Effect of Vegetation Change of Source Area on Dust Storms Occurrence in the West of Iran

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ABSTRACT There are many reports of serious problems of dust storm events in the western parts of Iran. Based on many researches, Iraq is one of the main sources of dust storms in western parts of Iran. The Radial Basis Function Network (RBFN) model has been used to assess wind erosion hazard in Iraq as a main source area of dust storms over several western cities of Iran. The percentage of vegetation is the only changeable factor of RBFN model. The wind erosion hazard map in two time periods (2003 and 2012) verified the vegetation changes over time. The results showed that the vegetation percentage index in all land use types of 2003 was higher than those of 2013. In addition to drought as a natural parameter, overgrazing, dam construction on Tigris and Euphrates Rivers (in Turkey) and high amount of water for crop production are human and policy factors causing loss of vegetation cover in source area and wind erosion exacerbation.

1 INTRODUCTION

Soil erosion by wind was recognized as an important mechanism for dust storm production (Gillette, 1978; Gillette *et al.,* 1980). Dust storms arise from the soil surface by surface wind (Loosmore and Hunt, 2000). Dust storms eroded from arid soils (Forster *et al.,* 2007).Wind erosion is mainly occurs in arid and semiarid areas where precipitation is rare, vegetation is sparse, wind is strong and frequent, and the loose ground surface material is susceptible to blowing away by wind (Hagen, 1991).

Conditions conducive to wind erosion exist when (1) the soil is loose, dry and finely granulated, (2) the soil surface is smooth and vegetative cover is sparse or absent and (3) the susceptible area is sufficiently large (Lyles, 1988). Wind erosion rates strongly affected by plant cover (Okin, 2008; Lyon and Smith, 2010) and anthropogenic activities (Gomes *et al.,* 2003). Low vegetation cover causes increasing the risk of wind erosion (Munson *et al.,* 2011; Parvari *et al.,* 2011; Yan *et al.,* 2011).

The Normalized Difference Vegetation Index (NDVI) has shown consistent correlation with vegetation biomass (Myneni *et al.,* 1995). The NDVI provides information about the spatial and temporal distribution of vegetation communities and vegetation biomass (Tucker *et al.,* 1991). A threshold of NDVI < 0.07 was

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chosen, which the ground cover by vegetation was assumed to be dense enough to inhibit dust deflation (Tucker *et al.,* 1991). Another index that has been developed MODIS (Moderate-resolution Imaging Spectroradiometer) is the Enhanced Vegetation Index (EVI) (Huete *et al.,* 2002). This index provides complementary information about the spatial and temporal variations of vegetation, as well as minimizes many of the contamination problems present in the NDVI, such as those associated with canopy background and residual aerosol influences. The EVI is more Near Infra-Red (NIR) sensitive and responsive to canopy structural variations, including LAI (Leaf Area Index), canopy type and architecture (Pettorelli *et al.,* 2005).

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 as rocks and vegetation (Marticorena and Bergametti, 1995). Dust storms emissions are caused by source area wind erosion (Gillette *et al.,* 1980).

Some of well-known wind erosion models are WEQ (Wind Erosion Equation), WEPS (Wind Erosion Prediction System), and RWEQ (Revised Wind Erosion Equation). Since these models have been developed on the basis of different environmental conditions and data availability, their application to other areas despite tedious work of calibration did not end necessarily into satisfactory results (Sadoddin *et al.,* 2011). Radial Basis Function Network (RBFN) is an artificial neural network that uses radial basis functions as activation functions. Therefore, the RBFN model that represents a simple method for quickly classifying wind erosion hazard by means of GIS (Huading *et al.,* 2007) has been used in this study. Based on literature review, wind erosion (Gillette *et al.*, 1980) and drought episode (Zhibao *et al.*, 2000) led to dust storm emission. So, wind erosion has significant

effects on dust storm emissions (Gillette *et al.,* 1980). However, the drought episode of 2007-2009 in Syria, Iraq and Iran corresponds to the driest two-year case since 1940 (Trigo *et al.,* 2010). But, precipitation caused better plant species establishment (Linderman *et al.,* 2005). Darvishi *et al.* (2012) reported that Iraq's 2003 average of precipitation was higher than its long term precipitation average.

Drought led to destruction of vegetation cover (Akhzari and Aghbash, 2013) and expansion of wind erosion (Zhibao *et al*., 2000) causing dust storm emission. RBFN is a wind erosion assessment model that has six main factors. Fine sand in soil, percentage of sandy land, average relief degree of land surface, the intensity of wind energy, vegetation percentage and the degree of soil dryness are the six indices of RBFN model (Huading *et al.*, 2007). The percentage of vegetation is the only changeable index of RBFN model. 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). These dust storms are created by Iraq's northwest wind that can move through the Tigris and Euphrates River valleys of central Iraq (Sissakian *et al*., 2013). Aeolian transport is an abiotic mechanism for movement of soil within and out of arid and semiarid lands (Larney *et al*., 1998). So, the present study was conducted to find out the effect of source area vegetation change on the number of pervasive dust storms emission (based on the reports of NASA earth observatory site) in western parts of Iran.

2 MATERIALS AND METHODS
2.1 Study area
Iraq as western neighbor of Iran is one of the main sources of dust storms which have been

occurred in western part of Iran (Prospero *et al*., 2002; Kutiel and Furman, 2003; Gerivani *et al*., 2011; Karimi *et al*., 2012). The wind erosion hazard map of Iraq reflexed the number of dust storm which occurs in the western parts of Iran. Wind erosion hazard map prepared by RBFN model in 2003 (as wet year) and 2013 (as drought year). The wind erosion hazard maps have been compared with the number of widespread dust storms was reported in the western cities of Iran. The widespread dust storms reports in the western cities in of Iran have been obtain from the NASA earth observatory site.

2.2 Methodology

Wind erosion hazard has been assessed by use of RBFN model. Standard values of RBFN model indices (fine sand in soil, percentage of sandy land, average relief degree of land surface, the intensity of wind energy, vegetation percentage and the degree of soil dryness) were extracted as RBFN model inputs (Huading *et al., 2007*).

Fine sand in soil and percentage of sandy land as two RBFN model indices were calculated in the following method: The particle size distribution for individual soils is described by four populations: clay, silt, medium or fine sand, and coarse sand (Blott and Pye, 2001). We derived global estimates from the soil texture class data from Food and Agriculture Organization/United Nations Educational, Scientific, and Cultural Organization soil map of the World (Zobler, 1986). The texture categories are fine, medium, coarse, or mixtures of these. In terms of the standard soil textural triangle (Fitzpatrick, 1980) based on Tegen *et al.* (2002) research we assume that the coarse texture category includes sands, loamy sands, and sandy loams; the medium texture category includes sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams,

and clay loams with <35% clay; and the fine texture category includes clays, silty clays, sandy clays, clay loams, and silty clay loams with >35% clay. The percentage of sand, silt, and clay particles in each texture category is estimated from the centroids of the appropriate texture classes in the textural triangle.

Average relief degree of land surface and the degree of soil dryness have been extracted from geographical map and ratio of regional yearly rainfall and heat precipitation of Iraq. The intensity of wind energy has been obtained for each pixel (SWERA, 2005).

The Enhanced Vegetation Index (EVI) (which appeared with MODIS) has been used to express the vegetation percentage index. Iraq as a main source area of western parts of Iran's dust storms has been divided in 1 square kilometer pixels. The mean values of EVI for each pixel were calculated using the red and NIR reflectance, using Equation 1 (Huete *et al., 2002*):

$$EVI = G \frac{(NIR - RED)}{(NIR + C1 \times RED + C2 \times BLUE + L)} \quad (1)$$

Where, C1 and C2 are coefficients designed to correct for dust storm scattering and absorption, which use the blue band to correct for dust storm 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*).

Based on Tables 1 and 2 data, the wind erosion hazard map in Iraq as a main source area of western parts of Iran's dust storms has been prepared for 2003 and 2013 (Figures 1 and 2).

3 RESULTS

The input indices of the RBFN model were estimated and summed up to prepare the wind erosion severity of land use types across Iraq as

a main source area of western parts of Iran's dust storms and their respective wind erosion hazard maps were then synthesized for 2003 and 2013. The GIS software used in this paper is ArcGIS 9.3; RBFN model was run by Matlab R 2013a.

Tables 1 and 2 show the standard values of RBFN model indices of wind erosion hazard classes of Iraq as a main source area of western parts of Iran's dust storms for 2013 and 2003, respectively.

Table 1 Standard values of RBFN model indices (2003) in Iraq

Land use types	RBFN Indices						Hazard class
	1	2	3	4	5	6	
Flat to undulating plains	0.08	0.92	0.83	0.09	0.16	0.05	Slight
Flat to undulating plains, poor traction in wet soils	0.76	0.13	0.18	0.83	0.09	0.11	Moderate
Near lakes and in depressions	0.82	0.11	0.23	0.38	0.07	0.44	Severe
Flat to gently rolling plains, hills and mountains	0.65	0.43	0.43	0.15	0.12	0.07	Slight
Severely dissected plains	0.87	0.15	0.16	0.82	0.05	0.93	Severe
Flat to undulating plains with numerous irrigation channels, high water table and row crop	0.06	0.82	0.85	0.18	0.15	0.06	Slight
Mountains	0.09	0.87	0.67	0.11	0.16	0.04	Slight

Values are all standardized and indexed from 1 to 6, respectively, represent the contents of fine sand in soil, percentage of sandy land, average relief degree of land surface, the intensity of wind energy, average EVI, the degree of soil dryness

Table 2 Standard values of RBFN model indices (2013) in Iraq

| Land use types	RBFN Indices						Hazard class
	1	2	3	4	5	6	
Flat to undulating plains	0.08	0.92	0.83	0.09	0.13	0.05	Slight
Flat to undulating plains, poor traction in wet soils	0.76	0.13	0.18	0.83	0.07	0.11	Severe
Near lakes and in depressions	0.82	0.11	0.23	0.38	0.01	0.44	Very Severe
Flat to gently rolling plains, hills and mountains	0.65	0.43	0.43	0.15	0.08	0.07	Moderate
Severely dissected plains	0.87	0.15	0.16	0.82	0	0.93	Very Severe
Flat to undulating plains with numerous irrigation channels, high water table and row crop	0.06	0.82	0.85	0.18	0.12	0.06	Slight
Mountains	0.09	0.87	0.67	0.11	0.11	0.04	Slight

Values are all standardized and indexed from 1 to 6, respectively, represent the contents of fine sand in soil, percentage of sandy land, Average relief degree of land surface, the intensity of wind energy, average EVI, the degree of soil dryness

The standard values of RBFN model indices reflect the wind erosion hazard classes in each study year. Some of these indexes have been changed across 2003 to 2013. The wind erosion hazard classes were not changed in flat to undulating plains, flat to undulating plains with numerous irrigation channels, high water table and row crop and mountains because the study indexes were not changed (Tables 1 and 2). The wind erosion hazard classes of other land uses have been changed across the studied years.

Based on standard values of RBFN model indices for 2003 and 2013, wind erosion hazard map prepared and shown in Figures 1 and 2. The wind erosion hazard maps in study years have been prepared based on RBFN indexes. Generally, the intensity classes of wind erosion hazard have been increased in flat to undulating plains, poor traction in wet soils, near lakes and in depressions, flat to gently rolling plains, hills and mountains and severely dissected plains.
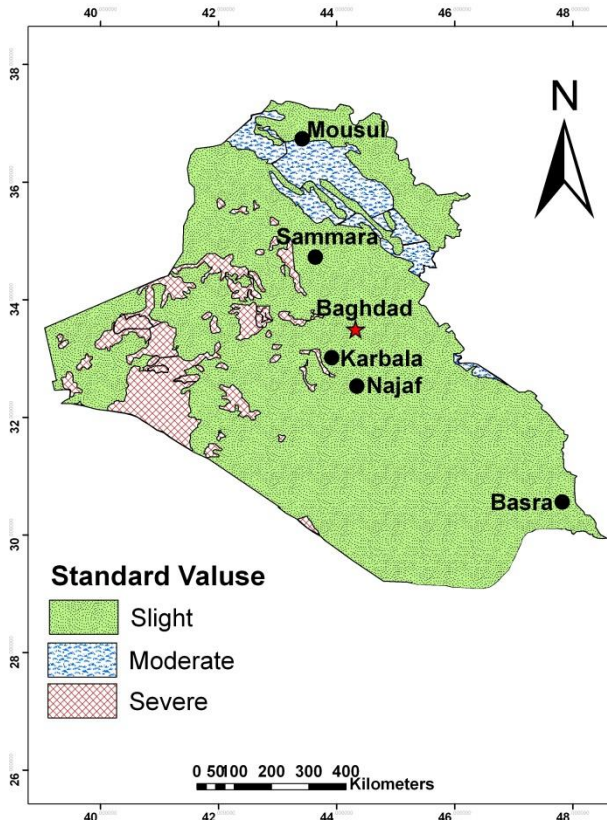
Figure 1 Wind erosion hazard map based on RBFN model indices in Iraq for 2003
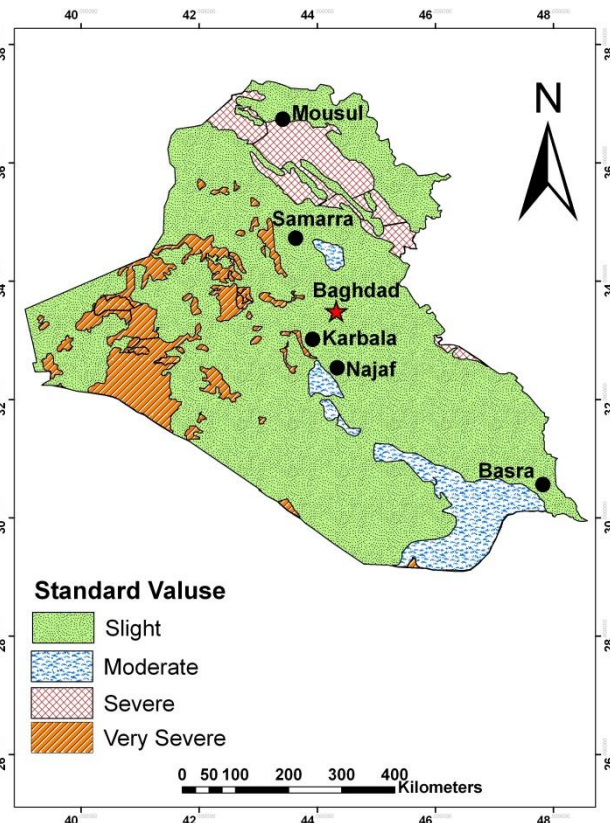
Figure 2 Wind erosion hazard map based on RBFN model indices in Iraq for 2013

4 DISCUSSION

Average annual precipitation of Syria and Iraq is 252 and 161 mm, respectively (Bou-Zeid and El-Fadel, 2002; AL-Timimi and AL-Jiboori, 2013) which reflect the characteristic of arid and semi-arid regions (Zhu-Guo *et al.,* 2005). Almost all annual precipitation of West and Central parts of Iraq takes place during winter, where the agricultural activities in summer suffer from water shortages (Zakaria *et al.,* 2012). In 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, north-east of Iraq, Syria, Persian Gulf, South Arabia, Yemen, and Oman.

West and Central parts of Iraq located 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 Ibrahim, 2013).

The occurrence of dust storms over several western cities is of Iran higher during spring and summer which vegetation percentage value shows reductions in the source areas. So, drought conditions of recent years caused the source areas vegetation degradations and the occurrences of dust storms in the western parts of Iran have become more frequent.

Compared to 2003, only the vegetation percentage index has been changed in 2013 (Tables 1 and 2). So according to the RBFN model results, the observed differences in the wind erosion hazard maps (Figures 1 and 2) of the 2003 and 2013 were due to the changes in vegetation percentage index. Vegetation coverage is one of the key factors influencing

wind erosion (Munson *et al.,* 2011; Parvari *et al.,* 2011; Yan *et al.,* 2011).

The maximum and minimum values of EVI of land use types were varied from 0.16 to 0.05 in 2003 and from 0.13 to 0 in 2013 (Tables 1 and 2). Generally, the EVI in all land use types of 2003 was higher than those of 2013 (Tables 1 and 2).

Iraq's 2003 precipitation was higher than its long term precipitation average (Darvishi *et al.,* 2012). In the arid and semiarid regions, precipitations were considered as important triggers for biological activities (Huxman *et al.,* 2004). Precipitation caused better establishment of plant species in Iraq. Plants grow rapidly following the onset of the wet season and remain as ground cover for several months until drying, grazing and trampling by livestock, and fires have removed their effectiveness in sheltering and protecting the soil surface (Linderman *et al.,* 2005).

Vegetation reduces wind speed at the soil surface and prevents much of the wind force from contacting soil particles and cause wind erosion reduction (Lyon and Smith, 2010). So wind erosion of Iraq has declined in 2003. Years of 2003 and 2013 wind erosion hazard maps comparison also reflects this fact (Figures 1 and 2). There wasn't any record of widespread dust storm in western parts of Iran in 2003 (NASA Earth Observatory, 2008). Wind erosion intensity in the source area is an important factor of dust storm production (Gillette *et al.,* 1980). Wind erosion is the primary process and the main driving force for dust storms in Middle East.

On the other hand, there was more than 10 storms were recorded in 2013 in the western part of Iran, because wind erosion severity was enough to develop dust storm events. In 2013, Iraq and other Middle East countries have been

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in drought condition. Drought led to the extensive destruction of vegetation cover and expansion of wind erosion (Zhibao *et al.,* 2000). So, drought conditions of 2013 caused the source areas vegetation degradations increment and the occurrences of western Iran's dust storms have become more frequent.

Wind erosion of soil is a natural process that has been shown to be exacerbated by anthropogenic activities (Gomes *et al.,* 2003). Many factors such animal feeding operations may also contribute to dust emissions due to wind erosion (Gillies *et al.,* 2005). Overgrazing in Iraq's rangelands has reached the stage of causing soil erosion and has severely reduced the carrying capacity of the rangelands (Abahussain *et al.,* 2002). During periods of drought, vegetation cover levels were reduced (either naturally or at an accelerated rate by over-grazing) leading to: increased wind erosion rates, decline in soil fertility and in soil moisture storage capacity (McTainsh and Strong, 2007). So, overgrazing in Iraq's rangelands caused to vegetation drastically destruction in drought conditions (Abahussain *et al.,* 2002). This factor cause to wind erosion exacerbates and dust storm occurrences in the west of Iran (McTainsh and Strong, 2007).

Production of soil dust storms depends on surface wind speed and soil surface properties (Lyles, 1988). On the other hand, Iraq is meeting water shortages and the problem is becoming more serious with the progress of time. The main water resources of Iraq (Tigris and Euphrates Rivers) suffer from severe reduction in their discharges due to construction dams on both banks of the rivers inside Turkey and Syria (Al-Ansari and Knutsson, 2011; Zakaria *et al.,* 2012). Dams cause major water balance changes and wetlands drying in the south-east parts of Iraq. Dried wetlands are suitable dust storm sources.

Nevertheless, the highest amount of water required for optimal crop production has been recorded in Iraq and some other countries, reflecting the ineffective use of irrigation in these countries (Doell and Siebert, 2002). High amount of water required for crop production causing loss of vegetation cover and wind erosion exacerbation.

5   CONCLUSION

The main dust storms of western parts of Iranian originated from Iraq. Vegetation reduction accelerated the wind erosion. Overgrazing, dam construction on Tigris and Euphrates Rivers (in Turkey) and high amount of water for crop production were human policy dimensions causing destruction of vegetation and wind erosion exacerbation. These human policy dimensions occurred at the same time with the extreme drought episode in Middle East. Based on the results of the present study, compared with 2003, the velocity of wind erosion has been increased in 2013. Grazing management and overgrazing prevention, stop construction of dams on Tigris and Euphrates Rivers (in Turkey) and the use of plant species with low water requirements may are the best management practices for vegetation improvement in the east and central parts of Iraq (as one of the main sources of dust storms which have been occurred in western parts of Iran).

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اثر تغییرات پوشش گیاهی در منطقه منشاء بر وقوع طوفان‌های گرد و غبار در غرب ایران

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چکیده گزارش‌های فراوانی در خصوص اثرات مخرب طوفان‌های گرد و غبار در غرب ایران وجـود دارد. تحقیقـات نشـان داده است که کشور عراق مهم‌ترین منشاء وقوع طوفان‌های گرد و غبار در غرب ایران اسـت. در ایـن تحقیـق، بـه‌منظـور تعیین خطر فرسایش بادی در عراق به‌عنوان اصلی‌ترین منشاء وقوع طوفان‌های گرد و غبـار در شـهرهای غربـی ایـران از مدل RBFN استفاده شده است. تنها فاکتور متغیر در مدل RBFN درصد پوشش گیاهی اسـت. نقشـه خطـر فرسـایش بادی در سال‌های ۲۰۰۳ و ۲۰۱۳ نشان‌دهنده تغییرات پوشش گیاهی در این بازه زمانی است. نتایج نشان داد کـه مقـدار عددی درصد پوشش گیاهی در همه کاربری‌ها در سال ۲۰۰۳ بالاتر از ۲۰۱۳ بوده است. علاوه بر خشکسالی به‌عنوان یک عامل طبیعی، عوامل دیگری مثل چرای بی‌رویه، سدسازی روی دجله و فـرات (در ترکیـه) و نیـاز آبـی بـالا بـرای تولیـد محصولات کشاورزی از جمله عوامل انسانی تخریب پوشش گیاهی و تشدید فرسایش بادی هستند.

کلمات کلیدی: MODIS، خشکسالی، شاخص پوشش گیاهی ارتقاء یافته، فرسایش بادی