Selcuk J Agr Food Sci, (2018) 32 (3), 355-360
e-ISSN: 2458-8377 DOI: 10.15316/SJAFS.2018.106

Selcuk Journal of Agriculture and Food Sciences

Wind Erosion Risk in Agricultural Soils under Different Tillage Systems in the Middle Anatolia

Kazım ÇARMAN[1], Kazım GÜR[2], Tamer MARAKOĞLU[1]

[1]University of Selcuk, Faculty of Agriculture, Department of Agricultural Machinery and Technology Engineering Konya, Turkey
[2]Bahri Dağdaş International Agricultural Research Institute, Konya, Turkey

ARTICLE INFO

Article history:

Received date: 16.08.2018
Accepted date: 21.09.2018

Keywords:

Wind erosion
Reduced Tillage
Stubble amount

ABSRACT

Today, depending intensive tillage on arid and semi-arid regions, wind erosion is an important environmental problem. Reduced tillage practices are often considered as effective in reducing erosion. In this study, the effects on the wind erosion of different soil tillage applications were examined. Trials were conducted at wind speeds of 13ms-1 in a wind tunnel. After tillage, stubble amount and cover ratio, and mean weighted diameter of soil values were measured. These values were varied from 42.67 to 128 gm-2 for stubble amount, 1.27 to 19.32 % for stubble surface cover ratio and 6.53 to 13.57 mm for mean weighted diameter. At 13 ms-1, sediment transport rates varied from 176 to 1365 gm-2h-1 as depending on different soil tillage. The results showed that the relationships between erosion and shear stress of soil, stubble amount, and mean weighted diameter were found significantly and regression coefficient of relation were R2=0.79, R2=0.95 and R2=0.95 respectively.

1. Introduction

Soil erosion is a major threat to agricultural sustainability in arid and semi-arid areas in Turkey. The loss of soil from current and past management is a major cause of low crop productivity and inefficient use of cropping inputs and can also have significant off-farm adverse impacts on the environment.

Soil erosion occurs through three main processes: wind, water and tillage erosion. Tillage is an important part of crop production and is known to affect wind erosion. However, tillage can also cause its own type of erosion. Tillage erosion is the net down-slope movement of soil that occurs due to tillage practices (Blanco and Lal, 2010).

During wind erosion, particles move by creeping, saltation, or suspension. Most soil particles are transported by saltation, which represents about 50–70% of total wind erosion. About 30–40% of particles are transported by suspension while about 5–25% by surface creep (White, 1997).The transport mode of a particular particle is controlled by wind speed (Greeley and Iversen, 1985). The highest rates of wind erosion have been reported for these areas (Liu et al. 2006).

In arid and semi-arid cultivated areas, where conventional tillage is used, owing to limited vegetation cover, tillage ridges and soil cloddiness are the only soil roughness elements which could help in reducing wind erosion (Fryrear, 1985; Arika et al., 1986). Laboratory-based wind tunnels have been used to analyse the links between soil erodibility and various physical factors to derive a numerical relationship between them (Han et al., 2009; Liu et al., 2006). Wind tunnels provide a controlled environment protecting against variable field conditions in order to investigate the effects of several particular factors on soil erosion behaviour. Wind factors, such as vertical profiles of wind speed and turbulence quantities can be artificially controlled in the wind tunnel and soil factors including soil texture, grain size, water content, surface roughness, soil compactness, etc. can be manually adjusted to be similar to field conditions.

Conservation tillage practices are important options to conserve soil water and produce abundant residues. Continuous cropping with annual and perennial plant species must be practiced on all cultivated soils to reduce risks of wind erosion. Type of tillage directly influences soil roughness and amount of crop residues left on the soil surface. Timing of tillage and type of tillage implements determine the distribution and burial of crop residues. No-till management is a conservation-effective strategy to reduce wind erosion because it leaves most of the residues and maintains an undisturbed soil surface. It improves soil water storage, reduces evaporation, and decreases desiccation. Moist soils are less susceptible to erosion (Blanco and Lal, 2010).

* Corresponding author email: *kcarman@selcuk.edu.tr*

Aggregate size distribution and soil surface roughness are important indicators of wind erosion rate (Zobeck 1991). Because the transport of wind-blown particles is affected mainly by surface roughness (Blumberg and Greeley 1993), aerodynamic roughness is supposed to be an effective index to assess soil erodibility by wind (Zhang et al. 2004). Measurements of the wind erosion rate in different tillage practices using a portable field wind tunnel were done and also a neural network was analyzed for the prediction of the wind erosion rate by Çarman et al., (2016). The overall results show that the artificial neural network can be used as an alternative method to find the wind erosion rate in these systems.

The lack of rainfall in the Middle Anatolia (<300mm), have extremely low organic matter in the soil (<1%). In addition, seed bed preparation is important in the region shown as grain store due to the most risk of the turkey. In this study, some physico-mechanical properties of soil and its effect on soil erosion have been evaluated in 4 different alternative tillage systems which can be used as examples of today's widely used protective soil treatment and direct sowing practices. In addition, some physical properties of the soil and the relationship between erosion is revealed. In this study, wind erosion was measured using a portable wind erosion tunnel in a semi-arid field.

2. Materials and Methods

The experiments were conducted in the field of Soil, Water and Combating Desertification Research Station (E32o31', N37o52', and 1050 m a.s.l.) in the fall of 2012. It is 10 km away from Konya province, which is located in the Middle Anatolia region of Turkey. The soils are classified as Typic Xerfluent in the US Soil Taxonomy. Physical and mechanical properties of the soil in the experiment field are given in Table 1.

Table 1
The some properties of soil and long-term weather data at the experimental station.

Texture (%)	Sand	36.88
	Clay	42.94
	Silt	20.18
Moisture content (%)		15.9
Organic matter (%)		0.76
Penetration resistance (MPa)		2.09
Surface roughness (%)		4.56
Shear stress (N cm^{-2})		2.23
Stubble amount (g m^{-2})		144
Long-term (64 years) weather Parameters		
Minimum air temperature (°C)		-26.5
Maximum air temperature (°C)		40.6
Average air temperature (°C)		11.6
Minimum precipitation (mm)		171.6
Maximum precipitation (mm)		413
Average precipitation (mm)		319.7
Maximum wind speed (m s^{-1})		13.2
Average wind speed (m s^{-1})		2.2

The experiments were carried out for five different tillage applications (Table 2). Some technical properties of the machines are presented in Table 3. Soil tillage applications were performed on October 15–16, 2012. The design of the experiment was a randomized complete block with three replications. Individual plot size was 100 × 10 m.

Table 2
Tillage treatments

I.	Conventional tillage (CT)	Moldboard plow + cultivator-float (two times)
II.	Reduced tillage (RTC)	Winged chisel plow-float
III.	Reduced tillage (RTVR)	Vertical shaft rototiller-float
IV.	Reduced tillage (RTHR)	Horizontal shaft rototiller (L-type foot)-float
V.	No tillage (NT)	Zero tillage

Table 3
The specifications of the tools used in experiment

Application	Working width (cm)	Working depth (cm)	Peripheral speed (m s^{-1})	Average speed (km h^{-1})
Horizontal shaft rototiller	250	13	5.5	2.6
Vertical shaft rototiller	215	18	5.3	3.2
Moldboard plow	120	22	-	5.5
Winged chisel plow	215	22	-	2.8

Samples were collected from a depth of 0-20 cm of soil to determine mean weight diameter of soil. The samples were passed in sieves with a mesh size of 40, 20, 16, 8, 4, and 2 mm. A total of 7 fractions were obtained. The fractions were weighted separately and 5 values were found. The following equations were used to find the mean weight diameter (MWD) (Black ve ark.1965).

MWD = Σ Xi Wi

Where;

Xi: Average diameter of any particle size group of i. aggregates separated by the sieve (mm).

Wi: Weight of the aggregates in i. size group of the analyzed total dry weight (g).

The soil shear testing device was used in order to determine the soil shearing strength which has a 10 cm diameter (d) and 12 cm height (h). Torque arm having a measuring range of 0-80 Nm was impaled on shear vane. The maximum torque was obtained via soil shear testing device as shearing strength (τ) was obtained by the following equation (Okello 1991):

$$\tau = T / [\pi d2 (h/2 + d/6)]$$

To determination of stubble intensity, digital camera was used. Images that were taken by camera were saved to the computer environment in picture format. MATLAB program was used to digitise stubble intensity.

In order to measure the wind erosion rate, the experiments were carried out using a portable field wind tunnel. The system consisted of three parts: a wind generator for producing different wind speeds, a working section with a cross-sectional area of 1 × 1 m, and a sediment collector. Moreover, it was a suctiontype tunnel with a 9 × 1 m working section that was placed on the field surface of each individual plot. The prepared surface (after tillage) was allowed to dry for at least 2 h prior to testing. Experiments were conducted for 30 min at a wind velocity of 13 m s-1. Sediment fluxes were measured with BEST cyclone-type dust (sediment) catchers (Basaran et al., 2011) that were placed on a vertical post at heights of 0.07, 0.24, 0.45, 0.70 and 0.95 m (Maurer et al., 2006). After each run, the sediment was collected; oven dried at 105°C, and weighed on a balance. To obtain the wind erosion rate (g m-2 h-1), the mass of the sediment (g) was divided by the test area (m2) and event duration (h) (Zamani and Mahmoodabadi, 2013; Çarman et al. 2016). Measurements were made once after one day from tillage in both years.

3. Results and Discussion

The effects of different tillage applications on shear stress of soil were given in figüre 1. Values of shear stress of soi varied between 0.59 and 2.23 N cm-2 as a depending on different tillage. As decreasing of 80 %, highest ratio of change in shear stress of soil was obtained in vertical shaft rotary tiller (RTVR).

Figure 1
The effect of treatments on shear stress of soil.

The effects of different tillage applications on fragmentation level of the soil (mean weight diameter) were shown in figüre 2. Mean weight diameter of the soil varied between 6.53 and 13.57 mm based on different tillage. The highest mean weight diameter was obtained in no tillage. The lowest change (14.7 %) was obtained from modified winged chisel practice, and the highest change (51.8 %) was obtained from practice performed by horizontal shaft rotary tiller. In the research performed by horizontal and vertical shaft rotary tillers that driven by PTO, Önal and Aykas (1993) determined that the mean weight diameter values of the soil ranged between 14.6 and 16.5 mm. Çarman et. al. (2012) found out that the mean weight diameter of two horizontal and one vertical shaft rotary tillers ranged between 7.28 and 11.76 mm.

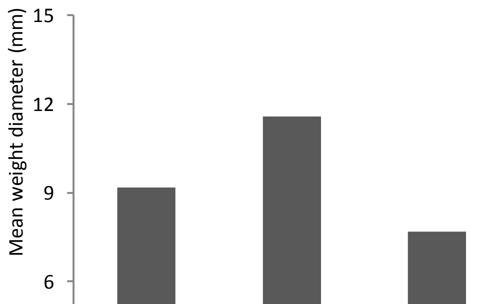

Figure 2
The effect of treatments on mean weight diameter of soil.

The amount of stubble that was left in the field after alternative tillage practices varied between 68 and 128 g m-2 (Figure 3). The effect on soil surface coverage ratio of stubble was given in figure 3. Soil surface covering ratios of stubble ranged between 1.27 % and 19.32 %. The highest surface covering ratio was obtained in no tillage practice (19.32 %), and the lowest surface covering ratio was obtained in conventional practice (1.27 %). Since stubble burial ratio was high in conventional practice, it caused covering ratio to remain low. In this region, the stubble is collected by the farmers after the harvest so that the stubble amount are low. Also, the grazing of small animals in the post-harvest stubble areas has caused this. Scott et. al. (2010) determined in their researches that the soil surface covering ratio of stubble, which remain vertically on the field surface, was 30% in conservation tillage practices. Inaddition, the soil surface covering ratio of leaned stubbles was ranging between 50% and 60% and they underlined that these figures are critical in terms of erosion. It was considered significant, in terms of conservation agriculture technique, that the surface covering ratio was realized under 30%, which was considered as reference value. The effect of alternative tillage practices on stubble covering ratio was found significantly (P<0.01).

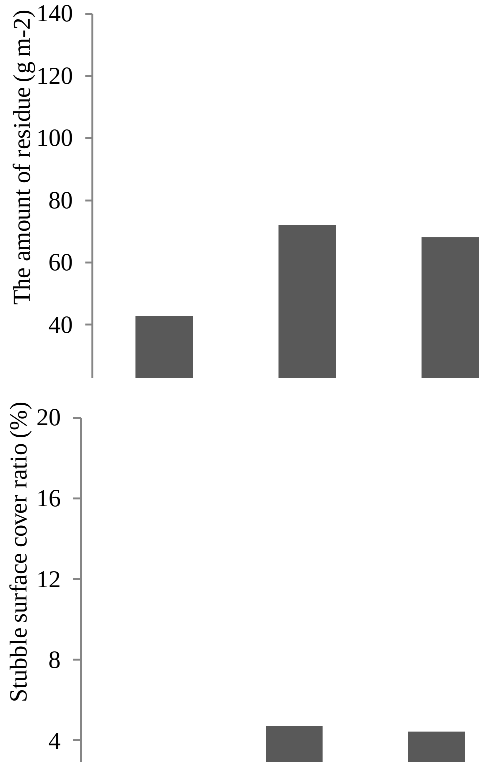

Figure 3

The effect of treatments on stubble amount and stubble surface cover ratio.

The wind erosion rates varied between 176 and 1365 g m-2 h-1 depending on five different tillage applications (Figure 4). On average, the lowest value of the wind erosion rate from a tillage was obtained in the application of no tillage and the highest value was obtained in the application of the horizontal shaft rotary tiller (L-type foot)-float. The variance analysis performed on erosion values showed an important difference between applications (P<0.01). While the difference between conventional (CT) and RTVE applications is not significant, the difference between other reduced and direct seeding practices is significant. A large activity of soil fragmenting according to the horizontal shaft rotary tiller caused the achievement of values of about more than 20.8 % of the wind erosion rate compared with the vertical shaft rotary tiller. Despite the increasing soil deformation in the winged chisel plow, the application of the vertical rupture soil tillage of the chisel plow, on average less than 40.3 % of the wind erosion rates were realized as compared with the other practices of the reduced tillage.

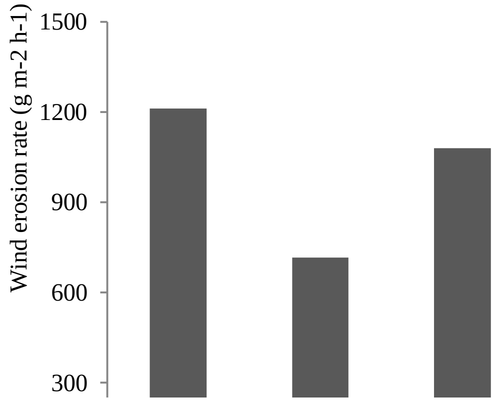

Figure 4

The effect of treatments on wind erosion rate.

The erosion rates at a wind speed of 18 m s-1 were estimated as 950 g m-2 min-1 for the sandy soil (2 mm), 175 g m-2 min-1 for the cultivated soil (2 mm), and 28 g m-2 min-1 for the cultivated soil (10 mm) (Zamani and Mahmoodabadi, 2013). Due to a very small mean weight diameter of the soil used in that study, the results shown in Figure 4 are lower than the results of that study. Liu et al. (2006) measured the rates of soil wind erosion as 40.49 g m-2 min-1 for the conventional flat tillage and as 16.70–26.32 g m-2 min-1 for different ridge tillage applications at a wind velocity of 15 m s-1. The results of that study are similar to our results.

The relationship between shear stress of soil values and erosion values is given in Figure 5. It shows that the erosion values decrease with increasing shear stress of soil and it is determined that there is a exponential relation between the two independent variables and that the regression coefficient (R2 = 0.79) is high.

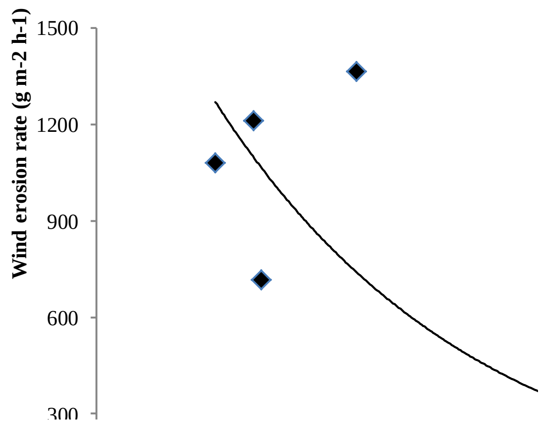

Figure 5

Relationship between shear stress of soil and erosion

The relationship between weighted mean diameter of soil and erosion values is given in Figure 6. It shows that the erosion values decrease with increasing weighted mean diameter values of soil and it is determined that there is a polynomial relation between the two independent variables and that the regression coefficient (R2 = 0.95) is very high.

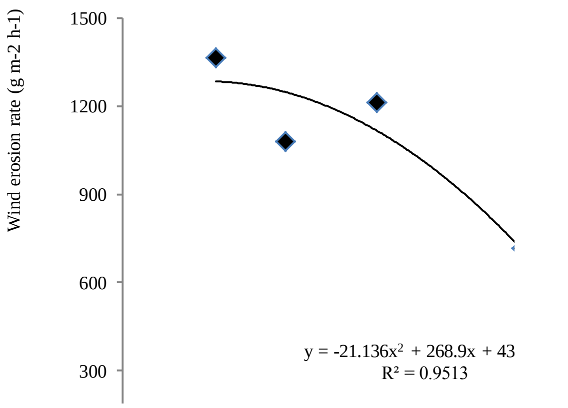

Figure 6
Relationship between weighted average diameter of soil and erosion

The relationship between the amount of residue and erosion values is given in Figure 7. It shows that the erosion values decrease with increasing the amount of residue and it is determined that there is a exponential relation between the two independent variables and that the regression coefficient (R2 = 0.95) is very high.

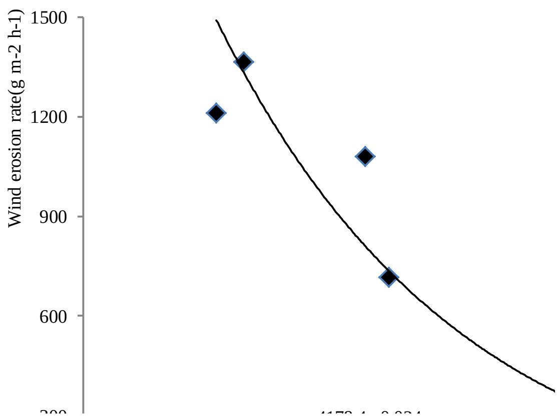

Figure 7
Relationship between the amount of residue and erosion

- In conclusion, the findings can be evaluated as follows:

- In particular, weighted average diameter values are found to be smaller due to the fact that the soil fragmentation activity is higher in the horizontal shaft rotary tiller machines pto-driven.

- In conventional practice, the high burial rate of stubble has led to a low surface coverage rate. The low amount of stubble on the surface before tillage caused the surface stubble coverage rates to be lower than the reference value in terms of protective tillage technique in all applications.

- The highest soil erosion was found in horizontal shaft rotary tiller applications. This is caused by the fact that the mean weight diameter of soil and the surface stubble coverage rates are low due to the intensive tillage in the application of horizontal shaft rotary tiller.

- Intensive cultivation accelerates and exacerbates soil erosion so that conservation tillage is a major factor to reduce soil erosion. When compared to other applications, in no tillage reduced erosion by 75-87 %.

4. References

Arika C. L., Gregoy, J. M., Borrelli, J., Zartman, R. E., 1986. A ridge and clod wind erosion model, ASAE Paper, No. 86-2531, St. Joseph, MI.

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 (3–4): 343-351.

Black C. A., 1965. Methods of soil analysis. Part I. American Society of Agronomy, Agronomy, 9.

Blanco H., Lal R. 2010. Principles of soil conservation and management, p. 109–133

Blumberg D.G., Greeley R., 1993. Field studies of aerodynamic roughness length. Journal of Arid Environments, 25: 39-48.

Çarman K., Marakoğlu T., Çıtıl E. Gür K., 2012. Kuyruk Milinden Hareketli Bazı Toprak İşleme Makinelerinin Koruyucu Toprak İşleme Açısından Değerlendirilmesi. Tarım Makineleri Bilimi Dergisi,

8(4), 345-352.

Çarman K., Marakoğlu T., Taner A., Mikailsoy F., 2016. Measurements and modelling of wind erosion rate in different tillage practices using a portable wind erosion tunnel. Zemdirbyste-Agriculture, 103(3), 327–334

Fryrear D.W., 1985. Soil cover and wind erosion, Transaction of the ASAE, 28, 781-784.

Greeley R., and Iversen, J. D., 1985. Wind as a geological process on Earth, Mars, Venus and Titan, Cambridge University Press, Cambridge, 333 pp.

Han Q., Qu, J., Zhang, K., Zu, R., Niu, Q., & Liao, K., 2009. Wind tunnel investigation of the influence of surface moisture content on the entrainment and erosion of beach sand by wind using sands from tropical humid coastal southern China. Geomorphology, 104, 230-237.

Liu M., Wang J., Yan P., Liu L., Ge Y., Li X., Hu X., Song Y., Wang L. 2006. Wind tunnel simulation of ridge-tillage effects on soil erosion from cropland. Soil and Tillage Research, 90: 242–249

Maurer T., Herrmann L., Gaiser T., Mounkaila M., Stahr K. 2006. A mobile wind tunnel for wind erosion field measurements. Journal of Arid Environments, 66: 257–271

Okello J. A., 1991. A review of soil strength measurement techniques for prediction of terrain vehicle

performance. Journal of Agricultural Engineering Research 50: 129-155

Önal İ., Aykas E., 1993. The effects of some pto-driven rotary-tillers on the soil, wheat growth and operational characteristics under the Agean region. 5th International Congress on Mechanization and Energy in Agriculture, Kuşadası, pp: 119-130.

Scott B.J., Eberbach P.L., Evans J. and Wade L.J., 2010. EH graham centre monograph. No 1: Stubble Retention In Cropping Systems. In Southern Australia: Benefits and challenges: www.grahamcentre.net

White R.E., 1997. Principles and practice of soil science: The soil as a natural resource, 3rd edn. Blackwell, Oxford

Zamani S., Mahmoodabadi M., 2013. Effect of particlesize distribution on wind erosion rate and soil

erodibility. Archives of Agronomy and Soil Science, 59 (12): 1743–1753.

Zhang C., Zou X., Gong J, Liu L., Liu Y., 2004. Aerodynamic roughness of cultivated soil and its influences on soil erosion by wind in a wind tunnel. Soil Tillage Research. 75: 53–59.

Zobeck T.M., 1991. Soil properties affecting wind erosion. Journal of Soil and Water Conservation, 46: 112–118.