doi: 10.17221/73/2016-SWR

Tillage-induced Wind Erosion in Semi-arid Fallow Lands of Central Anatolia, Turkey

Mustafa BAŞARAN[1,2], Oğuzhan UZUN[1,2], Sema KAPLAN[1], Fatih GÖRMEZ[3] and Gunay ERPUL[4]*

[1]Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Erciyes University, Kayseri, Turkey; [2]Erciyes University Technology Transfer Office, Melikgazi, Kayseri, Turkey; [3]General Directorate of Combating Desertification and Erosion, Ankara, Turkey; [4]Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ankara University, Ankara, Turkey

**Corresponding author: ouzun@erciyes.edu.tr*

Abstract

Başaran M., Uzun O., Kaplan S., Görmez F., Erpul G. (2017): Tillage-induced wind erosion in semi-arid fallow lands of Central Anatolia, Turkey. Soil & Water Res., 12: 144–151.

Wind erosion and resultant dust emissions create significant risks for land degradation and ecosystem health in arid and semi-arid regions. In these regions, fallowing constitutes a major component of conventional agriculture. The present study was conducted to determine wind erosion quantities and agricultural activity-induced mass transport from fallow lands and to assess the correlations of mass transport with climate and soil characteristics. Experiments were conducted over the fallow lands of two adjacent agricultural enterprises (Altinova and Gözlü, Turkey). Sediment flux was measured with passive traps in wet and dry seasons ($Q_{t\mathrm{WET}}$ and $Q_{t\mathrm{DRY}}$). Mass transport in wet and dry seasons was respectively measured as 11.38 and 11.40 kg/ha in Altinova and as 31.61 and 19.71 kg/ha in Gözlü. Both the differences between mass transport of the enterprises and the differences between $Q_{t\mathrm{WET}}$ and $Q_{t\mathrm{DRY}}$ of each enterprise were found to be significant ($P < 0.05$). Pearson's correlation analysis for the correlations of mass transport with soil characteristics revealed significant correlations with electrical conductivity and soil lime content (r = 0.721 and –0.635) ($P < 0.05$). Total mass transport from the fallow lands of both enterprises throughout a 7-month period of measurement was estimated at 600 t. Based on current findings it was concluded that fallowing should be abandoned and sustainable soil and land management practices from conventional agriculture like minimum tillage or crop rotations should be introduced.

Keywords: fallow; land use; mass transport; sediment flux

Wind erosion is a natural phenomenon, but it is a serious global problem and the primary factor responsible for desertification (Lal 1994). Such erosive processes result in significant losses in soil fertility because of losses in plant nutrients, organic matter, and fine fractions. Wind erosion decreases soil productivity through transporting nutrients from the soil surface (Visser & Sterk 2007). Wind erosion also influences climate change, spoils air quality, and significantly threats human health either directly or through the pathogens transported with it (Griffin 2007; Copeland *et al.* 2009; Watanabe *et al.* 2011). It transports micronutrients to terrestrial and marine ecosystems (Griffin & Kellog 2004). Wind erosion is more devastating in arid, semi-arid, and dry sub-humid regions (Stroosnijder 2007). Although wind erosion is a natural process in arid and semi-arid regions, it may reach drastic levels in degraded grass lands and agricultural fields through anthropogenic impacts (Gill 1996; Neff *et al.* 2008). Land use has significant impacts on vegetation cover by protecting soil surface against erosive

doi: 10.17221/73/2016-SWR

winds (Zhou *et al.* 2008). Several researches revealed the risks of wind erosion over degraded agricultural fields and over-grazed pastures in various parts of the world (Buschiazzo *et al.* 1999; Bielders *et al.* 2000; Goossens *et al.* 2001).

Fallow is a common practice over a majority of agricultural lands in Turkey and all over the agricultural lands of Konya Closed Basin. In Turkey, fallow is practiced on over 15 million ha of drylands out of 28 million ha of agricultural land (Haktanir *et al.* 2000). Concerns about insufficient precipitations and weed control force agricultural enterprises let the land lie fallow. Just because of the fallow system, about 50% of drylands are left without any protections throughout the growing season and soil tillage over fallow lands induces wind erosion and increases dust emissions through mechanical operations. It was reported that 465 913 ha of land area of Turkey was exposed to wind erosion and 69.22% of this exposure was experienced in Konya Closed Basin (Acar 2010). Irregular and insufficient precipitations, high wind speeds, smooth surface topography, light soil texture, poor aggregation associated with alkalinity and salinity, low organic matter content, and poor vegetation cover in rangelands constitute the main reasons why wind erosion is a major menace and land degradation problem in the basin (Youssef *et al.* 2010).

Wind erosion, resultant dust emissions, and potential effects on air quality have not been well-elucidated yet in Turkey. In this study, wind erosion and tillage-induced dust emissions were measured using passive traps in Konya Closed Basin where dry farming and fallow system have been most frequent. Measurements were performed over the fields of Altinova and Gözlü Agricultural Enterprises of the General Directorate of Agricultural Enterprises of the Ministry of Agriculture, Turkey. With the total farmland area of both enterprises of 60 000 ha, they belong to the largest agricultural enterprises of Turkey as well as worldwide. In the research site the fallow system best representing the dry farming system of both Konya Closed Basin and the whole Turkey has been continuously practiced. To our knowledge, any regional-scale study evaluating the effects of fallow system on wind erosion and agricultural activity-induced dust emissions in Turkey is missing. Resultant data can serve as a basis for estimating the contributions of fallow-induced dust emissions of the region.

MATERIAL AND METHODS

The study area were the agricultural fields of Altinova and Gözlü Agricultural Enterprises of the General Directorate of Agricultural Enterprises of Turkey. Altinova is located between 38°43'08.68''N and 32°10'34.73''E longitudes (Figure 1). Total land resource of the enterprise is 31 157 ha. Long-term average annual precipitation is 315 mm and average temperature is 11°C. Gözlü is located between 38°29'29.01''N and 32°27'30.22''E latitudes (Figure 2). Total land resource is 28 830 ha. Long-term average precipitation is 312.3 mm and average temperature is 11.5°C. Average wind velocity at both locations is 3.2 m/s. The cropping pattern is mostly rainfed agriculture and irrigated agriculture is very limited. Agricultural land is predominately covered with

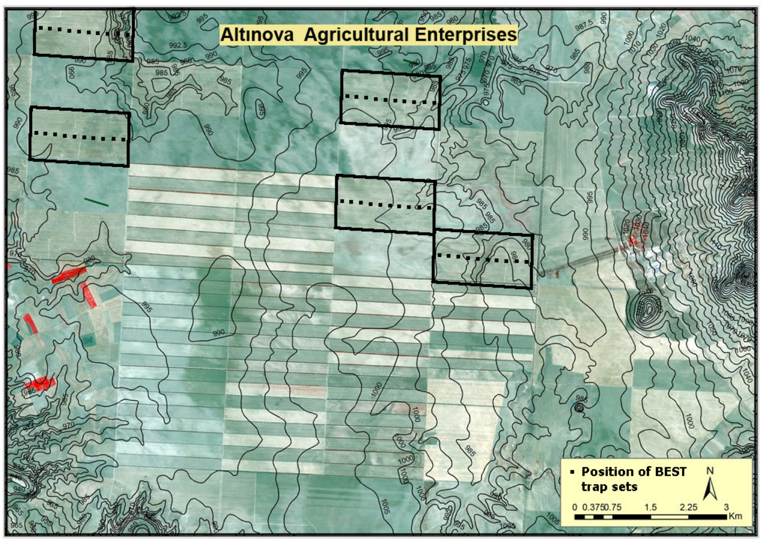

Figure 1. Antinova agricultural enterprise

doi: 10.17221/73/2016-SWR

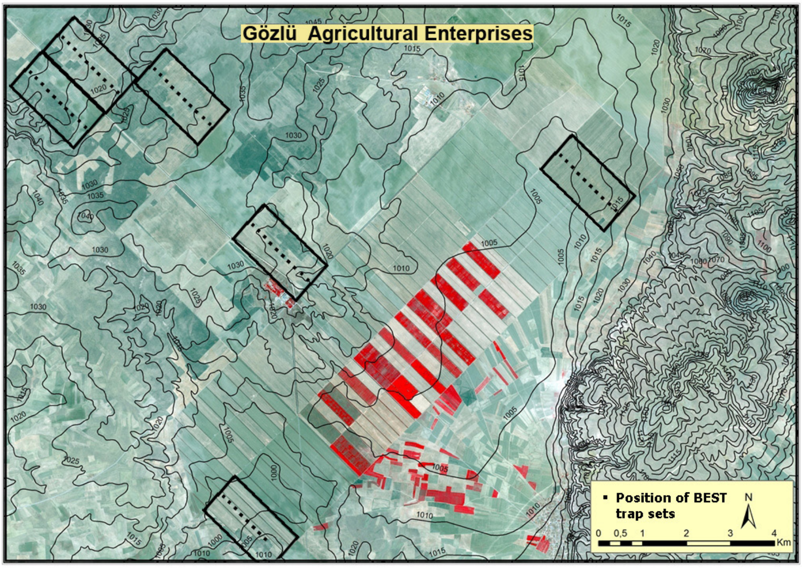

Figure 2. Gözlü agricultural enterprise

cereals and fallow is practiced over experimental fields (http://www.tigem.gov.tr/).

Wind erosion and tillage-induced dust emissions were measured over the experimental fields of Altinova and Gözlü between March and June (wet season) and between June and September (dry season). A total of 100 sediment traps were installed over fallow lands in 11 experimental plots of both enterprises (5 plots in Altinova and 6 plots in Gözlü) on March 1, 2015. In each plot of Altinova, 10 sediment trap sets were placed. Just because of shallow soil depths and geometrical variations in plot shapes and sizes in Gözlü, 8, 8, 7 and 7 sets were respectively placed in G2, G4, G5, and G6 numbered plots. Although the plots had a size of 2000 × 2000 m (except for G2, G4, G5, and G6 of Gözlü), they were divided into two sections (Figure 1 and 2). Thus, the plot size was 2 km^2 (2 × 1 km). In each plot, the sediment traps BEST (Figure 3) (Basaran *et al*. 2011) were fixed into the field with anchorage bars along a linear route and perpendicularly to prevailing wind direction. The cyclone BEST has a plastic body produced by a plastic injection system. It is mainly composed of three modular units: a lid including inlet and outlet, a cylindrical and conical cyclone body, and a collector. While outlet diameter is 20 mm ($Ø_1$), rectangular inlet is 12 × 20 mm in size. Diameter of the cylindrical body is 60 mm ($Ø_2$) and base diameter of the conical body is 14.5 mm ($Ø_3$). Heights of the conical and cylindrical bodies are 50 and 74 mm, respectively. Diameter ($Ø_4$) and height of the collector are 50 and 40 mm, respectively.

The sediment transport distance of prevailing winds (fetch length) is 500 m. The tillage clods were also levelled for free rotation of wings. The measurement sets were placed 200 m apart along a route in each plot. In the sediment measurement system, 5 traps were placed at 20, 40, 60, 80, and 100 cm elevations. Each measurement system was supplemented with a wing to continuously orient the trap inlets perpendicularly to wind direction. Following the installation of sediment trap sets, soil samples were taken from 0–10 cm soil depths of each plot to determine some soil physical and chemical characteristics. The soil samples were air-dried in the laboratory and prepared for analyses. They were analyzed for pH, electrical conductivity (EC) (Richards 1954), organic matter (OM) (Nelson & Sommers 1982), calcium carbonate content ($CaCO_3$) (Caglar 1958), and soil texture (clay, silt, and sand content) (Bouyoucos 1951).

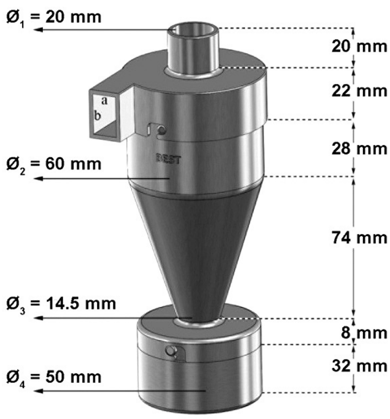

Figure 3. Design details of the sediment trap BEST

doi: 10.17221/73/2016-SWR

The amount of aggregates smaller than 0.84 mm was determined by measuring aggregate size distributions of samples with a dry sieving apparatus (CHEPIL 1952). Conventional agricultural machinery operations were performed over the experimental fields of both enterprises during a seven-month measurement period. Soil tillage was performed over fallow lands with mold plow in March to provide weed control and surface roughness in both enterprises. Weed control was practiced over cultivated lands through herbicide sprays with a holder in April. Since the precipitations of April and May were quite above the long-term averages, second soil tillage was performed over fallow lands with mold plough in June. Harvest was performed over cultivated lands with a combine harvester from the end of June to mid-July. The sediment flux (q_z, kg/m^2) was measured for each trap elevation by using the following equation:

$$q_z = m/A \quad (1)$$

where:
m – amount of sediment trapped by each trap (kg)
A – inlet area (m^2)

Then sediment flux (q_z, kg/m^2) at each point where traps were placed was calculated with the trapezium method.

Sediment flux rate (Q_r, kg/m) was calculated for each trap elevation through integration of q_z over each depth:

$$Q_r = \int_0^h (q_z)dz \quad (2)$$

where.
z – minimum trap elevation (m)
h – maximum trap elevation (m)
d – ???

Total mass transport (Q_t, kg) was calculated by using the following equation:

$$Q_t = \left(\frac{Q_r}{\eta}\right)L \quad (3)$$

where:
η – trap efficiency (80%)
L – plot width (2000 m) (BASARAN *et al.* 2011).

RESULTS AND DISCUSSION

Soil analysis results are provided in Table 1. The amount of aggregates sizing less than 0.84 mm was determined through dry sieving and modelled with exponential equation. The ratio of aggregates smaller than 0.84 mm is a significant indicator of wind erosion (FRYREAR 1985), and the A4 plot with 43% was identified as the plot most sensitive to wind erosion. Considering the dry aggregate size distribution, G1 plot (18%) was identified as the plot with the least risk of wind erosion. Average lime, sand, and < 0.84 mm aggregate contents of Altinova (respectively with 13.8, 48.6, and 35.4%) were higher than those of Gözlü

Table 1. Soil characteristics of Altinova and Gözlü

Plot	pH	EC (dS/m)	OM	$CaCO_3$	Clay	Silt	Sand	< 0.84 mm
			(%)					
A1	8.4	0.08	1.05	14.5	41.0	14.6	44.5	29.5
A2	8.5	0.09	1.27	22.6	26.4	22.9	50.7	36.1
A3	8.3	0.15	1.49	4.9	28.5	22.9	48.6	32.4
A4	8.7	0.09	1.13	14.9	30.6	22.9	46.5	44.0
A5	8.6	0.07	1.10	12.1	30.6	16.6	52.8	36.7
Mean	8.5	0.10	1.20	13.8	31.2	20.0	48.6	35.4
G1	8.6	0.07	1.12	12.6	38.9	16.6	44.5	18.4
G2	8.4	0.42	1.38	2.2	43.1	27.0	29.9	21.6
G3	8.6	0.07	1.74	1.8	16.0	49.3	34.7	26.8
G4	8.7	0.06	1.27	3.5	30.6	24.9	44.5	35.2
G5	8.5	0.16	1.34	4.1	24.3	27.0	48.6	40.4
G6	8.6	0.06	1.44	13.4	34.7	20.8	44.5	31.2
Mean	8.6	0.14	1.38	6.3	31.2	27.6	41.1	28.9

EC – electrical conductivity; OM – organic matter

doi: 10.17221/73/2016-SWR

Table 2. Wind and precipitation data for wet and dry seasons of Altinova and Gözlü

Date	Altinova				Gözlü			
	wind velocity (m/s)			total precipitation (mm)	wind velocity (m/s)			total precipitation (mm)
	mean	SD	CV		mean	SD	CV	
Wet season								
March	3.26	1.12	34.2	66.6	2.28	1.18	51.82	46.6
April	3.05	0.83	27.3	39.6	2.86	0.96	33.69	19.6
May	1.81	1.22	67.3	78.4	1.23	1.25	101.28	51.0
1–15 June	1.61	1.06	65.9	44.0	1.37	0.88	64.04	78.6
Mean/total	2.43	1.06	48.7	228.6	1.94	0.77	62.70	195.8
Dry season								
15–30 June	2.55	0.44	17.4	31.9	2.18	0.38	17.4	38.8
July	2.67	0.69	25.7	0.0	1.90	1.23	64.8	16.4
August	2.42	0.96	39.8	337	2.30	0.75	32.8	20.9
September	0.00	0.00	–	11.0	0.00	0.00	–	35.8
Mean/total	1.91	0.52	20.8	76.6	1.60	0.59	28.8	111.9

SD – standard deviation; CV – coefficient of variation

(6.3, 41.1, and 28.9%). On the other hand, pH, EC, OM, and silt contents of Gözlü (respectively with 8.6, 0.14 dS/m, 1.38%, and 27.6%) were higher than those of Altinova (8.5, 0.10 dS/m, 1.20%, and 20.0%).

Wind and precipitation values of both locations for March–October period were supplied from General Directorate of Meteorology (Konya, Turkey) (Table 2). Precipitation during the experimental period (March–October 2015) was above the long-term averages. However, wind velocity values were quite lower than the long-term averages. Average wind velocity of wet and dry seasons was respectively observed as 2.43 m/s and 1.91 m/s (Altinova) and 1.94 m/s and 1.60 m/s (Gözlü). Total precipitations in wet and dry seasons were respectively observed as 228.6–76.6 mm (Altinova) and as 195.8–111.9 mm (Gözlü). Compared to dry season, wind velocity higher by 0.52 m/s was observed in wet season in Altinova and by 0.34 m/s in wet season in Gözlü. When the wind velocities of the enterprises were compared, it was observed that Altinova had by 0.49 m/s higher wind velocity than Gözlü in wet season and by 0.31 m/s higher wind velocity in dry season. Altinova had by 32.8 mm more precipitation than Gözlü in wet season and Gözlü had by 35.3 mm more precipitation than Altinova in dry season. Despite the two enterprises are located quite close to each other, they had quite different precipitation and wind velocity distributions throughout the year.

The differences in minimum and maximum wind velocities were quite distinctive in Gözlü. While the average coefficient of variation for wind velocities in wet season was 62.7 in Gözlü and 48.7 in Altinova, in dry season the values observed were 28.8 in Gözlü and 20.8 in Altinova. Higher variation coefficients in Gözlü indicated higher differences between minimum and maximum wind velocities at that enterprise.

Totals for sediments transported from fallow lands of Altinova and Gözlü are provided in Table 3. Despite quite close locations and almost identical farming

Table 3. Mass transport from experimental plots (in kg/ha)

Enterprises	Plot No.	Q_{tWET}	Q_{tDRY}	Q_t
Altinova	A1	13.3	13.9	27.2
	A2	10.2	8.9	19.1
	A3	8.8	8.6	17.4
	A4	11.6	13.6	25.2
	A5	13.0	12.0	25.0
	mean	11.38	11.40	22.78
Gözlü	G1	20.5	8.6	29.1
	G2	65.5	31.3	96.8
	G3	17.6	14.0	31.6
	G4	52.7	19.0	71.7
	G5	23.7	38.7	62.4
	G6	9.7	6.7	16.4
	mean	31.61	19.71	51.32

Q_{tWET} – total mass transport in wet season; Q_{tDRY} – total mass transport in dry season; Q_t – total mass transport

doi: 10.17221/73/2016-SWR

Table 4. One sample t-test results for $Q_{t\text{WET}}$ and $Q_{t\text{DRY}}$ values

	Test value = 0					
	t	df	significance (2-tailed)	mean difference	95% confidence interval of the difference	
					lower	upper
$Q_{t\text{WET}}$	3.926	10	0.003	22.4	9.69	35.14
$Q_{t\text{DRY}}$	5.196	10	0.000	15.9	9.10	22.77

$Q_{t\text{WET}}$ – total mass transport in wet season (kg/ha); $Q_{t\text{DRY}}$ – total mass transport in dry season (kg/ha); df – degree of freedom

practices under the same conditions, the differences in mass transports were primarily related to precipitations and wind velocities. Altinova had by 32.8 mm more precipitation than Gözlü in wet season, however, wind velocity in wet season was 2.43 m/s in Altinova and 1.94 m/s in Gözlü. Lower soil moisture levels at Gözlü than at Altinova were because the low precipitation reduced the threshold dragging velocity and thus resulted in easy transport of individual particles and aggregates. The wetness or moisture content of the surface layer of particles, about 2 or 3 mm in depth, has a profound effect on wind erodibility of unconsolidated sediment. Many studies proved that moisture-dependent intergranular cohesion increased the threshold velocity needed for particle movement (McKenna-Neuman & Nickling 1989; Kroon & Hoekstra 1990; Seleh & Fryrear 1995; Chen *et al.* 1996). Dong *et al.* (2002) indicated that surface moisture was an extremely important variable controlling the entrainment process of sands by wind since the tensile force between the water molecules and sand grains produces cohesion.

However in dry season, despite higher precipitations and lower wind velocity at Gözlü than at Altinova, higher mass transport of Gözlü might be related to soil properties of the enterprise.

Correlations of sediment transport with some soil physical and chemical characteristics were performed for soils of both enterprises. Interestingly, while Q_t significantly correlated with EC and lime content (r = 0.721 and –0.635) ($P < 0.05$), the correlations between Q_t and erosion controlling parameters like texture, organic matter, and < 0.84 mm aggregate content were not found to be significant. Altinova soils had almost twice greater lime content than Gözlü soils. Higher water holding capacity of carbonates resulted in later dry out of Altinova soils, thus reduced cementing effect and resultant mass transport. Therefore, lower mass transport was observed in Altinova during both seasons. Calcium carbonate and high electrolyte concentration were found to be very effective against dispersion of soil aggregates (Gupta *et al.* 1984). The positive effects of lime on soil structure can be ascribed to the flocculating and cementing actions of $CaCO_3$ (Haynes & Naidu 1998).

Topography might have influenced sediment flux in both enterprises. Sediment flux may increase or decrease based on topographic position of selected plots. Several studies about the influences of topography on wind erosion and dust deposition were performed including field measurements, laboratory simulations in wind tunnels, and models (Hoffmann *et al.* 2008). The greatest erosion rates were observed on windward slopes close to the summits while on the leeward slopes, erosion rates were considerably lower (Goossens & Offer 1997).

When the enterprises were separately assessed with t-test in wet and dry seasons, it was observed that the difference in $Q_{t\text{WET}}$–$Q_{t\text{DRY}}$ was significant in

Table 5. The t-test results for $Q_{t\text{WET}}$–$Q_{t\text{DRY}}$ of Altinova (A) and Gözlü (G)

	Test value = 0					
	t	df	signifiacance (2-tailed)	mean difference	95% confidence interval of the difference	
					lower	upper
A ($Q_{t\text{WET}}$–$Q_{t\text{DRY}}$)	17.1	9	0.00	11.4	9.9	12.9
G ($Q_{t\text{WET}}$–$Q_{t\text{DRY}}$)	4.8	11	0.01	25.6	14.0	37.3

$Q_{t\text{WET}}$ – total mass transport in wet season (kg/ha); $Q_{t\text{DRY}}$ – total mass transport in dry season (kg/ha); df – degree of freedom

doi: 10.17221/73/2016-SWR

Table 6. Total sediment flux from the fallow lands of Altinova and Gözlü

Enterprises	Total arable area (ha)	Total fallow area (ha)	Q_t	Q
Atinova	31 200	13 157	22.78	300
Gözlü	28 800	5 920	51.32	303
Total	60 000	19 077	74.1	603

Q_t – ($Q_{t\text{WET}}$ + $Q_{t\text{DRY}}$) (t/ha); Q – total sediment loss from fallow lands of enterprises (t)

both enterprises ($P < 0.05$) (Table 4). While $Q_{t\text{DRY}} > Q_{t\text{WET}}$ (11.38–11.40 kg/ha) in Altinova, $Q_{t\text{WET}} > Q_{t\text{DRY}}$ (31.61–19.61 kg/ha) in Gözlü (Table 5). Higher mass transport in dry season of Altinova may be related to less precipitations rather than wind velocity. While Gözlü had 111.9 mm precipitation in dry season, at Altinova precipitation attained to 76.6 mm. The range of precipitation between wet and dry seasons at Gözlü was not as large as that at Altinova. Besides, high variation coefficient in wind velocity for wet season of Gözlü may be related to a broad range between minimum and maximum wind velocities. Longer exposure durations to high wind velocities in wet season and more frequent high wind velocities might have resulted in a higher variation coefficient and mass transport.

The total mass transport over the whole 7-month measurement period was estimated at 303 t for Gözlü and 300 t for Altinova (Table 6), i.e. 603 t from both. Although the size of fallow lands in 2015 was 13.157 ha at Altinova and 5.290 ha at Gözlü, Gözlü was considered to be exposed to greater risks of wind erosion and agricultural activity-induced sediment flux.

CONCLUSION

In this study, wind erosion and agricultural activity-induced sediment flux from the fallow lands of Altinova and Gözlü in Turkey were separately assessed for wet and dry seasons. Precipitations in the experimental year were almost twice as high as long term averages. Although mass transport per unit area was quite low, if the entire fallow lands of the country were taken into consideration, we would arrive to huge numbers. Just because of high precipitation in the experimental period, no significant correlations were observed between mass transport and soil characteristics controlling soil erosion. A significant correlation was observed only between mass transport and soil lime content. Precipitation was identified as the indicator factor of the differences in mass transport rates of the enterprises. Current findings revealed that to prevent land degradation, the traditional fallow system should be abandoned and erosion preventive measures like minimum tillage and crop rotation should be introduced to reduce the materials transport and to prevent soil surface from erosive winds.

Acknowledgements. This work was supported by General Directorate of Combating Desertification and Erosion.

References

Acar R., Dursun S. (2010): Vegetative methods to prevent wind erosion in Central Anatolia Region. International Journal of Sustainable Water and Environmental Systems, 1: 25–28.

Basaran M., Erpul G., Uzun O., Gabriels D. (2011): Comparative efficiency testing for a newly designed cyclone type sediment trap for wind erosion measurements. Geomorphology, 130: 343–351.

Bielders C.L., Michels K., Rajot J.L. (2000): On-farm evaluation of ridging and residue management practices to reduce wind erosion in Niger. Soil Science Society of America Journal, 64: 1776–1785.

Bouyoucos G.J. (1951): A recalibration of the hydrometer method for making mechanical analysis of soils. Agronomy Journal 43: 435–438.

Buschiazzo D.E., Zobeck T.M., Aimar S.B. (1999): Wind erosion in loess soils of the semiarid Argentinian pampas. Soil Science, 164: 133–138.

Caglar K.O. (1958): Soil Science. Faculty of Agriculture, Ankara University, Ankara. (in Turkish)

Chen W., Dong Z., Li Z., Yang Z. (1996): Wind tunnel test of the influence of moisture on the erodibility of loessial sand loam soils by wind. Journal of Arid Environments 34: 391–402.

Chepil W.S. (1952): Improved rotary sieve for measuring state and stability of dry soil structure. Soil Science of America Proceedings, 16:113–117.

doi: 10.17221/73/2016-SWR

Copeland N.S., Sharratt B.S., Wu J.Q., Foltz R.B., Dooley J.H. (2009): A wood-strand material for wind erosion control: effects on total sediment loss, PM10 vertical flux, and PM10 loss. Journal of Environmental Quality, 38: 139–148.

Dong Z., Liu X., Wang X. (2002): Wind initiation thresholds of the moistened sands. Geophysical Research Letters, 29: 1585.

Fryrear D.W. (1985): Determining soil aggregate stability with a rapid rotary sieve. Journal of Soil and Water Conservation, 40: 231–233.

Gill T.E. (1996): Eolian sediments generated by anthropogenic disturbance of playas: Human impacts on the geomorphic system and geomorphic impacts on the human system. Geomorphology, 17: 207–228.

Goossens D., Offer Z.Y. (1997): Aeolian dust erosion on different types of hills in a rocky desert: wind tunnel simulations and field measurements. Journal of Arid Environments, 37: 209–229.

Goossens D., Gross J., Spaan W. (2001): Aeolian dust dynamics in agricultural land areas in Lower Saxony, Germany. Earth Surface Processes and Landform, 26: 701–720.

Griffin D.W. (2007): Atmospheric movement of microorganisms in clouds of desert dust and implications for human health. Clinical Microbiology Review, 20: 459–477.

Griffin D.W., Kellogg C.A. (2004): Dust storms and their impact on ocean and human health: dust in Earth's atmosphere. Ecohealth, 1: 284–295.

Gupta R.K., Bhumbla D.K., Abrol I.P. (1984): Effect of sodicity, pH, organic matter, and-calcium carbonate on the dispersion behavior of soils. Soil Science, 137: 4.

Haktanır K., Cangir C., Arcak Ç., Arcak S. (2000): Soil Resources and Usage. In: 5th Agricultural Engineering Technical Congr. UCTEA, Ankara, Jan 17–19, 2000: 203–229. (in Turkish)

Haynes R.J., Naidu R. (1998): Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: a review. Nutrient Cycling in Agroecosystems, 51: 123–137.

Hoffmann C., Funk R., Wieland R., Li Y., Sommer M. (2008): Effects of grazing and topography on dust flux and deposition in the Xilingele grassland, Inner Mongolia. Journal of Arid Environments, 72: 792–807.

Kroon A., Hoekstra P. (1990): Eolian sediment transport on a natural beach. Journal of Coastal Research, 6: 367–380.

Lal R. (1994): Soil erosion by wind and water: Problems and prospects. In: R. Lal (ed.): Soil Erosion Research Methods. Soil and Water Conservation Society: 1–9.

McKenna-Neuman C., Nickling W.G. (1989): A theoretical and wind-tunnel investigation of the effect of capillary water on the entrainment of sediment by wind. Canadian Journal of Soil Science, 69: 79–96.

Neff J.C. (2008): Increasing eolian dust deposition in the western United States linked to human activity. Nature Geoscience, 1: 189–195.

Nelson D.W., Sommers L.E. (1982): Total carbon, organic carbon, and organic matter. In: Page A.L., Miller R.H., Keeney D.R. (eds): Method of Soil Analysis. Part 2. 2nd Ed. Madison, ASA: 539–579.

Richards L.A. (1954): Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Hand Book No. 60, Washington, USDA: 7–20.

Seleh A., Fryrear D.W. (1995): Threshold wind velocities of wet soils as affected by wind blown sand. Soil Science, 160: 304–309.

Stroosnijder L. (2007). Rainfall and land degradation. In: Sivakumar M.V.K., Ndiang'ui N. (eds): Climate and Land Degradation. Berlin, Springer: 167–195.

Visser S.M., Sterk G. (2007): Nutrient dynamics – wind and water erosion at the village scale in the Sahel. Land Degradation and Development, 18: 578–588.

Watanabe M., Igishi T., Burioka N., Yamasaki A., Kurai J., Takeuchi H., *et al.* (2011): Pollen augments the influence of desert dust on symptoms of adult asthma patients. Allergology International, 60: 517–524.

Youssef F., Saskia V., Karssenberg D., Erpul G. (2010): The spatial variation in wind-blow sediment transport in small scales in Karapinar-Turkey. Anadolu Journal of Agricultural Sciences, 25(S-2): 80–88.

Zhou Y.Z., Wang X., Yang G.X., Xin X.P. (2008): Influences of land using patterns on the anti-wind erosion of meadow grassland. Huanjing Kexue/Environmental Science, 29: 1394–1399.

Received for publication April 20, 2016
Accepted after corrections August 23, 2016
Published online March 10, 2017