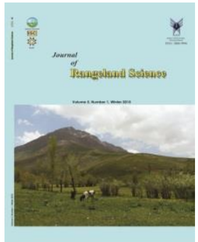
Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Effects of Wind Erosion and Soil Salinization on Dust Storm Emission in Western Iran

Davoud Akhzari[A], Behnoush Farokhzadeh[B], Iman Saeedi[C], Mohsen Goodarzi[D]

[A]Department of Range and Watershed Management, Malayer University, Malayer, Iran (Corresponding Author), Email: akhzari@malayeru.ac.ir
[B]Department of Range and Watershed Management, Malayer University, Malayer, Iran
[C,D]Landscape Engineering Department, Faculty of Agriculture, Malayer University, Malayer, Iran

Received on: 01/09/2014
Accepted on: 06/12/2014

Abstract. Dust storms are known as hazardous problems in western part of Iran. Iraq is one of the main sources for dust storm arriving to the western part of Iran. The Radial Basis Function Network model (RBFN) has been used to assess wind erosion hazards in the source area of dust storms over several western Iranian cities. Normalized Difference Salinity Index (NDSI) was used to determine the changes in the source area salinity over the studied years. The RBFN model has been used to assess the wind erosion severity of all land uses in the source area. Generally, NDSI values of all land uses in 2003 were higher than those in 2013. The maximum and minimum mean NDSI values were seen in severely dissected plains and mountainous lands, respectively. The observed differences in the wind erosion hazard maps of 2003, 2005, 2007, 2009, 2011 and 2013 were due to the changes in vegetation percent. Soil salinization caused the source area vegetation degradation and wind erosion exacerbation. So, the occurrences of dust storms in Western parts of Iran have become more frequent. The *in situ* observations showed that there were two, five, five, twelve and nine records of pervasive dust storms in western parts of Iran in 2003, 2005, 2007, 2009 and 2011, respectively.

Key words: Dust storm, Soil salinization, Wind erosion

Introduction

Soil erosion by the wind is recognized as an important mechanism for dust storm creation (Gillette *et al*., 1972; Gillette, 1974; Gillette and Goodwin, 1974; Gillette and Walker, 1977; Gillette, 1978; Gillette *et al*., 1980). Dust storms arise from the soil surface by surface wind (Kind, 1992; Loosmore and Hunt, 2000). Dust aerosols were eroded from the arid soils (Tegen and Lacis, 1996; Liao and Seinfeld, 1998; Seinfeld and Pandis, 1998; Forster *et al*., 2007). Wind erosion is mainly occurred in the 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 be blown away by wind (Skidmore, 1986; Hagen, 1991).

Iraq is one of the main sources dust storm in western part of Iran (Prospero *et al*., 2002; Kutiel and Furman, 2003; Gerivani *et al*., 2011; Karimi *et al*., 2012). Effects of dust storm depend on soil surface wind speed and properties (Marticorena and Bergametti, 1995). Dust storms spread abroad by the source area wind erosion (Gillette, 1974; Gillette and Goodwin, 1974; Gillette and Walker, 1977; Gillette, 1978; Gillette *et al*., 1980). Wind erosion rates were strongly affected by plant cover (Li *et al*., 2007; Okin, 2008).

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 applications to the other areas despite tedious work of calibration do not end necessarily into satisfactory results. The RBFN (Radial Basis Function Network) model represents a simple method for quickly classifying wind erosion hazards by the means of GIS (Huading *et al*., 2007). So, the RBFN model has been used in this study to classify wind erosion hazards.

RBFN is a wind erosion assessment model that has six main factors. Fine sand in soil, sandy land percent, mean relief degree of land surface, the intensity of wind energy, vegetation percent and the degree of soil dryness are the six indices of RBFN model (Huading *et al*., 2007). Salinity has considerable adverse impacts on plant (Lauchli and Epstein, 1990). It adversely affects the plant growth and development. An excess of soluble salts in the soil leads to osmotic stress, specific ion toxicity and ionic imbalances (Munns, 2003) and the consequences of them can be the plant death (Rout and Shaw, 2001). Ashraf *et al*. (2004) found that increasing salt concentrations caused a significant reduction in vegetation cover. Salinization transforms fertile and productive land to the barren one (Ghassemi *et al*., 1995). Dust storms and wind erosion are increased with the spread of soil salinity (Kokelj *et al*., 2012). So, increasing soil salinity caused widespread vegetation death and low vegetation cover causes the increased risk of wind erosion (Munson *et al*., 2011).

NDSI can be used for predicting salinity and sodicity (Aldakheel *et al*., 2005; Odeh and Onus, 2008). Khan *et al*. (2001) concluded that NDSI could be used to identify different salt classes based on the dry surface crust. NDSI gives good results in detecting salt-affected lands (Tripathi *et al*., 1997; Odeh and Onus, 2008). Setia (2011) has expressed that the vegetated areas should have a lower NDSI than non-vegetated ones.

The present study was aimed to study the effects of wind erosion and soil salinization on dust storm emission in Western Iran.

Materials and Methods

The RBFN model has been applied to assess the wind erosion severity of the source area. Wind erosion hazards had been assessed by the use of RBFN model. Standard values of RBFN model indices (fine sand in soil, sandy land percent, mean relief degree of land surface, the intensity of wind energy, vegetation percent and the degree of soil dryness) were extracted by the use of RS and GIS software (Huading *et al*., 2007). Among all RBFN model indices, only the vegetation percent index (EVI) has been changed in the studied years (Table 1).

Fine sand in soil and sandy land percent as two RBFN model indices were calculated by the following method:

The particle size distribution for the 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 given in the Food and Agriculture Organization (FAO)/ United Nations Educational, Scientific and Cultural Organization soil map of the World (Zobler, 1986). The texture categories are fine, medium, coarse or mixtures of them. In terms of standard soil textural triangle (Fitzpatrick, 1980) based on the studies of Tegen *et al*. (2002), 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, silt-clay loams and clay loams with <35% clay. The fine texture category includes clays, silt-clays, sandy clays, clay loams and silt-clay loams with>35% clay.

The sand, silt and clay particles percent in each texture category is estimated from the centroids of the appropriate texture classes in the textural triangle. Mean relief degree of land surface and the degree of soil dryness have been extracted from a geographical map and ratio of regional rainfall and heat precipitation in Iraq. The intensity of wind energy has been obtained for each pixel (Swera, 2005). EVI (Enhanced Vegetation Index) has been used to express the vegetation percent index. The source area has been divided in 1 km^2 pixels. The mean values of EVI for each pixel were calculated using the red and NIR reflectance (Equation 1) (Huete *et al*., 2002):

EVI= G (NIR- RED)/ (NIR+ C1× RED+ C2× BLUE+ L) (Equation 1)

Where

EVI= Enhanced Vegetation Index

C1 and C2 are the coefficients designed to correct the dust aerosol scattering and absorption which use the blue band to correct the dust aerosol influences in the red band (C1=6, C2=7.5).

G= a gain factor (set at 2.5)

L = a canopy background adjustment (set at 1.0) (Nagler *et al*., 2005)

Based on Tables 1 and 2, the wind erosion hazards map in the source area of western part of Iran's dust storms has been prepared for 2003, 2005, 2007, 2009, 2011 and 2013 (Fig. 1).

To determine the changes in the source area salinity over time, Landsat images were acquired during summer months (in 2003, 2005, 2007, 2009, 2011 and 2013) when agricultural land use would be near its lowest value and the evaporation near its highest one (Gibson, 2012). After the images were processed, they were converted to the NDSI (Equation 2). This index was derived by dividing the differences of red and NIR to their sum.

NDSI= [(Band 3 - Band 4) / (Band 3 + Band 4)] (Equation 2)

The GIS software used in this paper is ArcGIS 9.3; RBFN model was run by MATLAB software.

Results

The input indices of the RBFN model for 2003, 2005, 2007, 2009, 2011 and 2013 were estimated and illustrated in Table 1. The mean EVI values are the only modifiable indices of RBFN model which have been changed across various study years (Table 1). The maximum and minimum values for EVI were 0.16 and 0 for flat to undulating plains of 2003 and severely dissected plains of 2009, respectively (Table 1). Values were standardized and indices 1–6 respectively represent the contents of fine sand in soil, sandy land percent, mean relief degree of land surface the intensity of wind energy, mean EVI and the degree of soil dryness. The indices of the RBFN model for 2003, 2005, 2007, 2009, 2011 and 2013 across the source area were summed up to prepare the wind erosion hazard classes of land uses (Table 2). The most severe wind erosion rates in all land uses were found in 2009 and the lowest rates of wind erosion were seen in 2003 (Table 2). Wind erosion hazard maps for 2003, 2005, 2007, 2009, 2011 and 2013 were shown in Fig. 1. The maximum extent of area with severe and very severe wind erosion hazard classes was found in 2009 and 2003, respectively (Fig. 1).

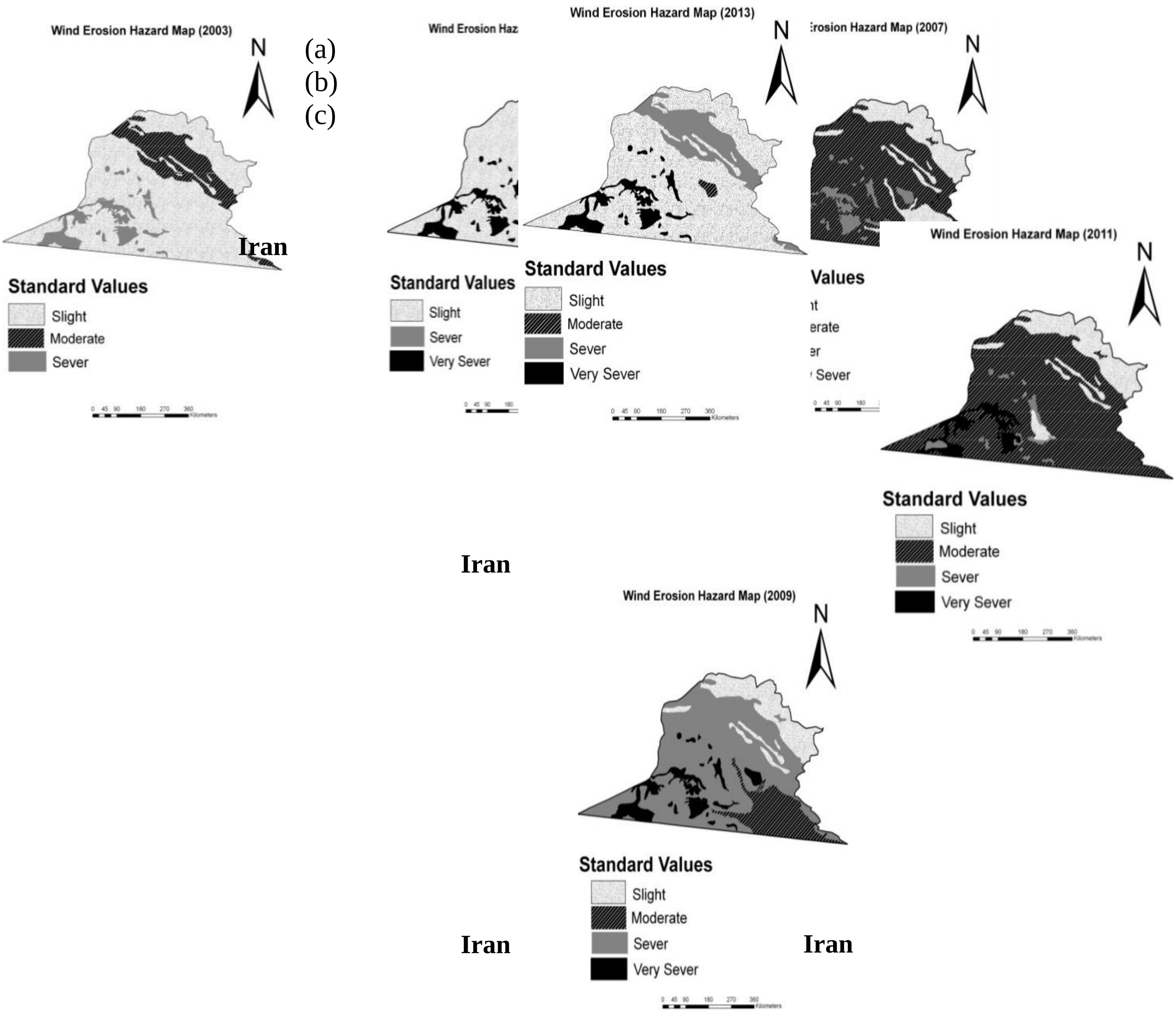
Table 1. Standard values of RBFN model indices for 2003, 2005, 2007, 2009, 2011 and 2013

Land Use Types	Index 1	Index 2	Index 3	Index 4	Index 5 Average EVI						Index 6
					2003	2005	2007	2009	2011	2013	
Flat to undulating plains	0.08	0.92	0.83	0.09	0.16	0.13	0.07	0.06	0.10	0.13	0.05
Flat to undulating plains, poor traction in wet soils	0.76	0.13	0.18	0.83	0.09	0.07	0.01	0	0.06	0.07	0.11
Near lakes and in depressions	0.82	0.11	0.23	0.38	0.07	0.06	0.02	0	0.04	0.01	0.44
Flat to gently rolling plains, hills and mountains	0.65	0.43	0.43	0.15	0.12	0.11	0.08	0.08	0.1	0.08	0.07
Severely dissected plains	0.87	0.15	0.16	0.82	0.05	0.04	0	0	0.03	0	0.93
Flat to undulating plains with numerous irrigation channels, high water table and row crop	0.06	0.82	0.85	0.18	0.15	0.12	0.06	0.04	0.09	0.12	0.06
Mountains	0.09	0.87	0.67	0.11	0.16	0.15	0.09	0.06	0.13	0.11	0.04

Index 1= contents of fine sand in soil; Index 2= percentage of sandy land; Index 3= average relief degree of land surface; Index 4= the intensity of wind energy; Index 5= average of EVI; Index 6= fine sand in soil

Table 2. Wind erosion hazard classes of the source area for 2003, 2005, 2007, 2009, 2011 and 2013

Land Use Types	Wind Erosion Hazard Class					
	2003	2005	2007	2009	2011	2013
Flat to undulating plains	Slight	Slight	Moderate	Severe	Slight	Slight
Flat to undulating plains, poor traction in wet soils	Moderate	Severe	Severe	Very Severe	Moderate	Severe
Near lakes and in depressions	Severe	Very Severe	Severe	Very Severe	Severe	Very Severe
Flat to gently rolling plains, hills and mountains	Slight	Slight	Moderate	Severe	Moderate	Moderate
Severely dissected plains	Severe	Very Severe	Severe	Very Severe	Very Severe	Very Severe
Flat to undulating plains with numerous irrigation channels, high water table and row crop	Slight	Slight	Slight	Moderate	Moderate	Slight
Mountains	Slight	Slight	Slight	Slight	Slight	Slight



(d) (e) (f)

Fig. 1. Wind erosion hazard map of the source area for 2003(a), 2005 (b), 2007 (c), 2009 (d), 2011 (e) and 2013 (f)

maximum and minimum mean NDSI values were seen in severely dissected plains and mountainous lands, respectively (Fig. 2). Generally, NDSI values of all land uses of 2003 were higher than those of 2013 (Fig. 2).

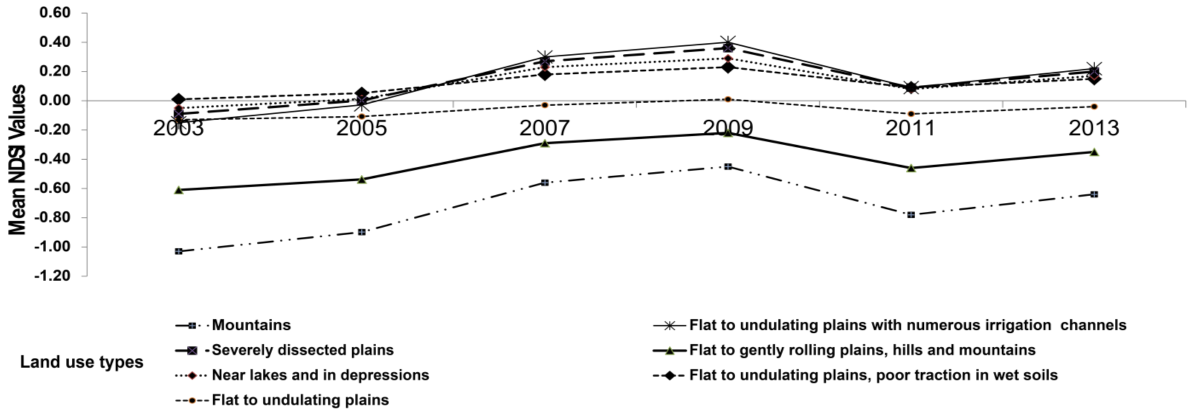


Fig. 2. Mean NDSI values for all pixels of each land use types

Discussion

Mean annual precipitation of Iraq is 161 mm (Bou-Zeid and El-Fadel, 2002; AL-Timimi and AL-Jiboori, 2013) which reflects the characteristics of arid and semi-arid regions (Zhu-Guo *et al*., 2005).

Dust storm emissions in the western part of Iran have been intensified by several involved factors in Iraq. These factors are aridity, inappropriate distribution of rainfall, drought episodes, farmlands abandon, over grazing, construction dams and highest amount of water required for optimal crop production. The effects of these factors on the occurrence of dust storms in the Western parts of Iran are discussed below.

Western and central parts of Iraq’s annual precipitation takes place during winter where summer agricultural activities suffer from water shortages (Zakaria, 2012). These regions' rainy seasons start in November and late May (Al-Khalidy, 2004). Summer was mentioned by Kutiel and Furman (2003) to be the time of dust storms' frequent occurrence in Iran, North-Eastern Iraq, Syria, Persian Gulf, South Arabia, Yemen and Oman.

Western and Central parts of Iraq's 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) is 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 Iranian cities is higher during spring and summer when vegetation percent shows the reductions in the source areas. So, recent years' drought conditions caused the source areas' vegetation degradations and the occurrences of Western Iranian dust storms have become more frequent.

During the studied years, RBFN model indices comparisons indicate that among all RBFN model indices, only the vegetation percent index has been changed (Table 1). Other RBFN model indices are pedological or topographic parameters which could not be altered by the amount of precipitation. So, according to the RBFN model, the observed differences in the wind erosion hazard maps (Fig. 1) of 2003, 2005, 2007, 2009, 2011 and 2013 are due to the changes in vegetation percent index. Vegetation coverage is one of the key factors influencing wind erosion (Yan *et al*., 2011).

The maximum and minimum values of vegetation percent index (EVI) of land uses were ranged from 0.16 to 0 (Table 1). The highest and lowest values of vegetation percent (EVI) were found in 2003 and 2009, respectively (Table 1).

Generally, the vegetation percent index (EVI) in all land uses of 2003 was higher than that of 2013 (Tables 1 and 2).

Iraq's precipitation was above the mean annual precipitation for the years 2000–2006 (Becker, 2014). By 2005, after 5 consecutive wet years, perennial plants were growing in the previously bare spaces. Consecutive wet years increased the power of perennial plant species establishment (Peters *et al*., 2012; USDA, 2012). But vegetation index (EVI) percent of 2003 was higher than that of 2005 (Table 1).

There is an explanation in this regard after several consecutive wet years; nutrient depletion is known to happen in the arid ecosystems (Ettershank *et al*., 1978; James and Jurinak, 1978; Fisher *et al*., 1988). This phenomenon could lead to decrease the plant growth in source area of western Iran's dust storms. Nutrient depletion may cause a decrease in vegetation cover in 2005; despite the mean rainfall in 2005, it is almost same as that of 2003 (Becker, 2014). On one hand, competition for space and light could limit the growth. Competitive interactions were probably minimal after a drought but they could be suddenly intensified after a consecutive year of high precipitation and high growth (Hessing *et al*., 1996).

The highest and lowest values of NDSI were found in 2003 and 2009, respectively (Fig. 2). Visual comparisons of mean NDSI values in all land uses during the studied years (2003, 2005, 2007, 2009, 2011 and 2013) indicate that the highest and lowest values of NDSI were found in 2003 and 2009, respectively (Fig. 2). So, soil salinization and soil wind erosion had an almost consistent trend.

The results of present study found NDSI as a reciprocal of vegetation percent index (EVI) which gives lower values for the vegetation cover. These results are in agreement with the results reported by Chandana *et al*. (2004) and Setia (2011) researche. Soil salinity was found as a severe environmental hazard that affected the plant establishment ability. Soil salinization reduces plant growth and may even cause the plant death.

As compared with *in situ* observations, there were two and five records of pervasive dust storms in western parts of Iran in 2003 and 2005. In 2013, Iraq and other Middle East countries have been in drought conditions. There were more than 10 observed dust storms in 2013 in the western part of Iran.

In general, the mean vegetation percent index (EVI) in all land uses of 2009 was less than that of all the other studied years (Table 1). Iraq's 2007-2009 drought episodes correspond to a two-year driest case since 1940 (Trigo *et al*., 2010). This adverse environmental consequence continued until 2010 (Gibson, 2012) although its intensity was reduced.

In situ observations comparison indicated that there were five records of pervasive dust storms in western Iran in 2007. The number of pervasive dust storms in western Iran in 2009 and 2011 was twelve and nine, respectively. Iraq's annual precipitation of 2011 was lower than 15 mean years (Becker, 2014).

The availability of water causes the plant biological activity in the 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 better establishment of plant species in Iraq. Plants grow rapidly following the onset of wet season and remain as ground cover for several months until being dried, grazed and trampled by livestock and fires have removed their effectiveness in sheltering and protecting the soil surface (Ehrlich *et al*., 1997; Herrmann *et al*., 2005; Linderman *et al*., 2005). Drought led to the extensive destruction of vegetation cover and expansion of wind erosion (Zhibao *et al*., 2000). So, drought conditions caused the source areas' vegetation degradations' increment and the occurrences of western Iran dust storms have become more frequent.

Wind erosion (Gomes *et al*., 2003) and soil salinization (Zhang, 2011) are known as natural processes that had been shown to be exacerbated by anthropogenic activities.

Agricultural lands have been reduced drastically due to water scarcity. There are lots of abandoned farmlands in Iraq. Thousands of hectares of farmlands are abandoned every year (ICARDA, 2013). Several years' cultivation and soil salinization process have caused that this area became a dust storm source area.

Vegetation reduces wind speed at the soil surface, prevents much of the wind force from contacting soil particles and causes the wind erosion reduction (Lyon and Smith, 2010).

Many factors such as 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 (Kaul and 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 caused loss of vegetation cover and wind erosion exacerbation.

Conclusion

Among all RBFN model indices, only the vegetation percent index has been changed across the study years. The highest and lowest values of NDSI were found in 2003 and 2009, respectively. The highest and lowest values of vegetation percent were seen in 2003 and 2009, respectively. Source area soil salinization caused vegetation destruction. Iraq's vegetation reduction has reached the stage of causing wind erosion. It is well known that wind erosion was known as a main mechanism for dust storm creation. *In situ* observations comparisons indicate that there were two, five, five, twelve and nine records of pervasive dust storms in

Thalen, 1971). During drought periods, vegetation cover levels are reduced (either naturally or at an accelerated rate by over-grazing) leading to the increased wind erosion rates, decline in soil fertility and in soil moisture storage capacity (McTainsh and Strong, 2007). So, overgrazing in Iraq's rangelands causes the vegetation destruction in drought conditions. This factor exacerbates the wind erosion and dust storm occurrences in the west of Iran.

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 reductions in their discharges due to the construction of dams on both banks of the rivers inside Turkey and Syria (Al-Ansari and Knutsson, 2011; Zakaria, 2012). Dams cause major water balance changes and wetland drying in South-eastern Iraq. Dried wetlands are suitable dust aerosol sources.

Nevertheless, the highest amount of water required for optimal crop
western Iran for 2003, 2005, 2007, 2009 and 2011, respectively.

Literature Cited

Al-Ansari, N. A., Knutsson, S., 2011. Toward prudent management of water resources in Iraq. *Jour. Advanced Science and Engineering Research*, 1: 53-67.

Aldakheel, Y., Elprince, A. M. and Al-Hussaini, A. I., 2005. Mapping of salt-affected soils of irrigated lands in arid regions using remote sensing and GIS, Proceedings of the 2nd International Conference on Recent Advantages in Space Technologies, 9–11 June 2005, Istanbul, Turkey, 467–472.

Al-Jumaily, K. J., Ibrahim, M. K., 2013. Analysis of synoptic situation for dust storms in Iraq. *International Jour. Energy and Environmental*, 4(5): 851-858.

Al-Khalidy, K. A., 2004. Preparation of geographical information system for the South Jazira irrigation project with the aid of remote sensing data, M.Sc. thesis, Mosul University.

AL-Timimi, Y. K., AL-Jiboori M. H., 2013. Assessment of spatial and temporal drought in

Iraq during the period 1980-2010. *International Jour. Energy and Environment*, 4(2): 291-302.

Ashraf, M., Mukhtar, N., Rehman, S. and Rha, E. S., 2004. Salt-induced changes in photosynthetic activity and growth in a potential plant Bishop's weed (*Ammolei majus* L.). *Photosynthetica*, 42: 543–50.

Becker, R. H., 2014. The stalled recovery of the Iraqi marshes. *Remote Sens*., 6: 1260-1274.

Blott, S. J. and Pye, K., 2001. GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surf. Process. Landf*., 26: 1237-1248.

Bou-Zeid, E., El-Fadel, M., 2002. Climate change and water resources in Lebanon and the Middle East. *Jour. Water Res Pl-Asce*., 128(5): 343-355.

Chandana, P. G., Weerasinghe, K. D. N., Subasinghe, S., Pathirana, S., 2004. Remote sensing approach to identify salt-affected soils in Hambantota District. Proceedings of the Second Academic Sessions, 128-133.

Doell, P., Siebert, S., 2002. Global modeling of irrigation water requirements. In: *Water Resour. Res*., 38: 1010-38.

Ehrlich, D., Lambin, E. F., Malingreau, J. P., 1997. Biomass burning and broad-scale land-cover changes in western Africa. *Remote Sens. Environ.,* 61: 201-209.

Ettershank, G., Ettershank, J., Bryant, M., Whitford, W. G., 1978. Effects of Nitrogen Fertilization on Primary Productivity in a Chihuahuan Desert Ecosystem. *Jour. Arid Environ.,* 1: 135-139.

FAO, 1987. Improving Productivity of Dry land Areas. Committee on Agriculture (Ninth session). FAO, Rome. http://www.fao.org/docrep/meeting/011/ag415e/ag415e04.htm#4.1

Fisher, F. M., Zak, J. C., Cunningham, G. L., Whitford, W. G., 1988. Water and nitrogen effects on growth and allocation patterns of creosote bush in the Northern Chihuahuan Desert. *Jour. Range Manage.,* 41: 387 -391.

Fitzpatrick, E. A., 1980. Soils, Addison-Wesley-Longman, Reading, Mass.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D. W., Haywood, J., Lean, J., Lowe, D. C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M., Van Dorland, R., 2007. Changes in atmospheric constituents and in radioactive forcing. Climate Change 2007: The Physical Science Basis, eds Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Gerivani, H., Lashkaripur, G. H., Ghafoori, M. and Jalili, N., 2011. The source of dust storm in Iran: a case study based on geological information and rainfall data. *Carpath. Jour. Earth Env.,* 6(1): 297-308.

Ghassemi, F., Jakeman, A. J. and Nix, H. A., 1995. Stalinization of land and water resources. CAB International, Wallingford, England.

Gibson, G. R., 2012. War and agriculture: Three Decades of Agricultural Land Use and Land Cover Change in Iraq. Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Geospatial and Environmental Analysis. p: 145.

Gillette, D. A., 1978. A wind tunnel simulation of the erosion of soil: effect of soil texture, sandblasting, wind speed and soil condition on dust production. *Atmos. Environ.,* 12: 1735-1743.

Gillette, D. A., Adams, J., Endo, C., Smith, D., 1980. Threshold velocities for input of soil particles into the air by desert soils. *Jour. Geohys. Res.,* 85: 5621-5630.

Gillette, D. A., Blifford, I. H. J., Fenster, C. R., 1972. Measurements of aerosol size distributions and vertical fluxes of aerosols on land subject to wind erosion. *Jour. Appl. Meteorol. Clim.,* 11: 977–987.

Gillette, D. A., Goodwin, P. A., 1974. Microscale transport of sand-sized soil aggregates eroded by wind. *Jour. Geohys. Res.,* 79; 4080-4089.

Gillette, D. A., Walker, T. R., 1977. Characteristics of airborne particles produced by wind erosion of sandy soil, high plains of West Texas. *Soil Sci.,* 123: 97-110.

Gillette, D. A., 1974. On the production of soil wind erosion aerosols having the potential for long-range transport. *Jour. Rech. Atmos.,* 8: 735-744.

Gillies, D. A., Etyemezian, V., Kuhns, H., Nikolic, D., Gillette, D. A., 2005. Effect of vehicle characteristics on unpaved road dust emissions. *Atmos. Environ.,* 39(13): 2341–2347.

Gomes, L., Arrúe, J. L., López, M. V., Sterk, G., Richard, D., Gracia, R., Sabre, M., Gaudichet, A., Frangi, J. P., 2003. Soil aerosol production in a semi-arid agricultural area of Spain: the WELSONS project. *Catena*, 52 (3-4): 235-256.

Hagen, L. J., 1991. A wind erosion prediction system to meet the users' need. *Jour. Soil and Water Conserv.,* 46(2): 106-111.

Herrmann, S. M., Anyamba, A., Tucker, C. J., 2005. Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environ. Change*., 15: 394-404.

Hessing, M. B., Lyon, G. E., Sharp, G. A., Ostler, K. O., 1996. The vegetation of Yucca Mountain, Nevada: Effects of site characterization on vegetation. Las Vegas, Nevada: Office of Civilian Radioactive Waste Management System Management.

Huading, S., Jiyuan, L., Dafang, Z., Yunfeng, H., 2007. Using the RBFN model and GIS technique to assess wind erosion hazard of Inner Mongolia, China. *Land Degrad. Dev.*, 18: 413–422.

Huete, A., Didana, K., Miura, T., Rodriguez, E. P., Gao, X. and Ferreira, L. G., 2002. Overview of radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sens. Environ.,* 83: 195–213.

Huxman, T. E., Snyder, K. A., Tissue, D., Leffler, A. J., Ogle, K., Pockman, W. T., Sandquist, D. R., Potts, D. L., Schwinning, S., 2004. Precipitation pulses and carbon fluxes in semiarid and arid ecosystems. *Oecologia*, 141: 254–268.
Remote Sensing, 5–9 November 2001, Singapore, unpaginated.

Kind, R. J., 1992. Concentration and mass flux of particles in eolian suspension near tailings disposal sites or similar sources. *Jour. Wind Eng. Indus. Aerodyn.*, 41(44): 217-225.

Kokelj, S. V., Lantz, T. C., Solomon, S., Pisaric, M. F. J., Keith, D., Morse, P., Thienpont, J, R., Smol, J. P., Esagok, D., 2012. Using multiple sources of knowledge to investigate northern environmental change: regional ecological impacts of a storm surge in the outer Mackenzie delta, N.W.T. Arctic, 65(3): 257 – 272.

Kutiel, H. and Furman, H., 2003. Dust storms in the Middle East: sources of origin and their temporal characteristics. *Indoor Built Environ*., 12: 419–426.

Lambers, H., Chapin, F. S., Pons, T. L., 1998. Plant physiological ecology. Springer, Berlin Heidelberg New York, p 540.

Lauchli, A. and Epstein, E., 1990. Plant responses to saline and sodic conditions and agricultural salinity assessment and management, pp: 113–37. ASCE, New York.

Li, J. and Okin, G. S., Alvarez, L., Epstein, H., 2007. Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA. Biogeochemistry, 85: 317–332

ICARDA, 2013. Iraq salinity assessment. http://www.icarda.org/iraq-salinity-project/assessment IR imagery of Meteosat: 1. Infrared difference dust index, *Jour. Geohys. Res.*, 106 (D16).

James, D. W. and Jurinak, J. J., 1978. Nitrogen fertilization of dominant plants in the Northeastern Great Basin Desert. In West, N.E. Skujins, J. (Eds.), Nitrogen in Desert Ecosystems. Stroudsburg, Pennsylvania: Dowden, Hutchinson, and Ross.

Karimi, N., Moridnejad, A., Golian, S., Samani, J. M. V., Karimi, D. and Javadi, S., 2012. Comparison of dust source identification techniques over land in the Middle East region using MODIS data. Canadian *Jour. Remote Sens.*, 38 (5): 586-599.

Kaul, R. N. and Thalen, D. C. P., 1971. Range ecology at the institute of applied researches in natural resources, Iraq. *Nat. Resour.*, 7: 2-15.

Khan, N. M., Rastoskuev, V. V., Shalina, E. V. and Sato, Y., 2001. Mapping salt-affected soils using remote sensing indicators: A simple approach with the use of GIS IDRISI, Proceedings of the 22nd Asian Conference on

Liao, H., Seinfeld, J. H., 1998. Radiative forcing by mineral dust aerosols: Sensitivity to key variables. *Jour. Geohys. Res.*, 103: 31637–31645.

Linderman, M., Rowhani, P., Benz, D., Serneels, S., Lambin, E. F., 2005. Land-cover change and vegetation dynamics across Africa. *Jour. Geohys. Res.*, 4: 110-121.

Loosmore, G. A., Hunt, J. R., 2000. Dust resuspension without salutation. *Jour. Geohys. Res.*, 105(20): 663-672.

Lyon, D. J., Smith, J. A., 2010. Wind erosion and its control. Institute of agriculture and natural resources at the university of Nebraska–Lincoln cooperating with the counties and the United States Department of Agriculture.http://www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=130

Marticorena, B., Bergametti, G., 1995. Modeling the atmospheric dust cycle: 1. Design of a soil-derived dust emission scheme. *Jour. Geohys. Res.*, D8 (100), 16: 415-430.

McTainsh, G., Strong, C., 2007. The role of Aeolian dust in ecosystems. *Geomorphology*, 89: 39–54.

Munns, R., 2003. Comparative physiology of salt and water stress. *Plant Cell Environ*., 25: 239–50.

Munson, S. M., Belnap, J. and Okin, S. G., 2011. Responses of wind erosion to climate-induced vegetation changes on the Colorado Plateau. Proceedings of the National Academy of Sciences of the United States of America, 108(10): 3854–3859.

Nagler, P. L., Cleverly, J., Glenna, E., Lampkin, D., Hu, P., 2005. Predicting riparian evapotranspiration from MODIS vegetation indices and meteorological data. *Remote Sens. Environ.*, 94: 17–30.

Odeh, I. O. A. and Onus, A., 2008. Spatial analysis of soil salinity and soil structural stability in a semiarid region of New South Wales, Australia. *Jour. Environ. Manage.*, 42(2): 265- 278.

Okin, G. S., 2008. A new model of wind erosion in the presence of vegetation, *Jour. Geophys. Res.*, 113: F02S10,

Peters, D. P. C., Yao, J., Sala, O. E., Anderson, J., 2012. Directional climate change and potential reversal of desertification in arid and semiarid ecosystems. *Glob Chang Biol.*, 18: 151-163.

Prospero, J., Ginoux, M., Torres, P., Nicholson, S. E. and Gill, T. E., 2002. Environmental characterization of global sources of atmospheric soil dust identified with the NIMBUS 7 total ozone mapping spectrometer (TOMS) absorbing aerosol product. *Rev. Geophys.*, 40: 2-31.

Rout, N. P. and Shaw, B. P., 2001. Salt tolerance in aquatic macrophytes: Ionic relation and interaction. *Biology of Plant*, 55: 91–5.

Seinfeld, J. H., Pandis, S. N., 1998. Atmospheric chemistry and physics: from air pollution to climate change (Wiley, New York).

Setia, R., 2011. Severity of salinity accurately detected and classified on a paddock scale with high resolution multi-spectral satellite imagery. *Land Degrad. Dev.*, doi:10.1002/ldr.1134.

Skidmore, E. L., 1986. Soil erosion by wind. In: El-Baz, F., Hassan, M.H.A., (eds). Physics of desertification. Dordrecht: Martinus Nijhoff Publishers.

Solar and Wind Energy Resource Assessment (SWERA), 2005. Wind energy map of East Asia.http://maps.nrel.gov/swera?visible=swera_wind_nasa_lo_resandopacity=50andextent=38.79,29.06,48.56,37.38

Tegen, I. and Lacis, A. A., 1996. Modeling of particle size distribution and its influence on the radiative properties of mineral dust aerosol. *Jour. Geohys. Res.*, 101:19237-19244.

Tegen, I., Harrison, S. P., Kohfeld, K., Prentice, I. C., Coe, M. T., Heimann, M., 2002. Impact of vegetation and preferential source areas on global dust aerosol: Results from a model study. *Jour. Geophysical Research*, 107 (D21), AAC 14-1-AAC14-27, 4576.

Trigo, R. M., Gouveia, C. M., Barriopedro, D., 2010. The intense 2007–2009 drought in the Fertile Crescent: Impacts and associated atmospheric circulation. *Agricultural and Forest Meteorology*, 150, 1245–1257.

Tripathi, N. K., Rai, B. K. and Dwivedi, P., 1997. Spatial Modeling of Soil Alkalinity in GIS Environment Using IRS data. 18th Asian conference on remote sensing, Kualalampur, 81-86.

USDA, 2012. Climate change may help restore arid grasslands. file:///D:/NDSI/USDA.htm.

Yan, Y., Xu, X., Xin, X., Yang, G., Wang, X., Yan, R., Chen, B., 2011. Effect of vegetation coverage on aeolian dust accumulation in a semiarid steppe of northern China. *Catena*, 87: 351–356.

Zakaria, S., 2012. Rain water harvesting at Eastern Sinjar Mountain, Iraq. *Jour. Geohys. Res.*, 3(2): 100-108. (In Persian).

Zhang, T. T., 2011. Assessing impact of land uses on land salinization in the Yellow River Delta, China using an integrated and spatial statistical model. *Land Use Pol.*, 28: 857-866.

Zhibao, D., Xunming, W., Lianyou, L., 2000. Soil and water conservation society. All rights reserved. *Jour. Soil Water Conserv.*, 55(4): 439-444.

Zhu-Guo, M., Cong-Bin, F., Dan, L., 2005. Decadal variations of arid and semi-arid boundary in China. *Chinese Jour. Geophy.*, 48(4): 574-581.

Zobler, L., 1986. A world soil file for global climate modeling, Tech. Rep. NASA TM– 87802, 32 pp., NASA, Washington, D. C.

اثر فرسایش بادی و شوری خاک بر وقوع طوفان‌های خاک در غرب ایران

داود اخضری[الف]، بهنوش فرخزاده[ب]، ایمان سعیدی و محسن گودرزی[ج]

[الف] گروه مرتع و آبخیزداری، دانشگاه ملایر، ملایر، ایران (نگارنده مسئول)، پست الکترونیک: akhzari@malayeru.ac.ir

[ب] گروه مرتع و آبخیزداری، دانشگاه ملایر، ملایر، ایران

[ج] گروه مهندسی لنداسکیپ، دانشکده کشاورزی، دانشگاه ملایر، ملایر، ایران

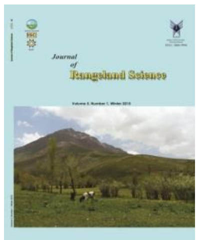
چکیده. در غرب ایران، طوفان‌های خاک به عنوان یک مساله زیان‌آور شناخته می‌شوند. کشور عراق به عنوان یکی از منابع اصلی تامین بار برای وقوع طوفان‌های خاک غرب ایران شناخته می‌شود. در این تحقیق از مدل RBFN برای بررسی شدت فرسایش بادی در منطقه منشأ طوفان‌های خاک غرب ایران استفاده گردید. به منظور بررسی تغییرات شوری خاک در سال‌های مورد بررسی پارامتر NDSI بکار گرفته شد. نتایج نشان داد که تغییرات نقشه خطر فرسایش بادی در منطقه منشأ در سال‌های ۲۰۰۳، ۲۰۰۵، ۲۰۰۷، ۲۰۰۹ و ۲۰۱۱ در اثر تغییر درصد پوشش گیاهی رخ داده است. مدل RBFN برای بررسی شدت فرسایش بادی در منطقه منشأ ریزگردها و در همه کاربری‌ها مورد استفاده قرار گرفت. نتایج نشان داد که مقدار عددی شاخص شوری (NDSI) در سال ۲۰۰۳ و در همه کاربری‌ها از سال ۲۰۱۳ زیادتر است. به طورکلی، بیشترین و

کمترین مقدار کمی شاخص NDSI به ترتیب در دشت‌های به شدت شور و قلیایی و اراضی کوهستانی دیده شده است. شوری خاک باعث تخریب پوشش گیاهی گردیده و خطر وقوع فرسایش بادی را شدت داده است. تعداد دفعات وقوع طوفان خاک در غرب ایران زیادتر شده است. مشاهدات میدانی نشان داد، وقوع طوفان‌های خاک فراگیر در غرب ایران در سال های ۲۰۰۳، ۲۰۰۵، ۲۰۰۷، ۲۰۰۹ و ۲۰۱۱ به ترتیب ۲، ۵، ۵، ۱۲ و ۹ بار گزارش گردیده است.

کلمات کلیدی: طوفان خاک، شور شدن خاک، فرسایش بادی

Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Variations of Water Soluble Carbohydrate in Plant Organs of *Bromus tomentellus* and *Festuca ovina* in Three Phenological Stages

Hoseyn Arzani[A], Mehdi Zohdi[B], Ghavam Aldin Zahedi[C], Raziyeh Shahbandari[D], Roja Safaian[E]

[A]Prof., College of Natural Resources, University of Tehran, Iran (Corresponding Author), Email: harzani@ut.ac.ir
[B]Ph.D. Student, Science and Research Branch of Islamic Azad University of Tehran, Tehran, Iran
[C]Prof., College of Natural Resources, University of Tehran, Tehran, Iran
[D]M.Sc. in Desert Region Management, University of Tehran, Tehran, Iran
[E]Assistant Professor, College of Agriculture, University of Shiraz, Shiraz, Iran