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Determination of dust emissions concentration in desert wetlands (Case study: Meighan wetland, Iran)

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Abstract

The hunting prohibited area in Arak's Meighan wetland is located in the central part of Iran country and in an arid and semi-arid region. In the warm season, the region with its particular desert condition is considered as one of 187 important cores of desertification and dust emissions in the center of the country and in the vicinity of Arak metropolis. The study was using Maxent method with eight variables i.e. soil moisture, wind erosion, temperature, land use, ndvi, wind speed, rainfall, and soil type, and 200 focal points of dust emission. The emission rate was calculated using EPA formulation. The modeling of dust emissions concentration was undertaken employing SCREEN3 for Windows software. The results indicate that an area of 11123.48ha, equivalent to 46.30 %, in the hunting prohibited area of Meighan wetland is the focal point of dust emission. The model validity is 0.844 revealing the excellent performance of Maxent method. Wind speed, soil type, wind erosion, soil moisture and land use are respectively known as the variables with the greatest impact on dust emissions. The rate of dust emission from Meighan wetland is 1067.71 tons/year. Dust emissions concentration in summer and under optimum atmospheric condition with the increase of dust, F and D class, within 10 km of dust emission focal point is 214.97 µg/m³. Comparison of the modeled data and real data confirms the acceptable accuracy of the modeled data. Appropriate solutions are wind erosion control using desertification procedures, protection of water demand in Meighan wetland, and prevention measures against land use changes.

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Introduction

Dust aerosol in the atmosphere has a significantly direct and indirect effect on climate on various spatial scales, from local and regional to global (Huang *et al.,* 2006). It has been recognized that most (perhaps 80% or more) of the matter suspended in the atmosphere is emitted from natural surfaces (Chow *et al.,*1994). In arid and semiarid areas, dust storms occur frequently. Sand and dust storms (SDS) have caused devastating damages to properties and human health in the southwest of Asia. When surface winds are strong, large amounts of sand and dust can be lifted from bare, dry soils into the atmosphere and transported downwind affecting regions hundreds to thousands of kilometers away.(Jaffe *et al.,*2003). have shown that extreme episodes of dust transport can adversely impact air quality in regions far from the original emission source. (Zoljoodi *et al.,* 2013). have developed a research on dust events in western Iran and drought expansion over the Middle East, through this investigation they have detected firstly the dust source areas over Iraq and Syria, then it is found that the recent droughts in the external dust source areas (over Iraq and Syria) had the remarkable potential to increase the dust events in the west of Iran. Dust storms and the emissions of fine particulate matter (PM10), airborne particles with aerodynamic diameters less than 10.0 µm, have been studied across many of Earth's endorheic basins and dry plains. Most of the studies oriented towards the sources of PM10 have typically focused on geomorphological settings, soil types, anthropogenic factors, land cover, climatic and meteorological drivers of atmospheric dust loading or, in some cases, the discernment of dust plumes in satellite imagery. In addition, some recent studies have turned to the sub-basin scale and even include attempts at locating individual dust sources in MODIS imagery (Lee *et al.,*2009;Baddock *et al.,*2009). Wind directions were derived in 2014 using dust plume image objects segmented from the MODIS thermal band translations of three dust storms (Charles *et al.,* 2015).

Dust emission rates need to be predicted more reasonably in order to understand the pollution level of the gravel sites. However, it is difficult to precisely predict since few data exist about the relationship between influential parameters and emission rates. Influential parameters include weather condition, silt content, moisture content of gravel and sand, and types of emission sources (Clausnitzer, 1996; Kulshrestha, 1996; Liu, 2002; Veranth *et al.*, 2003).The development of an object-oriented maximum entropy approach for modeling dust source suitability distributions began in 2013 as an attempt to utilize what was previously done by (Lee *et al.,* 2009)and (Rivera Rivera *et al.,* 2010). Developed a method for locating dust sources in NOAA GOES and POES satellite imagery that translated five synoptically forced dust storms in the border region during 2002 and 2003. Of the five dust storms in (Rivera Rivera *et al.*,2010), only three have samples with at least 15 presences located in the higher spatial resolution NOAA POES AVHRR imagery to take advantage of the 'hinge features' in the presence-only maximum entropy modeling software known as Maxent (Phillips *et al.,*2008). According to Gillette (1979), the main factors of significance are the aerodynamic forces and the forces holding the particles in the soil. Those are wind speed, soil erodibility and its silt content, surface moisture, and some other factors concerning terrain and plant (snow) covers. Some of the semi-empirical formulae have been recommended by US EPA for calculating the dust emission factor from open surfaces, e.g. OAPQS of US EPA (1977). The SCREEN3 model was developed to provide an easy-to-use method of obtaining pollutant concentration estimates. These estimates are based on the document "Screening Procedures for Estimating The Air Quality Impact of Stationary Sources" (EPA, 1995). The main objective of this study is determination Factors affecting the Foci of dust emissions and Modeling concentrations of dust in Desert Wetlands (Case study: Meighan Wetland, Iran).

Materials and methods

Study area

Due to its location in the country center and in the incidence angle of Alborz and Zagros mountain ranges in an arid and semi-arid region, the hunting prohibited area in Arak's Meighan wetland has a very significant biodiversity such that during the summer and winter seasons it hosts a large number of migratory birds especially common crane because of its favorable conditions as a habitat and its position among 24 international wetlands and 105 important bird habitats in the country. The region with its unique desert condition in the summer season is among 187 most important hubs of desertification and dust emissions in the center of the country. The wetland is located within 10 kilometers from the northeast of Arak metropolis in the vicinity of Davood Abad city (Fig.1). In 2008, the Meighan wetland region with an area of about 24025 ha was stablished as one of the hunting prohibited areas by Environment Protection Agency for five years. However, the hunting prohibition in this area is still persisted. The basin of Meighan wetland is devoid of any vegetation due to flooding but in the margin of the desert wetland there are some vegetation including *Juncus sp Alearopus litralis Nitraria schoberi, Cyperus eremicus* and *Atriplex hymenelytra* (Ansari, 2016).

Maxent method

At first, the study region was modeled in the form of a raster map with *n* equal-sized cells. Then, the dependent variable data i.e. the studied dust emissions presence/non-presence was collected. In order to develop the dust emissions presence map, the field operation and observation of the dust emissions using the GPS device resulted in the detection of the dust status, and other information related to the dust observation location was recorded in the field visit form by 200 focal points of dust emission.

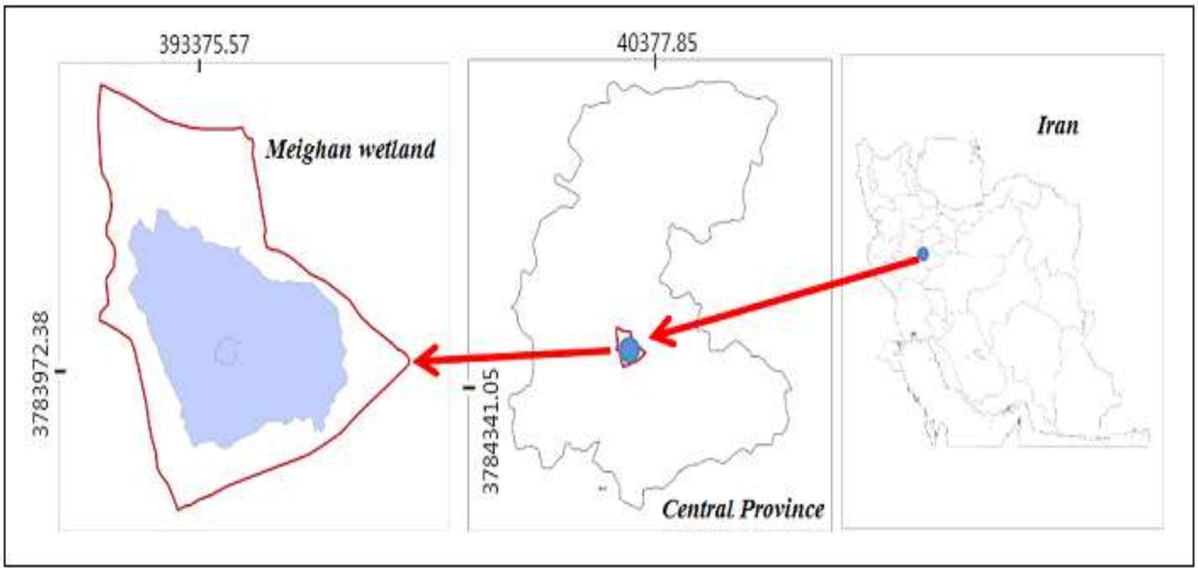

Fig. 1. Geographical location Meighan wetland in Iran.

Afterward, the independent ecological variables were identified including Soil moisture, wind erosion, temperature, land use, soil type, Normalized Difference Vegetation Index (ndvi), Rainfall and wind speed and in during August 2015. The MAXENT method is based on the comparison of the ecological features of the dust emissions presence points with the ecological features of the region as a whole.

Data analysis was under taken using ERDAS IMAGINE 2014,ArcGis and MAXENT; data preparation, data verification, data correlation, dust emissions suitability mapping, models validation, and dust emissions suitability map classification were also carried out.

Emission rates of dust

US EPA formula and determining factors The following equation is of those recommended by US EPA (1977):$Q=ceKCLVA$(1), where Q denotes the annual emission quantity, t yr^{-1}, from the surface of A hectares; c the TSP content, i.e. the weight ratio of the suspended particles (diameter less than 0.05 mm) over the total erodible soil particles; e the erodibility index of the soil type (t ha^{-1} yr) (Jutze *et al.*, 1976); K the surface roughness factor, 1 or 0.5 for smooth or rough surfaces, respectively; C the climatic factor, $C=0.504\ u^3\ /PE^2$ (2); here u is the annual mean wind speed (m/s) and PE the Thornthwaites precipitation-evaporation index (PE=100(P/E*)(3), (Thornthwaite, 1948); the unsheltered field width factor, 0.7 or 1.0 for fields of width 300 m (or less) or 600 m (or more), respectively; and » denotes the vegetation cover factor, 1.0 if no vegetation.

Modeling concentrations of dust

The data needed for modeling of dust concentration in different intervals using SCREEN3 for Windows software was prepared and applied as the software input. Given the atmosphere-related data especially Arak's annual wind rose data, it was revealed that in summer time, the prevailing wind direction was from east to west i.e. from the wetland toward Arak which gave it a higher importance. Thus, dust emission concentration was modeled under the prevailing atmospheric condition in the summer season. A combination of wind speed and stability class in the Screen Model of the software was employed (Turner, 1964). Then, the obtained concentration values were compared with the information from Air Quality Monitoring Station in Arak's Environment Monitoring Center, Arak's Weather Station, and an accredited environment laboratory.

Source Type = Area
Emission Rate = ?g/s
Release Height = 0
Longer Side Lenght = 20000 m
Shorter Side Lenght = 5500 m
Wind Directions = 90° and All Directions
Source Position = Rural

Results

The results indicate that among the considered variables, the highest importance and contribution is attached to the wind speed and then to soil type and land use, and also the lowest rank is devoted to soil moisture and vegetation index (Table 1).

Table 1. Percent contribution and Permutation importance of variables on development of dust emissions centers in Arak's Meighan wetland

Variable	Percent contribution	Permutation importance
wind speed	52	47.6
Rainfall	6.8	7.5
ndvi	0.2	2.6
soil type	18.8	16.7
land use	16.8	9.4
temperature	2.8	5.1
wind erosion	1.8	7.5
Soil moisture	1	3.6

The study of variables reveals that severe wind erosion class is the most appropriate class for the creation of dust in Meighan wetland. Salt marsh lands, lands without any vegetation, grasslands, and deserts are the most convenient places for dust emission in the region. With the increase of vegetation index (ndvi), dust emission is reduced in the region.

Table 2. development of dust emissions centers with the method of MAXENT in Arak's Meighan wetland.

Class name	MAXENT	
	Area(ha)	Percent
Sutiable	11123.148	46.30
Un sutiable	12902.238	53.70
Total	24025.386	100

The increase of average annual precipitation is associated with lower dust emissions. Semi-deep clay loam soil is the most appropriate soil class for dust emissions in the region. In addition, the increase of temperature is desirable for dust emission. Some locations which are free of moisture increase the probability of dust emissions; the increase of soil moisture decreases the mentioned probability.

The increase of wind speed is associated with higher rate of dust emission. Based on the results of Jackknife test, it is observed that the most important variable in the expansion of dust emission centers are wind speed, Land use, wind erosion, and soil moisture on the spread of dust emission centers in Meighan wetland (Fig. 2).

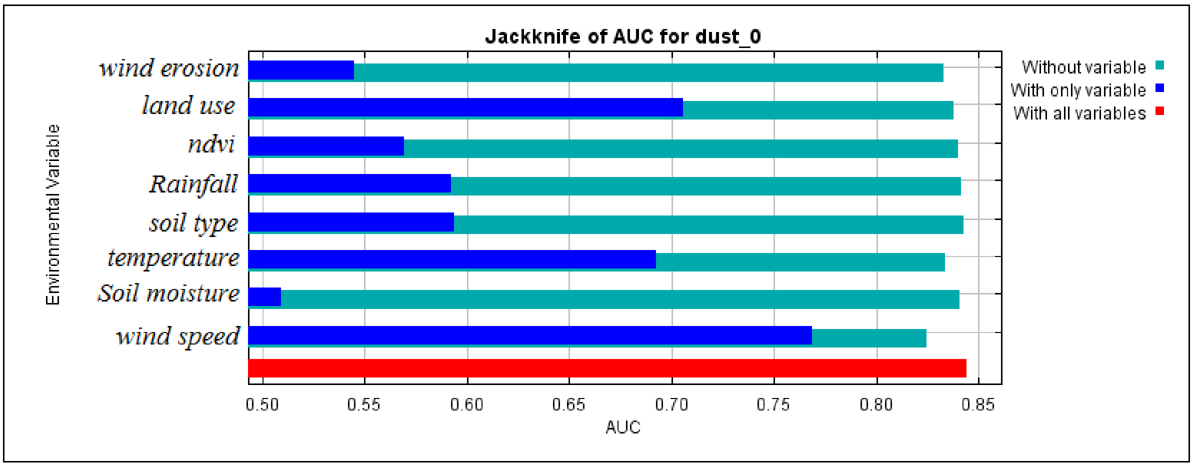

Fig. 2. Chart Jackknife, related variables on development of dust emissions centers in Arak's Meighan wetland.

The validation results of MAXENT show that the area under the ROC curve is equal to 0.844 with Standard Deviation (SD ±0.08). Figure 3 shows the dust emissions centers in Arak's Meighan wetland (Fig. 3). Eventually, from the all of hunting prohibited area of Meighan wetland, an 11123.48 ha area equivalent to 46.30 %, is determined as the center of dust emission. (Table 2)

In order to determine the emission rate, firstly the total suspended particles rate and erodibility i.e. e and c factors in equation (1) are calculated. Given that the soil type in the region of Meighan wetland is a sandy loam, thus e=331 and c=0.010. The K factor is 1 given the flatness on the region.

The weather factor is determined using equation (2) and according to the annual wind speed in meters per second (U), and PE is obtained through equation (3) with 34° northward latitude of Arak's Meighan wetland. The potential evapotranspiration is calculated applying Thornthwaite software (E*=805.1). The average annual precipitation is P=328.7. Thus, the weather factor is C=0.029. Given that there are more than 600 meters of land without any shelter in the region, so L factor is considered as 1, and due to the lack of vegetation in such an area, V factor for vegetation is also equal to 1. An area of 11123.48 ha is considered as the center of dust emission. Based on the obtained information and calculations using EPA equation, the rate of emission in the wetland is 1067.71 tons/year. In order to model the dust concentration in different intervals, the emission rate is based on g/s (Q=33.85 g/s). Then the other parameters are entered into SCREEN3 for Windows software.

Figure 4 shows that in the summer season and under optimal atmospheric conditions, dust increase, Class F, and wind speed of 1 meter/second at a distance of 10 kilometers from the center of dust emissions, dust concentration is equal to 214.97 µg/m³.

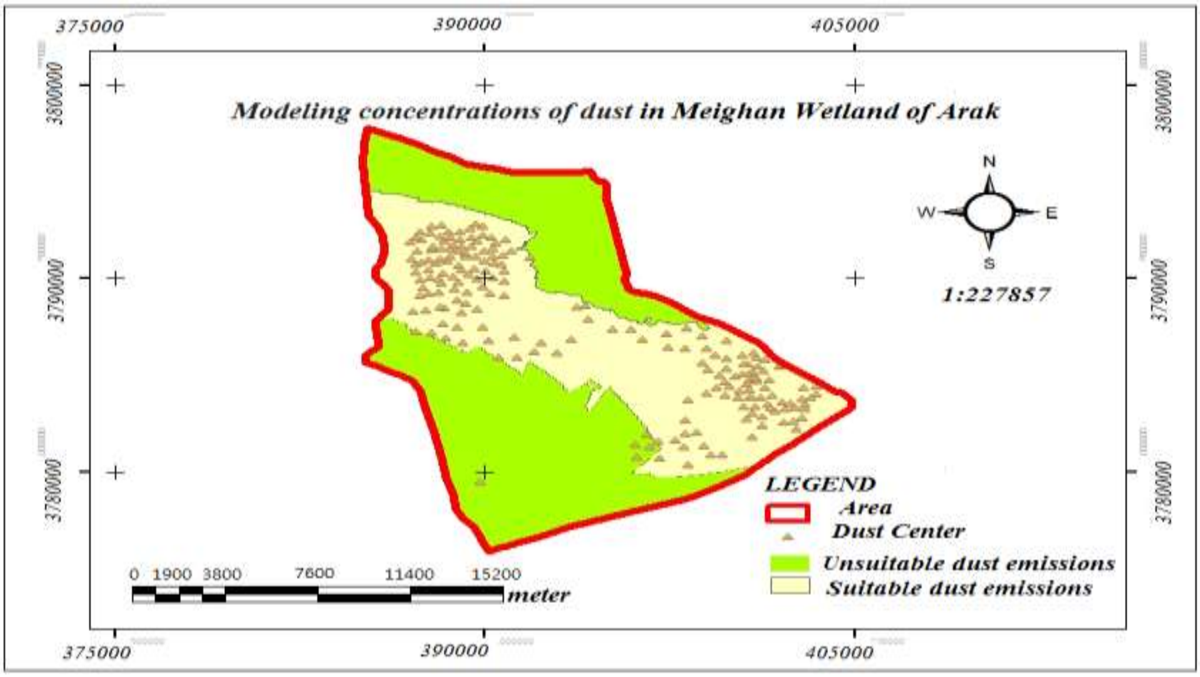

Fig. 3. The dust emissions centers in Arak's Meighan wetland.

Discussion

The study results show that the validation results of MAXENT model indicate that the area under the ROC curve is equal to 0.844 confirming the excellent performance of the MAXENT model (Giovanelli *et al.*, 2010). The proposed model for the spread of dust emission centers shows a positive relationship with wind speed and land use, and a negative relationship with soil moisture and vegetation cover percent. It means that the increase of wind speed and air temperature and also the decrease of land use and soil moisture will increase the spread of dust emission centers. For the wind speed factor, it should be mentioned that the studied region is a desert wetland and variations of wind speed will cause some changes in dust emissions such that the increase of wind speed is associated with the increase of dust emission. However, the results of MAXENT model and distribution of dust emission centers reveal that the variable has a unique effect.

The study on Chihuahuan desert as one of the dust particles sources in northern part of the USA during 2001 to 2005 showed that the factors resulting in the dust phenomenon were wind speed higher than 10 m/s, land with low level of vegetation, wind erosion, and availability of surface soft particles (Gillette *et al.*, 2006). Other studies indicate that the dust storms are meteorological phenomena usually happening in the arid and semi-arid regions with annual rainfall less than 200 to 250 mm and harsh winds with speeds higher than a specified threshold. The occurrence of the phenomenon is under the influence of both atmosphere and earth systems such that its main causes are high wind speed, shortage of moisture, and lands without any vegetation (Di, 2008; Mattsson, 1996). The study on the relationship between the distribution of dust storms and NDVI in northwest China indicate that the storms repeatedly occur in areas with low vegetation cover (Zheng *et al.*, 1998).

The study on the source of wind deposits in wells in Zabul demonstrate that drought and reduction of vegetation pave the way for wind erosion and dust storms, and its most important expressions are extraordinary harvests, abandoned lands, sandy territories and salty and puffy fields in the bed of Hamoon lake and Northern plains in Afghanistan (Jadidaleslam, 2011). Further investigations reveal that the warmest months of the year coincide with the maximum number of dusty days and the coldest months concur with the minimum number of dusty days (Helali, 2013).

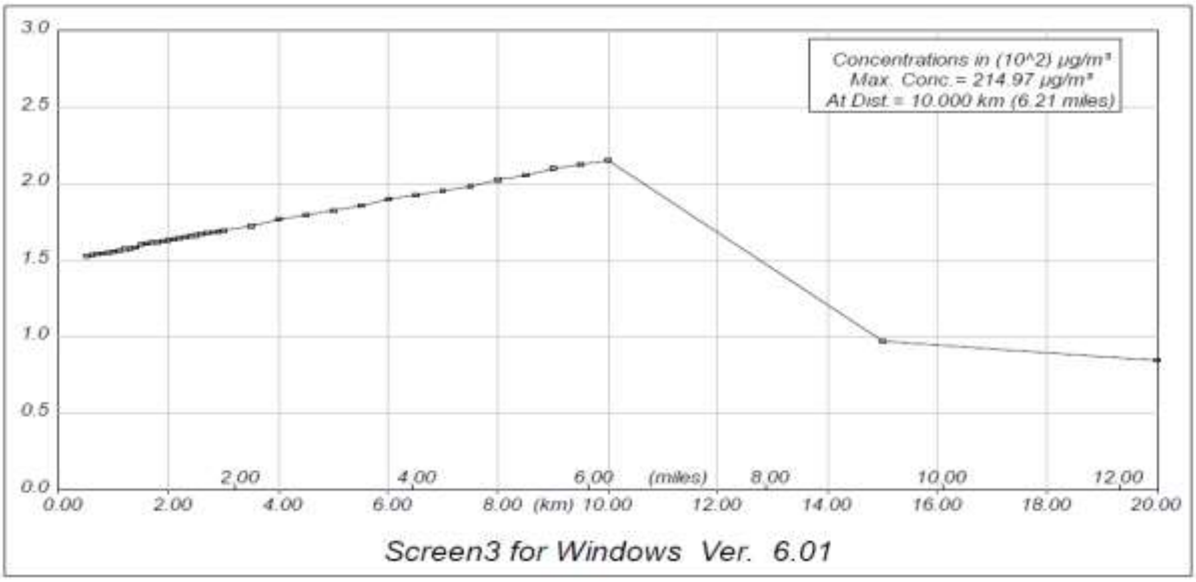

Fig. 4. Dust concentration in Class F and wind speed of 1 m/s.

As indicated by the results, the concentration of dust during the summer season under optimal atmospheric conditions, increase of dust, and Class F, at a distance of 10 kilometers from the center of dust emission is 214.97 $\mu g/m^3$ .In order to validate the proposed model, the best and most reliable method is the real measuring of air pollution in the study area. Of course, all of the locations in the study limit are suitable for the field measurements, but the best point is the point where concentration is at maximum level.

The data obtained from the Air Quality Monitoring Stations in Arak's Environment Monitoring Center at 10 km of Meighan wetland during the summer season for 24-hour concentration of suspended particles with diameter less than 10 microns showed that the maximum value for the concentration was 256 $\mu g/m^3$ at 16/7/2013, and for suspended particles with diameter less than 2.5 microns, the maximum value for the concentration was 221 $\mu g/m^3$ at 17/8/2013 (Arak's Environment Monitoring Center, 2016).

Based on the accredited environment laboratory data at 8/2014, the maximum value of concentration was obtained as 96 $\mu g/m^3$ at 1500 km of Meighan wetland for the suspended particles with diameter less than 10 microns, and for suspended particles with diameter less than 2.5 microns, it was 47 $\mu g/m^3$ (Environment Research Group, 2014). According to Arak's Weather Station, the number of dusty days during the summer season was at least 46 days in 2012 and at most 90 days in 2014 (Arak's Weather Station, 2016). Generally, the use of a model for simulating the distribution and spread of air pollutions is always associated with some standard deviations. In the Screen3 model, the deviations includes deviation in determining the earth shape, the exact status of meteorology, the emission rate of pollutants, the height of pollutants receiver, and the impact of other pollution sources on dust concentration (EPA, 1995). The study area is only a small part of Meighan wetland with 540 thousand hectare area.

Given the vicinity of dust centers to other areas outside of Markazi province especially Qom province, the wind direction from east to west during the summer season is very important contributing factor in the concentration of suspended particles in the region (Ansari, 2016).

Conclusions

In this regard, the comparison of the data obtained from the proposed model and the real measured data show that there is a little difference between the modeled data and real data confirming the accuracy of dust emission rate and concentration calculations. Appropriate solutions are wind erosion control using desertification procedures, protection of water demand in Meighan wetland, and prevention measures against land use changes.

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References

Ansari A. 2016. The final report of the research project "Identification of harvesting centers and effective factors of dust storms in Mighan Desert Wetland". Arak University.

Baddock MC, Bullard JE, Bryant RG. 2009. “Dust source identification using MODIS: A comparison of techniques applied to the Lake Eyre Basin, Australia”. Remote Sensing of Environment **113,** 1511-1528.

Charles PJ. 2015 .CAUTION DUST STORMS DO EXIST (and so do mountains): Modeling dust source suitability within an object-oriented geoecology . Institute of Geoecology and Geoinformation, International Society for Geomorphometry, Poznań.

Chow JC. 1994. A laboratory resuspension chamber to measure fugitive dust size distributions and chemical compositions. Atmospheric Environment, **28,** 3463-3481.

Clausnitzer H. 1996, Respirable-dust Production from Agricultural Operations in the Sacramento.

Di M, Lu X, Sun L, Wang P. 2008. A Dust-Storm Process Dynamic Monitoring With Multi-Temporal MODIS Data.21st, International Society for Photogrammetry and Remote Sensing. Journal of Photogrammetry and Remote Sensing **37,** 965-970.

Environment Research Group, 2014. The final report of the project Study Factory activity on the ecosystem effects of sodium sulfate Meghan Arak. And management options. *Mineral salts companies in Iran.*

Gillette DA. 1979. Environmental factors affecting dust emission by wind erosion. Morales: Saharan Dust, Ch. 4. Wiley, New York.

Giovanelli JGR, De Siqueira MF, Haddad CFB, Alexandrino J. 2010. Modeling a spatially restricted distribution in the Neotropics: how the size of calibration area affects the performance of five presence-only methods. Ecological Modelling, **221**, 215–224.

Helali J. 2013. "Zoning number of days with dust phenomenon in Iran, using GIS techniques." The third national conference on wind erosion and dust storms.
http://download.freedownloadmanager.org/Windows-PC/SCREEN3-for-Windows/FREE-6.1.html
http://markazi.doe.ir/Portal/home/http://markazimet.ir/

Huang JP, Minnis P, Lin B, Wang T, Yi Y, Hu Y, Sun-Mack S, Ayers K. 2006. Possible influences of Asian dust aerosols on cloud properties and radiative forc- ing observed from MODIS and CERES. Geophysical Reseach Letters, **33**.

Jaffe D, Snow J, Cooper O. 2003. The 2001 Asian dust events: Transport and impact on surface aerosol con- centrations in the US. *Eos*, **84**, 501-506. https://doi:10.1029/2003EO460001.

Jdidaleslam D. 2011. " the source finding of wind deposits half of well Zabul." Journal of Applied Geology.

Jutze C. 1976. Factors inßuencing emissions from fugitive dust. Proc. Symposium on Fugitive Emission Measurement and Control. May 1976, Hartford, CT.

Kulshrestha UC. 1996. Investigation into Atmospheric Deposition Through Precipitation Studies at New Delhi. Atmospheric Environment **30,** 4149-4154.

Lee JA, Gill TE, Mulligan KR, Dominguez Acosta M, Perez AE. 2009. "Land use/land cover and point sources of the 15 December 2003 dust storm in southwestern North America". Geomorphology **105,** 18-27.

Liu WD. 2002. Study on the Methods of Evaluating Fugitive Dust Emission Rate in Taiwan, The fifteenth conference of air pollution control strategies, ROC.

Masatoshi Y. 2002. Climatology of yellow sand (Asian sand, Asian dust or Kosa) in East Asia. Science in China Series D: Earth Sciences, **45,** 59-70.

OAQPS (EPA). 1977. Guideline for Development of Control Strategies in Areas with Fugitive Dust Problems. EPA- **405,** 2-77-029.

Phillips SJ, Dudík M. 2008. "Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation". Ecography **31,** 161-175.

Rivera Rivera NI, Gill TE, Bleiweiss MP, Hand JL. 2010. "Source characteristics of hazardous Chihuahuan Desert dust outbreaks". Atmospheric Environment **44,** 2457-2468.

Thornthwaite CW. 1948. An approach toward a rational classification of climate. Geography Review. **38,** 55-94.

Turner DB. 1964. A diffusion model for an urban area. J. Appl. Meteor **3,** 83-91.

U.S. Environmental Protection Agency. 1995. SCREEN3 Model User's Guide, EPA-454/B-95-004. U.S. Environmental Protection Agency. Research Triangle Park, NC 27711.Valley. Journal of Environmental Quality, **25**,877-884.

Veranth JM, Pardyjak ER, Seshadri G. 2003. Vehicle-generated Fugitive Dust Transport: Analytic Models and Field Study, *Atmospheric Environment*, **37**, 2295–2303. www.beeline-software.com/downloadSCREEN3-for-Windows

Zheng X, Lu F, Fang X, Wang Y, Guo L. 1998. Study of dust storms in china using satellite data, optical remote sensing of the atmospher and clouds. **3501,** 163-168.

Zoljoodi M, Didevarasl A, Ranjbar A. 2013. Dust events in the western parts of Iran and the relationship with drought expansion over the dust-source areas in Iraq and Syria. Atmospheric and Climate Sciences (ACS), in pressGoudie, A.S., Middleton, N.J., 2006. Desert dust in the Global system. Springer, printed in Germany **287,** 157-165.