DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 21-2 (2016) 133-141

A study on the wind erosion potential of agricultural lands after crop harvesting (Case study: Damghan Region)

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Received: 2 February 2016; Received in revised form: 14 November 2016; Accepted: 26 November 2016

Abstract

Aeolian process and subsequently soil erosion are key factors in dryland environments. Such phenomena are related not only to geoecological factors (lithology, topography, and climatology) but also to land-use and plant cover changes. Formation of new sand dunes in Damghan explains the development of human activities over the past. The aim of this study is to explain the land use changes and their contributions and impacts on Aeolian sediments in Damghan Region. The study was carried out using topographic and geologic maps, satellite imagery, aerial photographs, meteorological data, field observation and samplings. According to meteorological data, period of strong winds (May to Jun) were identified. This period is wind activity period. So, based on this period, unprotected soil surface by crop residues with the interpretation of satellite images was determined. The field samples were carried out from May to June 2008 when the wind was active. The study methods include sieving soil granulometry, and analyzing the particle size. Granulometric analyses were performed using conventional dry sieve method. The results of statistical analysis of grain size distribution showed that the mean and median of particle size were composed of coarse and very coarse sand particles. The study indicated that 90% of the agricultural lands contained more than 23% soil aggregates, where in areas with sensitive particles to erosion the Figure was 35%. It can be argued that agricultural land in study area are resistant to wind erosion.

Keywords: Damghan, Granulometry; Soil Aggregates; Human Activities; Sensitive Particles

1. Introduction

Wind erodibility of agricultural lands is a problem that impacts on dryland regions of the world. Wind erosion is a world-wide environmental concern (Houyou *et al*., 2014; Martínez-Graña *et al*., 2015) but some regions of the world are more affected due to their climatic conditions (Cerdà *et al*., 2010; Borrelli *et al*., 2016). In Iran, wind erosion occurs most notably in the arid and semi-arid regions. Over the past few decades, due to technological advances in the groundwater harvesting, vast areas from the removal region of aeolian process of Damghan Erg (as rangeland) have been changed to Agricultural land (Mashhad 2013). This poses the question what is the contribution of the new farmland (after crop harvesting) on the sand supply.

The factors that influence on wind erosion can be divided into two main groups: climatic factors and ground surface features. The climatic factors include wind and precipitation and ground surface features include micro-topography and presence of a protective cover. The most important feature of ground surface is soil texture, so that the physical and chemical properties of the soil, determines dust emission and saltation (Shao, 2001; Shao and Lu, 2000). Also, Vegetation

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protects soil from wind erosion because it reduces the wind speed and soil erodibility and traps more eroded material (Touré *et al*., 2011; Leenders *et al*., 2011; Lozano *el al*., 2013; Asensio *et al*., 2015). Wind erosion requires an unprotected soil surface and occurs when the soil loses substantial covering vegetation or crop residues (Barring *et al*., 2003). In a study done by Barth (1968), it was showed that in the areas of rice cultivation, large fields were ploughed while the once- flooded basins had been drained and dried out. When this happens, even normal winds can lead to deflation, and wind erosion attains massive proportions. Generally, three factors, including the seasonal cycle of crop development (phenology), agricultural activities and climate, determine the seasonal cycle of wind erosion (Barring *et al*., 2003).

In Damghan, the above-mentioned condition occurs after the crop harvesting while at the same time the strongest winds and the driest ground surface are observed. This means that the most sensitive period of soil erosion in the region is approximately from June to September.

2. Materials and Methods

2.1. The study area

The study area is located in the southeast of Damghan city, with its boundary approximately in coordinates 54° 16´ to 54° 29´ eastern longitudes and 35°, 54´, to 36°, 13´, northern latitude (Figure 1). It covers an area of approximately 27,000 hectares, its altitudes varied from 1100 to 1200 m with an average of 1150m above sea level. The climate is cold arid with an average rainfall of 110 mm and mean annual temperature is 16.3 degrees Celsius.

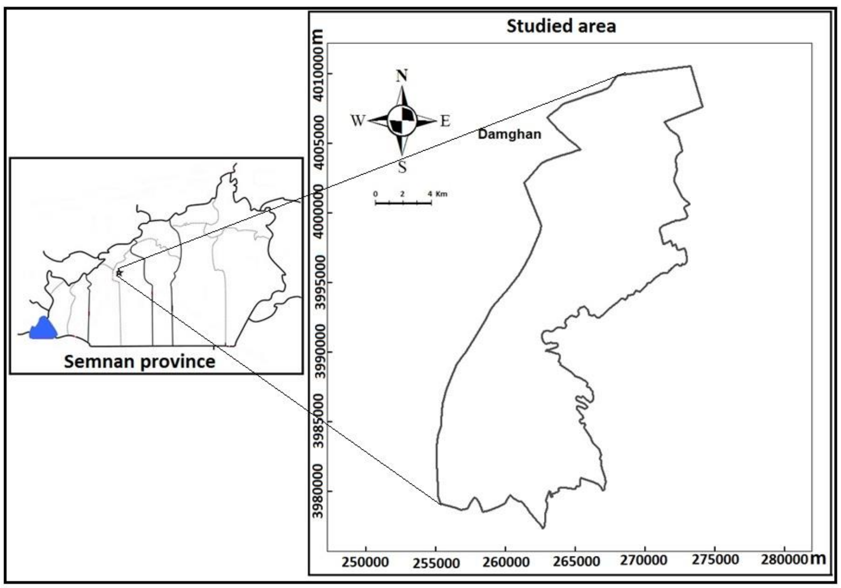

Fig. 1. Locationof the study area in the Semnan province

2.2. Materials

The study employed the following datasets and maps:

- The Climatic data provided by meteorological stations in the region to study the climatic characteristics
- Topographic maps with a scale of 1: 50,000. Geological map at a scale of 1: 250,000
- Field observations and soil samplings up to a depth of ten centimeters
- using shaker for Granulometry of samples

The study also used softwares such as WDConvert, WR Plot View, Pebble Count Data Sheet, GRADISTAT, and GIS for data analysis.

2.3. Methodology

Keeping in mind the research aim, a variety of methods were carried out in the sequence in the following steps.

-Determining the study area boundary on the basis of the wind function

The study area was determined based upon analyses of models which show the relationship between sand dune morphology and direction of the wind. Finally, studied region was implemented on the lithology and topographic maps (Figur2).

-Land use map

Land use map for the one period (2007) was extracted based on satellite images interpretation. Information was organized according to its geometric properties and by kml format. According to the plan aim, agricultural lands are selected in the land use map.

-Soil sampling

To assess the influence of soil physical properties on wind erosion, the granulometry survey was carried out in the selected agricultural lands. Due to action of wind erosion on the surface, soil samples were taken at one depth (0-10 cm) (Zaady *et al* 2006). 24 samples were collected from the study area (Figure 2). Soil sampling was carried out based upon three principles; a: dry period in area b: season with strong winds and c: soil without covering vegetation or crop residues. These conditions occur from June to September.

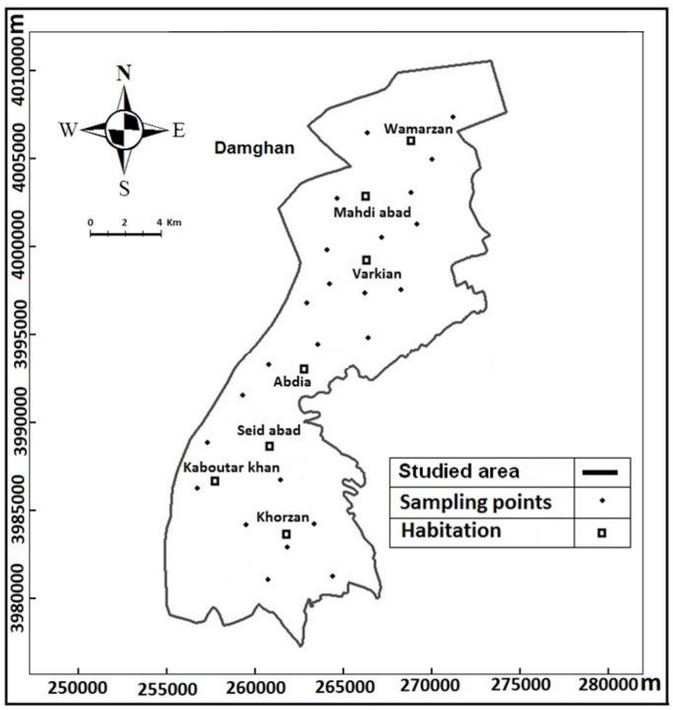

Fig. 2. Base map and sampling points

- Granulometry of samples

The granulometry of samples was carried out using dry sieves (sieve analysis, Anderson, 2004). In this method, approximately 100 gram of each soil samples was used.

- Grain size analysis

Samples analyses were done using GRADISTAT (SIMON *et al*, 2001) and EXCEL software.

-Presentation of maps

The distribution of susceptible and resistant to wind erosion were also assessed (Mashhadi *et al*, 2010).

3. Results and Discussion

- Climatic data analysis

The analysis of Damghan meteorological station data determined that the average annual precipitation as 110 mm with daily average temperature of 16.3 ̊c. The climate of the region is regarded as cold dry, on the basis of De Martonne method. Based on Embrothermic curve of Damghan station, the dry period is observed from March to the end of December covering 8 months (Figure3).

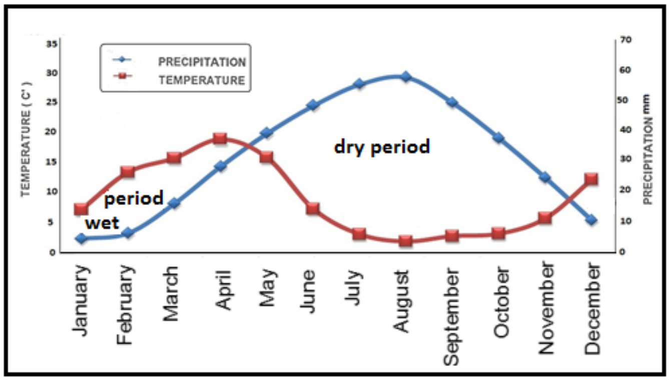

Fig. 3. Embrothermic curve of Damghan station

According to the annual wind rose and storm rose, wind directions of prevailing and strong in all seasons are northwestern wind (292.5 ̊ to 337.5 ̊). The highest percentage of blowing wind is seen in spring (32%) and the lowest in winter (12.8%) (Hanifehpour, 2013).

The results showed that 8 months of year were dry (Figure 3), spring and summer are windy seasons in this area.

The conditions of the temperature and precipitation in the region have caused a high degree of dryness in topsoil. Therefore, based on the climatic data, it can be indicated that climate erodibility is relativity strong. This is consistent with the result obtained by Dadfar *et al* (2011) in Qazvin. Barth (1986) showed that the decisive factors causing wind erosion are wind speed, low-water period and seasonal shifts in trade winds in the interior Delta of the Niger in Mali.

-Land use and boundary of samples

Overall four classes of land use dynamic were detected during the survey (Figure 4).The analysis of the sequential activities of agricultural land use showed the high level of transformations of soil erosion and land use.

-Granulometry

The results of samples granulometry are listed in Table 1.

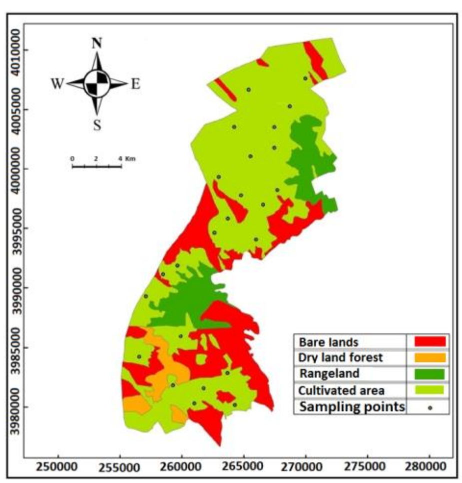

Fig. 4. Land use map

Table 1. Percentage distribution of grain size in microns

Grain size (µ) / Samples	>2000%	2000-1000%	1000-500%	500-250%	250-125%	125-62.5%	<62.5=Pan%	Total
1	10.7	11.0	39.1	22.6	9.1	6.3	1.2	100
2	73.5	14.0	5.2	3.7	2.8	0.6	0.2	100
3	35.7	10.5	30.1	14.9	5.9	2.1	0.8	100
4	53.2	12.2	12.6	12.0	3.2	3.9	2.9	100
5	33.7	21.8	24.2	13.9	5.1	1.2	0.1	100
6	51.7	11.2	11.0	14.6	6.6	3.7	1.3	100
7	52.5	17.1	14.1	9.5	4.2	1.9	0.6	100
8	47.2	15.4	16.4	12.0	6.8	1.6	0.7	100
9	34.0	10.3	13.7	26.4	9.5	4.9	1.1	100
10	43.2	12.8	16.8	16.2	7.5	2.7	0.8	100
11	74.8	7.9	6.1	5.2	3.3	2	0.8	100
12	69.0	9.3	8.9	6.6	3.5	2.2	0.5	100
13	53.6	18.4	15.1	7.4	3.2	1.7	0.6	100
14	36.3	13.3	19.6	23.5	4.8	1.9	0.6	100
15	46.5	12.9	13.8	16.6	5.0	4.0	1.2	100
16	53.9	10.2	12.5	15.9	3.6	2.5	1.4	100
17	53.5	7.4	9.7	13.0	7.7	6.8	2.0	100
18	60.4	6.6	7.4	14.6	6.9	3.4	0.8	100
19	44.9	8.6	14.0	18.8	8.9	3.4	1.5	100
20	55.9	9.1	9.1	15.6	6.9	2.3	1.0	100
21	39.1	8.2	14.4	3.8	28.7	4.6	1.2	100
22	54.1	9.6	19.7	10.9	3.7	1.6	0.4	100
23	51.6	7.7	8.7	15.5	9.5	5.7	1.3	100
24	48.8	7.2	13.1	24.9	3.1	1.8	1.0	100

Table 2. Statistical analysis and its description on samples (Folk and Ward method 1957)

Samples	Skewness(µ)	Sorting	Sorting (µ)	Mean	Mean (µ)	Kurtosis	Kurtosis(µ)	Skewness
1	-0.211	poorly	2.347	coarse sand	591.7	Mesokurtic	1.025	very fine
2	12.95	Very well	1.188	Very coarse sand	1303.7	Very platykurtic	-1.253	very coarse
3	-0.612	moderately	1.883	coarse sand	758.7	platykurtic	0.689	very fine
4	-1.592	moderately	1.985	coarse sand	941.5	Leptokurtic	1.185	very fine
5	0.916-	moderately	1.754	coarse sand	874.2	Very platykurtic	0.642	very fine
6	-1.611	moderately	1.955	coarse sand	907.8	platykurtic	0.812	very fine
7	-1.829	moderately	1.637	Very coarse sand	1055.9	Leptokurtic	1.201	very fine
8	-1.532	moderately	1.804	coarse sand	941.7	platykurtic	0.859	very fine
9	-0.471	poorly	2.175	coarse sand	640.7	Very platykurtic	0.577	very fine
10	-1.169	moderately	1.942	coarse sand	821.7	platykurtic	0.699	very fine
11	-2.283	well	1.389	Very coarse sand	1163.4	Very platykurtic	-1.559	very fine
12	-1.834	moderately well	1.499	Very coarse sand	1075.7	Extremely Leptokurtic	132.3	very fine
13	-1.953	moderately well	1.534	Very coarse sand	1105.4	Leptokurtic	1.387	very fine
14	-0.716	moderately	1.887	coarse sand	755.6	Very platykurtic	0.555	very fine
15	-1.389	moderately	1.969	coarse sand	874.7	platykurtic	0.786	very fine
16	-1.656	moderately	1.821	coarse sand	945.9	platykurtic	0.855	very fine
17	-1.500	poorly	2.207	coarse sand	825.9	platykurtic	0.826	very fine
18	-1.544	moderately	1.903	coarse sand	877.6	platykurtic	0.834	very fine
19	-1.112	poorly	2.042	coarse sand	770.7	Very platykurtic	0.649	very fine
20	-1.600	moderately	1.881	coarse sand	901.1	platykurtic	0.777	very fine
21	-0.710	poorly	2.401	coarse sand	571.6	Very platykurtic	0.455	very fine
22	-1.830	Moderately Well	1.606	Very coarse sand	1039.1	Mesokurtic	0.904	very fine
23	-1.533	poorly	2.158	coarse sand	837.1	platykurtic	0.729	very fine
24	-1.574	moderately	1.795	coarse sand	906.0	Very platykurtic	0.563	very fine
total	----	moderately	1.865	coarse sand	895.3	---	----	-----

Grain size parameters show that the mean of grain size in the all samples are coarse to very coarse, with poor-sorted and moderate respectively. Skewness indicates that the samples are very fine-skewed. Kurtosis shows that the grains distributions are platykurtic with the tails part of the distribution better sorted than the center.

Coarse-grained sizes in the samples may be the result of adhesion of the particles by organic fertilizer (Table1). Also, it is proved by poor to moderate sorting features. Therefore, the wind role is low as selector factor of grains.

This interpretation is supported by the very fine-skewed distributions in sample sites (mode of distribution of particles toward coarse grains) and kurtosis of distribution curve.

The represented interpretations about the low effect of wind on Aeolian proses are confirmed by particles in size more than 2000 micron (Soil aggregates) (Table 1).

-Determination of sensitive and resistant areas to erosion based on grain size (potential of the sedimentation)

Dynamic and physical analysis of grain movement by wind showed that particles with different diameters had experienced different forms of transport, and each of the forms of transportation complied with wind specified speeds (Lancaster 2009).

According to Table 1, and on the basis of the most vulnerable of particle size (62.5 to 125 microns) a map of sensitive areas to erosion was generated. Also, based on particles of resistant to erosion (greater than 2000 microns), a map of resistance areas to erosion was drawn (Figures 5 and 6). Classes contain vulnerable and resistant particles are summarized in table 3.

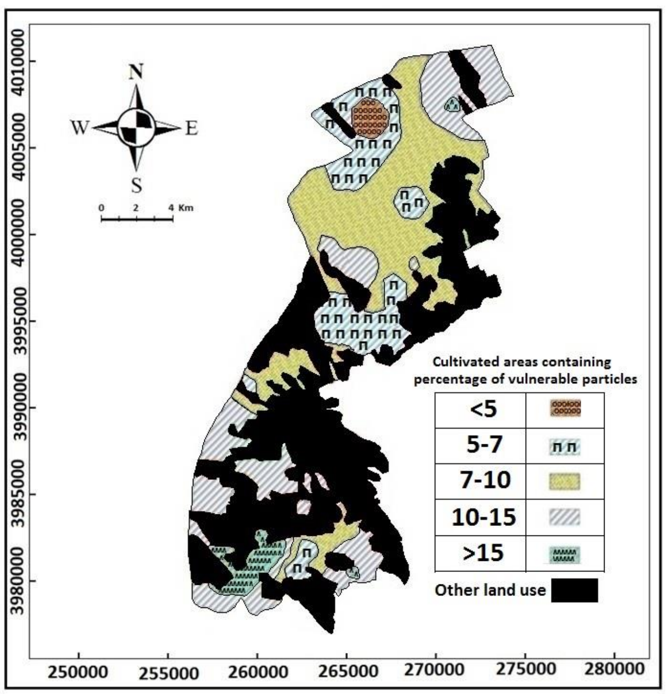

Fig. 5. Sensitive areas to wind erosion based on vulnerable particles

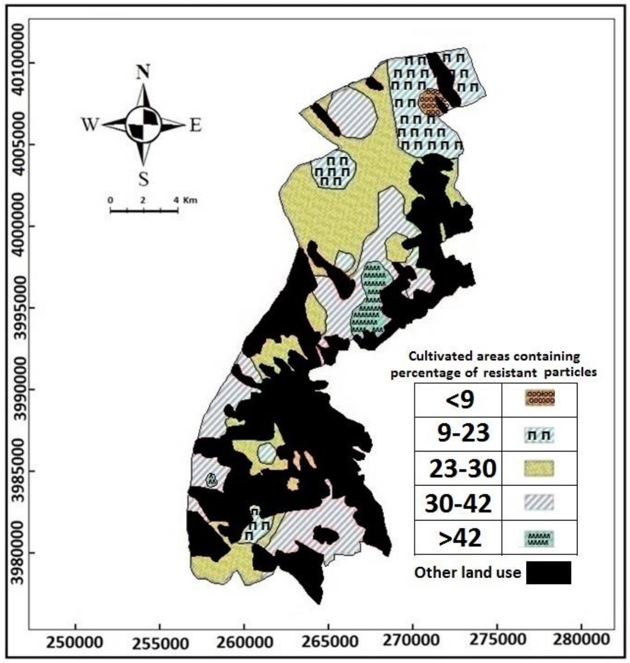

Fig. 6. Resistant areas to wind erosion based on resistant particles

Table 3. Classes of the Values distribution of the most vulnerable and particle size of resistant in the study area (in ha and percent)

most vulnerable of particle(size 125-62.5)			particles of resistant (size > 4000)		
Class of Values	Hectares	%	Class of Values	Hectares	%
5% <	318	2	9% <	127	1
7-5%	3114	21	23-9%	1907	13
10-7%	6420	43	30-23%	6991	46
15-10%	4449	29	42-30%	5530	37
33-15%	699	5	57-42%	445	3
total	15000	100	total	15000	100

-Relationship between the amounts of soil aggregates and soil erodibility

Figure 7 shows the relationship between the amounts of soil aggregates and soil erodibility, which is a logarithmic relationship. There is a turning point (23% soil aggregates), that is the decisive factor from the point of view of the Aeolian dynamics (Figure 7).

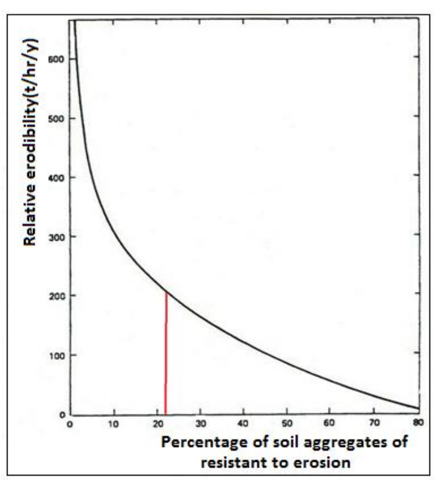

Fig. 7. Relationship between the percentage of soil aggregates and relative erodibility (Refahi, 2009)

According to diagram of Figure 7, the data of table 4 are derived. The values listed in table 4 shows that land with more than 23% of the soil aggregates occupy about 90% of the land of area.

Table 4. Occupied areas by resistant particles to wind erosion in the study area (in ha and percent)

Particles of resistant (size> 4000)		
Class of Values	Hectares	%
<23%	2034	14
>23%	12966	86
total	15000	100

The presented values about the most vulnerable of particles (Table 3) show that sensitive areas to erosion containing more than 15% of particles of vulnerable cover only about 5 per cent of soil of study area (Table5).

Table 5. Occupied areas by most vulnerable particles to wind erosion in the study area (in ha and percent)

most vulnerable of particles= size(125-62.5)		
Class of Values	Hectares	%
<15%	14301	95
>15%	699	5
total	15000	100

4. Conclusion

Climate factors (wind regime, precipitation, temperature, and humidity), Surface roughness, and surface properties (Types of surface soil, Particle size of surface soil, and Moisture content of surface soil) play important roles in soil wind erosion.

Investigation revealed that the factors such as temperature and rainfall were important.

The research indicated that, in study region, the average particle size of the all soil samples are coarse sand (895.3µ), indicating a particle that is high resistance to wind erosion. Therefore, the wind power which needs to move the particles should be great.

Values of soil aggregates in samples are high, which has resulted to a Coherent soil.

Generally, according to the favorable condition of climate factors for erosion in area, the impact of wind erosion in agricultural land depends on vegetation and surface soil properties.

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