

# Impact of Source Area Desertification on Dust Storm Emission in the Western Parts of Iran

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## ABSTRACT

Iraq is one of the main sources of western part of Iran's dust storm. Iran's western part dust storms considered hazardous problem that cause many environment and socio-economic impacts. Sensitive areas to desertification were identified by Environmental Sensitivity Areas (ESAs) in the source area of western part of Iran's dust storms for 2003 and 2007. RS and GIS data have been used to assess the desertification severity and its relation with the pervasive dust storms occurrences in western parts of Iran. The comparison of ESAs maps over studied years, indicate the severity of desertification has been increased in 2007. Source area desertification may cause western part of Iran's dust storms. Generally, the occurrences of western part of Iran's dust storms have become more frequent over studied years.

**Key words:** Desertification; Dust storm emission;  
Environmental Sensitive Areas; Western parts of Iran

## INTRODUCTION

Desertification is one of the most drastic problems in many countries (UNCCD, 2008). This phenomenon resulted by process set in vulnerable environments. Arid and semi-arid natural vegetation resources exploitation causes soil erosion that has led to desertification (Mainguet and Letolle, 1998). Source area wind erosion leads to dust storm emission (Gillette *et al.*, 1980). Loss of vegetative ground cover is the first sight might appear to be desertification.

For identification of areas vulnerable to desertification the ESAs model could be used (Kosmas *et al.*, 1999). The ESAs model was based on four indicators that represent of the soil quality (texture, rock fragments, drainage, parent material, soil depth), the climate (rainfall, aridity, aspects), vegetation (plant cover, fire risk, erosion protection, resistance to aridity) and of the management

practices (intensity of land use in rural zones, pastures and forest areas, managerial policies) (Ladisa *et al.*, 2002).

Dust storms occur in arid and semi-arid area (Urban *et al.*, 2009). Dust Storms have hazardous effects in western parts of Iran (Gerivani *et al.*, 2011). Desertification caused dust storms emission (Wang *et al.*, 2006). Middle East is known as an arid and semi-arid region with frequent and severe dust storms that subject to desertification (Harahsheh, 2001). Dust storms occurs when the surface wind shear velocity in the source area exceeds a threshold value, which is a function of surface properties such as the presence of roughness elements containing structural elements such as rocks and vegetation (Marticorena and Bergametti, 1995). Remote sensing techniques could be used to monitor trends of land degradation and desertification (Chen *et al.*, 1998).

**MATERIALS AND METHODS**

Northern parts of Al Anbar, Nineveh and Salah ad-Din Governorates in western of Iraq have been selected as study area. The study area has been shown in Figure 1.

The ESAs model has been applied to assess the desertification severity of the source area. Soil quality, climate quality, vegetation quality and management quality were ESAs model indicators (Basso *et al.*, 1999; Kosmas *et al.*, 1999; Giordano *et al.*, 2002; Ladisa *et al.*, 2002).

Soil quality index (SQI) of ESAs model has been calculated in terms of (a) soil texture, (b) parent material, (c) rock fragment cover, (d) soil depth, (e) slope grade, and (f) drainage conditions using equation 1.

$$SQI = (\text{texture} \times \text{parent material} \times \text{rock fragment} \times \text{depth} \times \text{slope} \times \text{drainage})^{1/6} \quad \dots(1)$$

The description and range of Soil Quality Index (SQI) were shown in Table 1. Climate quality index was extracted from mean annual temperature and precipitation data. Equation 2 has been used to Bagnold-Gosen aridity Index (BGI) calculation.

$$BGI = \sum_{i=1}^n (2Ti - Pi)k \quad \dots(2)$$

Where, BGI is Bagnold-Gosen Index, Ti refers to temperature of the i month (°C), Pi insinuate

total monthly precipitation of the i month (mm) and k show the frequency of the condition  $2Ti - Pi > 0$  for the i month (%) (Bagnouls and Gaussens, 1952). Based on equation 3, BGI and average annual rainfall were used to generate climate quality raster layer. Equation 3 has been used for Climate Quality Index (CQI) assessment.

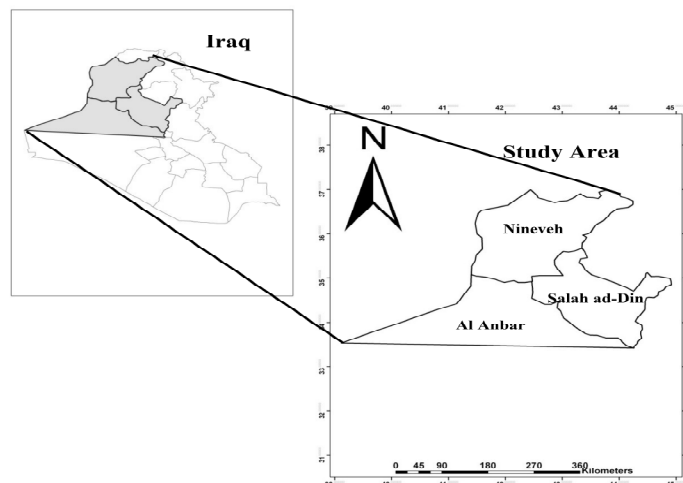
$$CQI = (\text{rainfall} \times \text{aridity})^{1/2} \quad \dots(3)$$

Description and range of Climate Quality Index (CQI) has been shown in Table 2. Vegetation Quality Index (VQI) of ESAs model has been assessed in terms of (a) fire risk and ability to recover, (b) soil erosion protection, (c) drought resistance and (d) plant cover (Basso *et al.*, 2010). These four vegetation characteristics were assessed to product the vegetation quality index by use of equation 4.

$$VQI = (\text{fire risk} \times \text{erosion protection} \times \text{drought resistance} \times \text{vegetation cover})^{1/4} \quad \dots(4)$$

The description and range of each classes of Vegetation Quality Index (VQI) were shown in Table 3. EVI has been used to express the vegetation percentage index. The source area has been divided in 1 square kilometre pixels. The mean values of EVI for each pixel were calculated using the red and NIR reflectance, using Equation 5 (Huete *et al.*, 2002):

$$EVI = G (NIR - RED) / (NIR + C1 \times RED + C2 \times BLUE + L) \quad \dots(5)$$



**Fig. 1: The location of study area**

Where, C1 and C2 are coefficients designed to correct for dust aerosol scattering and absorption, which use the blue band to correct for dust aerosol influences in the red band. C1 and C2 have been set at 6 and 7.5, while G is a gain factor (set at 2.5) and L is a canopy background adjustment (set at 1.0) (Nagler *et al.*, 2005).

The intensity of land use and the enforcement of policy on environmental protection have been assessed for each land use for any land use type. The management quality index (MQI) was assessed using equation 6.

$$MQI = (\text{land use intensity} \times \text{policy enforcement})^{1/2} \dots(6)$$

The description and range of each Management Quality Index (MQI) classes have

been shown in Table 4. Physical environmental qualities indices (soil, climate, vegetation) and the management quality index were determined for assessing the environmentally sensitive areas (ESA's) to desertification. The four derived indices are multiplied for the assessment of the ESAs index (ESAI) as equation 7.

$$ESAI = (SQI \times CQI \times VQI \times MQI)^{1/4} \dots(7)$$

Types of ESAs and corresponding ranges of indices have been shown in Table 5. Based on ESAs model, the desertification severity map of source area of western part of Iran's dust storms has been prepared for 2003 and 2007 (Figure 2).

After that, Meteorological data of 2003 and 2007, including precipitation and dust storm

**Table. 1: The description and range of Soil Quality Index (SQI)**

|                          | Class | Description      | Range Index |
|--------------------------|-------|------------------|-------------|
| Soil Quality Index (SQI) | 1     | High quality     | < 1.13      |
|                          | 2     | Moderate quality | 1.13-1.45   |
|                          | 3     | Low quality      | > 1.46      |

**Table. 2: Description and range of Climate Quality Index (CQI)**

|                             | Class | Description     | Range Index |
|-----------------------------|-------|-----------------|-------------|
| Climate Quality Index (CQI) | 1     | Very favourable | < 1.15      |
|                             | 2     | Favourable      | 1.15-1.81   |
|                             | 3     | Unfavourable    | > 1.81      |

**Table. 3: The description and range of each classes of Vegetation Quality Index (VQI)**

|                                | Class | Description      | Range Index |
|--------------------------------|-------|------------------|-------------|
| Vegetation Quality Index (VQI) | 1     | High quality     | 1.2-1.6     |
|                                | 2     | Moderate quality | 1.7-3.7     |

**Table. 4: The description and range of each Management Quality Index (MQI) classes**

|                                | Class | Description      | Range Index |
|--------------------------------|-------|------------------|-------------|
| Management Quality Index (MQI) | 1     | High quality     | 1-1.25      |
|                                | 2     | Moderate quality | 1.26-1.5    |
|                                | 3     | Low quality      | > 1.51      |

frequency from meteorological stations in western parts of Iraq and pervasive dust storms in western parts of Iran were provided.

The object of this study was to conduct assessment the desertification severity using ESAs model in western parts of Iraq and its relation with

the pervasive dust storms occurrences in western parts of Iran based on RS and GIS data.

**RESULTS**

The ESAs model has been used to assess desertification sensitivity in source area of dust storms over several Iranian western cities. The input indices of ESAs model were estimated and summed up to prepare the desertification severity of land use types (Table 6) across the source area. After that, their respective desertification severity maps were then synthesized (Figure 2) for 2003 and 2007.

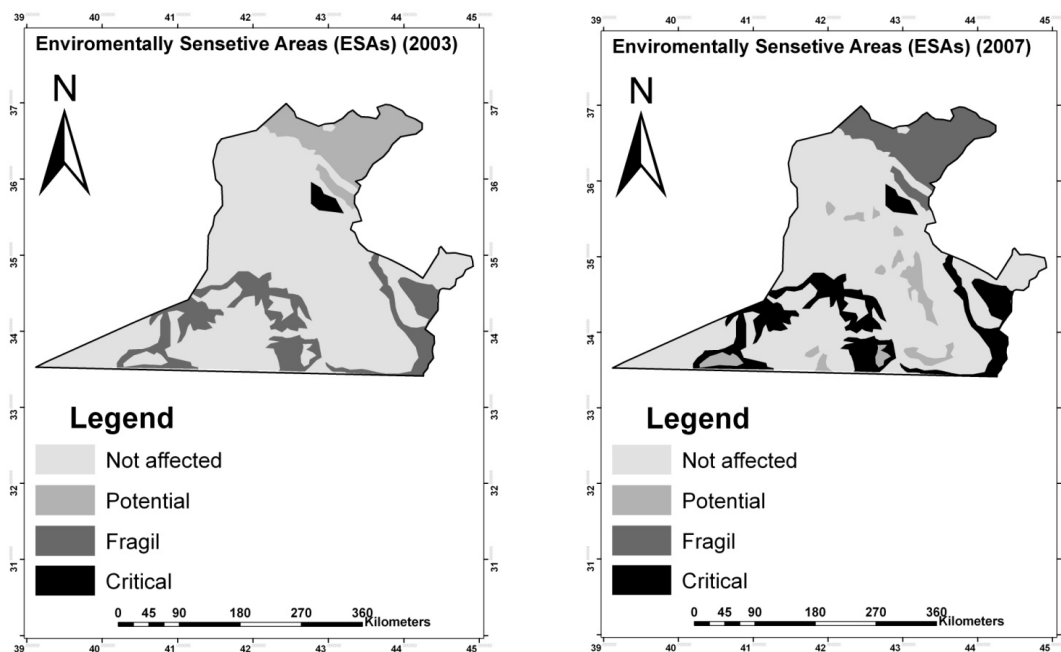
**Table 5: Types of ESAs and corresponding ranges of indices**

| Types of ESAs | Description  | Range Index |
|---------------|--------------|-------------|
| 1             | Not affected | 0-1.22      |
| 2             | Potential    | 1.23-1.30   |
| 3             | Fragile      | 1.31-1.41   |
| 4             | Critical     | 1.41-2      |

Figure 2 shows the distribution of ESAs in 2003 (A) and 2007 (B) in Northern parts of Al Anbar, Nineveh and Salah ad-Din Governorates in western of Iraq.

**Table 6: The ESAs areas in 2003 and 2007**

| Types of ESAs | ESAs      | Area (km <sup>2</sup> ) (2003) | Area (%) (2003) | Area (km <sup>2</sup> ) (2007) | Area (%) (2007) |
|---------------|-----------|--------------------------------|-----------------|--------------------------------|-----------------|
| Not affected  | 0-1.22    | 66373.65                       | 63              | 57945.25                       | 55              |
| Potential     | 1.23-1.30 | 15803.25                       | 15              | 8428.4                         | 8               |
| Fragile       | 1.31-1.41 | 20017.45                       | 19              | 15803.25                       | 15              |
| Critical      | 1.41-2    | 3160.65                        | 3               | 23178.1                        | 22              |



**Fig. 2: Sensitivity to desertification of western parts of Iraq in 2003 (A) and 2007 (B)**

Table 6 demonstrates the ESAs areas in 2003 and 2007. It is clear that most of the study area is not affected by desertification; these classes exhibit 63 and 55% of the total area in 2003 and 2007, respectively. Compared with 2003, potential, fragile and critical areas percentages have been increased in 2007 (Table 6).

On the other hand, Meteorological data of 2003 and 2007 comparison indicate that there were two and five records of pervasive dust storms in western parts of Iran that originated from Iraq for 2003 and 2007, respectively.

### DISCUSSION

Iraq is one of the main sources of western part of Iran's dust storm (Prospero *et al.*, 2002; Kutiel and Furman, 2003; Gerivani *et al.*, 2011; Karimi *et al.*, 2012). Desertification occurs mainly in arid and semi-arid regions [20] and caused dust storm emission (Wang *et al.*, 2006). Western parts of Iraq's all annual precipitation takes place during winter (Zakaria *et al.*, 2012).

Iraq's western parts geographical location in a dry area which is characterized by water scarcity and low annual rainfall (Al-Ansari and Knutsson, 2011) with uneven distribution (FAO, 1987) believed to be the major sources of dust storms in the area (Al-Jumaily and Ebrahim, 2013). These regions rainy seasons start in November and nearly end in May (Al-Khalidy, 2004). Summer was mentioned by (Kutiel and Furman, 2003) to be the time dust storms frequently occurred in Iran. The occurrence of dust storms over several Iranian western cities is higher during spring and summer which vegetation percentage value shows reductions in the source areas.

Potential, fragile and critical areas percentages have been increased in 2007 in comparison with 2003 (Table 6). Compared with in situ observations, there were two records of pervasive dust storms in western parts of Iran in

2003. In situ observations comparison indicate that there were five records of pervasive dust storms in western parts of Iran that originated from Iraq for 2007.

Desertification caused increased frequency and severity of dust storms (Wang *et al.*, 2006).

Iraq's 2003 precipitation was higher than the long term precipitation average (Darvishi *et al.*, 2012). The availability of water cause plants biological activity in arid and semi-arid areas (Lambers *et al.*, 1998). In the arid and semiarid regions, precipitation pulses are important triggers for biological activity (Huxman *et al.*, 2004). Precipitation caused plant species better establishment in Iraq. Plants grow rapidly following the onset of the wet season and remain as ground cover for several months (Herrmann *et al.*, 2005).

But Iraq's 2007 drought episode corresponds to the driest year case since 1940 (Trigo *et al.*, 2010). Drought led to the extensive destruction of vegetation cover and expansion of wind erosion (Zhibao *et al.*, 2000). Dust aerosols eroded from arid soils. During periods of drought, vegetation cover levels are reduced (McTainsh and Strong, 2007). So, drought conditions caused the source areas vegetation degradations increment and the occurrences of western Iran dust storms have become more frequent.

Drought caused wipe out the vegetation cover. Drought conditions in 2007 caused the source areas vegetation degradations and desertification. So, the occurrences of Western Iran dust storms have become more frequent. But, Desertification process has been shown to be exacerbated by some other anthropogenic activities. Farmlands abandonment (ICARDA, 2013), Overgrazing (Kaul and Thalen, 1971), construction dams (Al-Ansari and Knutsson, 2011; Zakaria *et al.*, 2012) and highest amount of water required for optimal crop production (Doell and Siebert, 2002) has been recorded in Iraq that caused desertification exacerbation.

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