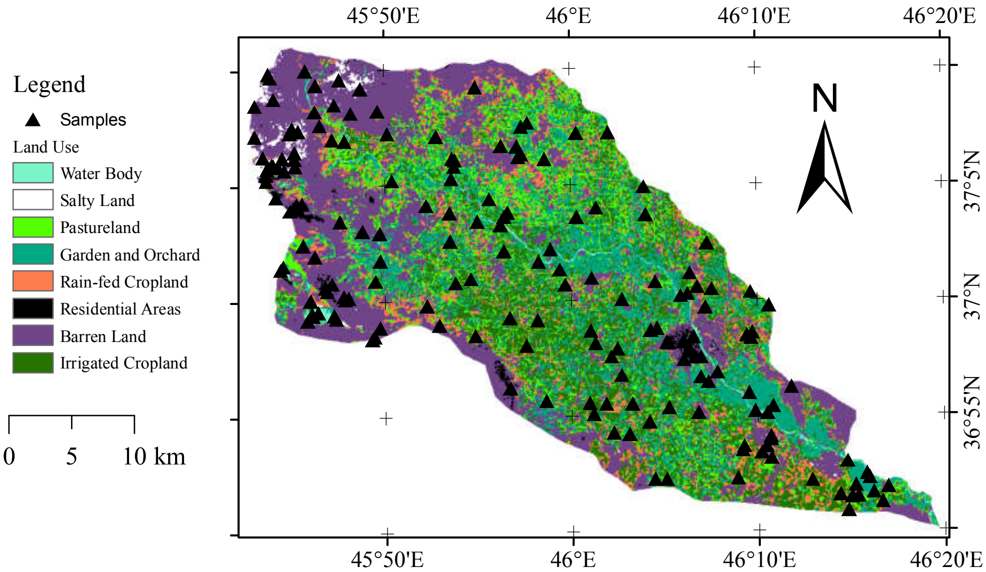

Figure (2): The main land use/cover in the study area and the training samples

Vegetation indicator includes a) fire risk and ability to recover (four categories), b) erosion protection (four categories), c) drought resistance (five categories) and d) plant cover (three categories). Table 2 shows their relative scores for three parameters. The parameter of plant cover is also weighted as shown in Table 3.

Table (2): Land types and their relative weight indices for three parameters of fire risk, erosion protection and drought resistance (adopted from Ferrara, 2005)

Code	Land Type	Fire risk	Erosion protection	Drought resistance
1	Bedrock	1	1	1
2	Mixed Mediterranean macchia/evergreen forests	1	1	1.3
3	Olives	1	1.3	1.2
4	Bare soil	1	2	1
5	Mediterranean macchia	1.3	1.3	1
6	Deciduous forests	1.3	1.6	1.2
7	Orchards, almonds, ...	1	1.8	1.4
8	Vines	1	2	1.4
9	Perennial grasslands, pasture	1.3	1.3	1.7
10	Pines and other conifer forests	2	1.3	1.2
11	Annual crops (maize, tobacco, sunflower, ...), horticulture	1	2	2
12	Cereals, annual grasslands	1.3	2	2
13	Very low vegetated area	1.3	2	2
14	Open shrub lands	1.3	1.3	1.7

Table (3): The classes and weights of the parameters related to the vegetation cover of plan cover percentage (adopted from Ferrara, 2005)

Parameters	Range of vegetation fraction (fc, %)	Weight index
Plant cover	$fc > 40$ $10 \leq fc \leq 40$ $fc < 10$	1 $1 + \frac{40 - fc}{40 - 10}$ 2

The vegetation quality index (VQI) is measured via the following equation;

$$VQI = \sqrt[4]{\mathrm{FR} \times \mathrm{EP} \times \mathrm{DR} \times \mathrm{PC}} \quad (3)$$

where FR, EP, DR, and PC represent fire risk, erosion protection, drought resistance and plant cover scores, respectively. The VQI is categorized into three classes, including very high quality (<1.13), medium quality (1.13 - 1.38) and low quality (>1.38).

2.3. Soil Quality Index (SQI)

Soil is an important factor for the productivity of a land as well as the protection of an ecosystem against desertification, especially in drylands. Soil is a basis for a plant, and it can play a vital role in water storage capacity and erosion protection (Ferrara, 2005; Zdruli et al., 2010). Therefore, in addition to auxiliary maps such as geology map and slope percentage, a field survey was performed to score the weights of other relative parameters of soil according to Table 4.

Table (4): The classes and weights of the parameters of the Soil Quality Index (adopted from Kosmas et al., 1999; Ferrara, 2005)

Parameters	Description	Class	Weight index
Rock fragment %	Very stony Stony Slightly stony	F>60 20 ≤ F ≤ 60 F < 20	1 $1 + \frac{60 - F}{60 - 20}$ 2
Soil depth (cm)	Deep Shallow to moderate Very shallow	Depth>75 15 ≤ Depth ≤ 75 Depth < 15	1 $1 + 3 \times \frac{75 - Depth}{75 - 15}$ 4
Slope %	Good Moderate Poor	Slope < 6 6 ≤ Slope ≤ 35 Slope > 35	1 $1 + \frac{Slope - 6}{35 - 6}$ 2
Texture	Good Moderate Poor Very poor	Loamy (L, SCL, SL, LS, CL) Sandy (SC, SiL, SiCL) Clayey (Si, C, SiC) Extremely sandy (S)	1 1.2 1.6 2
Parent material	Good	Shale, schist, basic, ultrabasic, conglomerates, unconsolidated;	1
	Moderate	marble, limestone, rhyolite, granite, ignimbrite, gneiss, sandstone, siltstone	1.7
	Poor	pyroclastic, marl	2
Drainage	Well drained		1
	Imperfectly		1.2
	Poor drained		2

The soil quality index (SQI) is calculated by the following equation;

$$\mathrm{SQI} = \sqrt[6]{\mathrm{RF} \times \mathrm{Sd} \times \mathrm{S} \times \mathrm{T} \times \mathrm{Pm} \times \mathrm{D}} \quad (4)$$

where RF, Sd, S, T, Pm, and D indicate the relative soil parameters of rock fragment, soil depth, slope, texture, parent material, and drainage, respectively. Later, SQI is also divided into three classes, including very high quality (<1.13), medium quality (1.13 -1.46) and low quality (>1.46).

2.4. Land Management Quality Index (MQI)

To investigate the impact of human factors on demolition by referring to villages and based on the statistics from the Statistics Center of Iran, the management and planning organization of the province, parameters such as population, income, product production, and access to services are used. Land use intensity indices for cropland and pastureland have been used to obtain this criterion. The land use intensity in croplands is determined by the degree of mechanization, use of materials, and fertilizer. Additionally, types of plant varieties are classified according to Table (5). Furthermore, the land use intensity in rangelands is measured by the estimated sustainable stoking rate and actual sustainable stoking (ASR) for different parts of the land under grazing. It is divided into three classes (Table 5).

Table (5): Land use intensity for agricultural land (pasture land)

Parameters	Description	Class	Weight index
Land use intensity for cropland	Good Moderate Poor	Low land use intensity Medium land use intensity High land use intensity	1 1.5 2
Land use intensity for pastureland (Stocking rate)	Good Moderate Poor	ASR<SSR from ASR=SSR to ASR=1.5×SSR ASR> 1.5 SSR	1 1.5 2

The sustainable stoking rate (SSR) is calculated by the following equation (Kosmas et al., 1999; WB2, 2008).

$$SSR = X \times P \times F/R \qquad (5)$$

Where R indicates the annual biomass requirement in the animal, X is a correction factor for the unpredicted biomass associated with the next growth season (under 0.5 and 0.5% non-biodegradable). P is the average biomass of palm plants after the growth season (kg/ha) in kilograms per hectare and F is the average surface covered with annual species.

Management quality index is grouped into three classes such as high (<1.25), moderate (1.25-1.51) and low quality (>1.51).

2.5. The indicator of Environmental Sensitivity (ES)

Indicators of each criterion are evaluated based on the points defined in the system, and the geometric mean of each criterion will be calculated based on the equation (6).

$$\text{Index}_x = [(\text{Layer}_1) \times \ldots . \times (\text{Layer}_n)]^{\frac{1}{n}} \qquad (6)$$

The severity of desertification was obtained via the geometric mean of the quality maps of soil, climate, vegetation, and land management, then it is divided into four classes (Table 6), through which the areas subjected to slight, moderate, severe and very severe categories of desertification are measured.

Table (6): Desertification status class

Level of sensitivity	Type of areas	Sensitivity score
Very low	Not affected (N)	1 - 1.170
Low	Potential (P)	1.170 - 1.225
Medium	Fragile (F1)	1.225 -1.265
	Fragile (F2)	1.265 -1.325
	Fragile (F3)	1.325 - 1.375
High	Critical (C1)	1.375 - 1.415
	Critical (C2)	1.415 -1.530
	Critical (C3)	> 1.530

3. Results and Discussion

The analysis of the four indicators for Miandoab Plain represents that its central part covered by orchard, the irrigated cropland, and rain-fed agriculture area, is ranked as high environmental sensitivity, having low quality (Figure 3 and 4). The most important indicators were vegetation, land management and soil. They present a low environmental quality in 96.7%, 76.6.4% and 34.2% of the study area, respectively, while climate, soil, and land management quality show values of 78.4%, 65.3% and 21% in the medium environmental quality of the Miandoab plain, respectively (Figure 4). The low quality of the vegetation is induced by intensive practices and low level of management in croplands and high pressure of livestock grazing on pasturelands. Therefore, vegetation cannot be developed to protect the soil against erosion (De Pina Tavares et al., 2015).

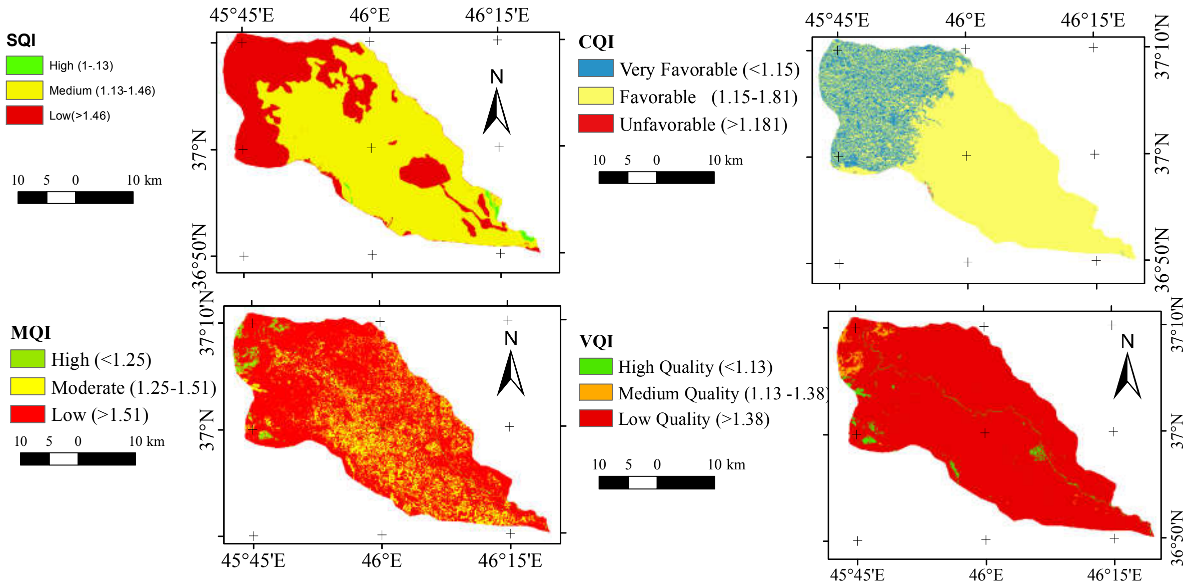

Figure (3): Four indicator quality maps: climate quality (CQI), soil quality (SQI), vegetation quality (VQI), and management quality (MQI)

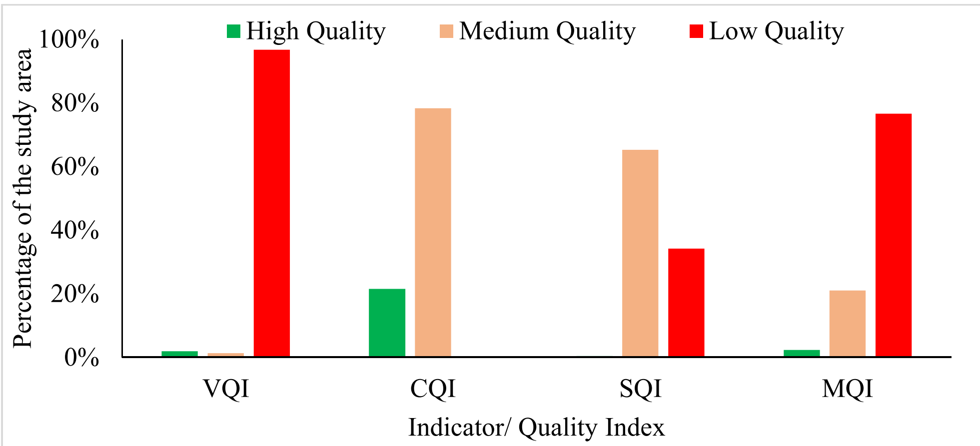

Figure (4): Percentage of coverage of the four indicator qualities and their extent in the study area; climate quality (CQI), soil quality (SQI), vegetation quality (VQI), and management quality (MQI)

The high sensitive areas to desertification (SAD) cover approximately 97% of the study area (Figures 5 and 6), especially in croplands alongside mainstreams and near residential areas, where the vegetation and land management quality is poor. Similar results were reported in the semi-arid and arid parts of central Iran (Sepehr et al., 2007; Zehtabian et al., 2010; Mosavi et al., 2011). The areas located in the humid and sub-humid region might show from low to medium sensitivity to desertification (De Pina Tavares et al., 2015). Concerning severe desertification in the study area, it is vital to provide local farmers with the knowledge of sustainable land use, and to increase the awareness about the costs of desertification to the main stakeholders in the study area.

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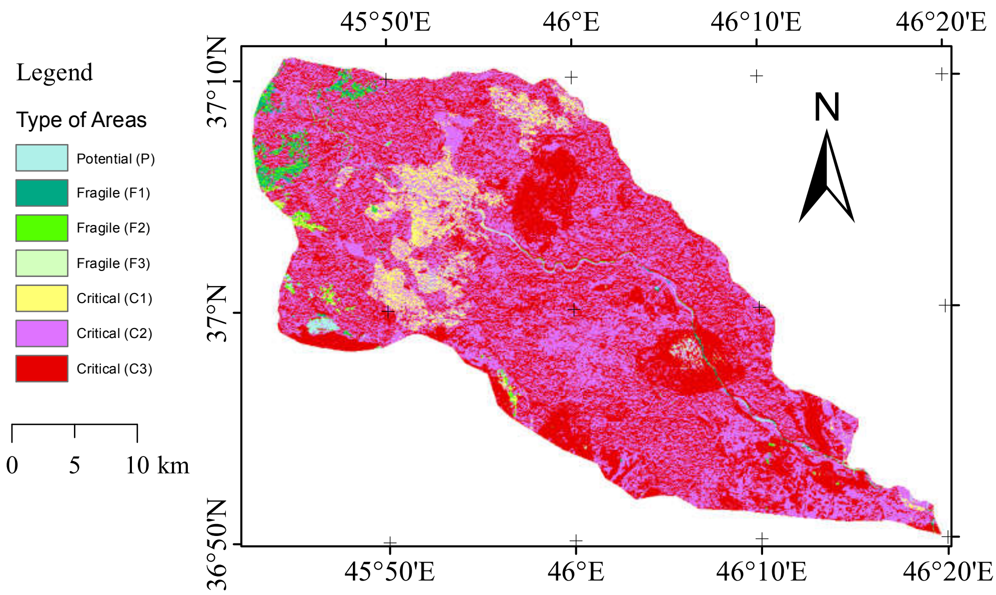

Figure (5): The distribution of sensitivity areas to desertification in the Miandoab plain

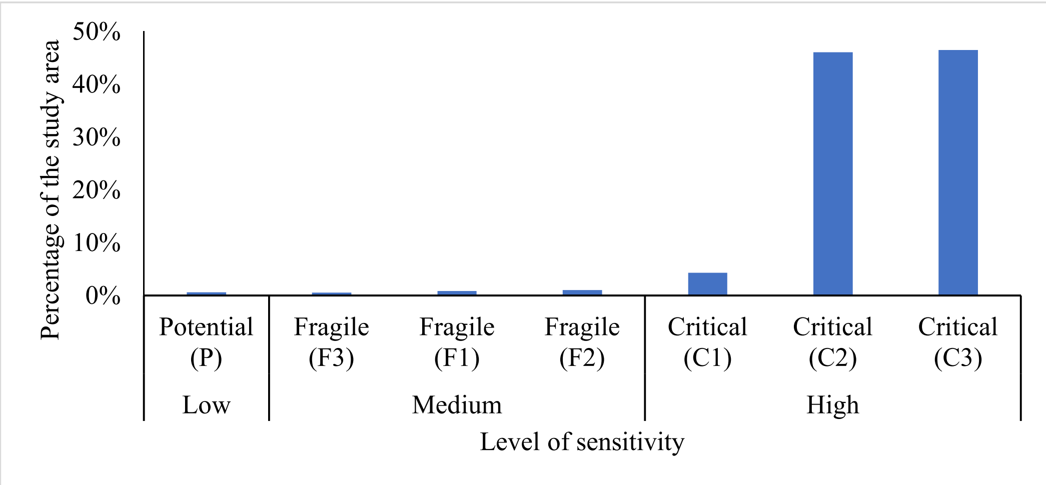

Figure (6): Summarized results of sensitive area to desertification in the Miandoab plain

Many methods of desertification assessment were applied using the combination and multiplication of various indicators and parameters in different regions. This research also adopted the same approach of desertification assessment performed in Mediterranean countries (Kosmas et al., 1999; Ferrara, 2005; Brandt & Geeson, 2015), and Iran (Zehtabian et al., 2010; Mosavi et al., 2011; Honardoust et al., 2011). However, the numbers of indicators and parameters in these researches were not similar (Table 7); 15 parameters grouped in four indicators were used to map the desertification severity over of the Miandoab plain.

Table (7): Indicators and parameters numbers in desertification assessment

Indicators	Parameters	Region	Reference
4	15	Mediterranean Countries	(Kosmas et al., 1999)
4	15	Agri basin, Italy	(Ferrara, 2005)
6	24	Fidoye–Garmosht plain (Southern Iran)	(Sepehr et al., 2007)
6	22	Aqqala-Gomishan plain, Golestan, Iran	(Honardoust et al., 2011)
7	29	Hable Rood Watershed, Semnan, Iran	(Zehtabian et al., 2010)
6	22	Cape Verde Archipelago	(De Pina Tavares et al., 2015)
6	31	Downstream of Atrak Watershed, Golestan, Iran	(Bakhshi et al., 2016)
9	29	Agh-band, Golestan, Iran	(Arami and Ownagh, 2017)
4	15	Miandoab Plain, West Azerbaijan	This study

Nevertheless, these authors did not use the same indicators and parameters to evaluate desertification (Table 4); data availability affects the choice of parameters (De Pina Tavares et al., 2015). To further study mapping desertification, temporal changes of desertification trend should be considered, and the parameters should be standardized to local conditions (Nateghi et al., 2009; Zehtabian et al., 2010). The prepared desertification hazard map here must be used as a base map for future land management program; a reference framework should be defined in analyzing various situations. Furthermore, to apply desertification hazard in any warning system, its risk must be also evaluated (Akbari et al., 2016).

4. Conclusions

Assessment of land degradation helps land managers to understand the effective factors to be considered in land capability and its resource management. In this study, the findings have confirmed the severity of desertification hazard, in the watershed, around Lake Urmia, is induced by vegetation deterioration and inappropriate land management. The model used in this study indicates that 97% of the study area is subject to sever desertification. Vegetation and land management are the most important factors in the desertification process; therefore, they are induced by anthropogenic factors such as overgrazing of pasturelands and converting them into croplands, and unsuitable practice of croplands. Although climate quality has been shown as the moderate level, climate conditions, including drought, have influenced the vegetation status. Considering these issues in the Miandoab plain, it is necessary to apply a proper management plan such as lowering the livestock pressure and planting of productive and drought-tolerant species.

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