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Soil coverage evolution and wind erosion risk on summer crops under contrasting tillage systems

Mariano J. Mendez [a,*], Daniel E. Buschiazzo [a,b]

[a] National University of La Pampa, Faculty of Agronomy (UNLPam) and Institute for Earth and Environmental Sciences of La Pampa (INCITAP, CONICET-UNLPam), Argentina, cc 300, 6300 Santa Rosa, Argentina

[b] Anguil Experimental Station, National Institute for Agricultural Technology (INTA), Santa Rosa, Argentina

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ABSTRACT

The effectiveness of wind erosion control by soil surface conditions and crop and weed canopy has been well studied in wind tunnel experiments. The aim of this study is to assess the combined effects of these variables under field conditions. Soil surface conditions, crop and weed coverage, plant residue, and non-erodible aggregates (NEA) were measured in the field between the fallow start and the growth period of sunflower (*Helianthus annuus*) and corn (*Zea mays*). Both crops were planted on a sandy-loam Entic Haplustoll with conventional-(CT), vertical-(VT) and no-till (NT) tillage systems. Wind erosion was estimated by means of the spreadsheet version the Revised Wind Erosion Equation and the soil coverage was measured each 15 days. Results indicated that wind erosion was mostly negligible in NT, exceeding the tolerable levels (estimated between 300 and 1400 kg ha^{-1} year^{-1} by Verheijen et al. (2009)) only in an year with high climatic erosivity. Wind erosion exceeded the tolerable levels in most cases in CT and VT, reaching values of 17,400 kg ha^{-1}. Wind erosion was 2–10 times higher after planting of both crops than during fallows. During the fallows, the soil was mostly well covered with plant residues and NEA in CT and VT and with residues and weeds in NT. High wind erosion amounts occurring 30 days after planting in all tillage systems were produced by the destruction of coarse aggregates and the burying of plant residues during planting operations and rains. Differences in soil protection after planting were given by residues of previous crops and growing weeds. The growth of weeds 2–4 weeks after crop planting contributed to reduce wind erosion without impacting in crops yields. An accurate weeds management in semiarid lands can contribute significantly to control wind erosion. More field studies are needed in order to develop management strategies to reduce wind erosion.

1. Introduction

Wind erosion of arid and semiarid regions of the world, including the semiarid Pampas of Argentina, is an important soil degradation process (Peterson et al., 2006; Buschiazzo et al., 1999). In addition, this process produces particulate matter smaller than 10 μm (PM10) which have negative effects on human health and affect some physical and chemical processes in the atmosphere like the formation of clouds and the radiation budget (Pope et al., 1995; Seinfeld and Pandis, 1997). Wind erosion of cultivated soil depends on the surface soil coverage with plant canopy and residues as well as the soil surface roughness produced by tillage practices. The effectiveness of these parameters in controlling wind erosion has been mostly quantified, under controlled wind tunnel conditions (Fryrear, 1984; Bilbro and Fryrear, 1994; Armbrust and Bilbro, 1997). However, little is known about the combined effect of all these cover types on wind erosion of summer crops under field conditions. The main advantage of agricultural field studies is that they provide information about the interactions that affect the success of the system and as such may better represent true farming systems (Nokes et al., 1997). The major disadvantage is the difficulty in understanding specific causal relationships because of the variability introduced by different farming practices (Temple et al., 1994). The influence of each soil cover component in real production systems changes with time depending on tillage operations, crop growth habits, fallow length, weed growth and, above all, climatic conditions. Under field conditions, weeds develop during the fallow and crop growth. However, previous wind erosion studies have not taken into account the soil protection given by weeds together with other types of soil cover like non-erodible

* Corresponding author. Tel./fax: +54 02954 433092.
E-mail addresses: marianomendezz@hotmail.com (M.J. Mendez), buschiazzo@agro.unlpam.edu.ar (D.E. Buschiazzo).

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aggregates, residues and crop canopy. For this reason, it is necessary to measure the soil protection given by weeds in order to assess their contribution to wind erosion control in different tillage systems.

The determination of the relative effect of each kind of cover on wind erosion as a function of time can be useful to decide management systems that minimize soil degradation and to develop additional functions in the currently available wind erosion prediction models. Most of existing studies of soil protection against wind erosion by crops were carried out for two small grain crops: spring wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) (Merrill et al., 1999; López et al., 2003; Mendez and Buschiazzo, 2010), but less information is available for large grain crops like corn (*Zea mays*) or sunflower (*Helianthus annuus*). In the central semiarid pampas of Argentina the more important large grains crops are cropped in between the Spring and the Summer. In the central semiarid pampas of Argentina, the climatic erosivity is higher during the spring when winter crops are in advanced vegetative stages and summer crops are planted (Panebianco and Buschiazzo, 2008). Because of that, we expect that wind erosion of large grain summer crops will be higher than for winter crops (Mendez and Buschiazzo, 2010).

The objective of this study was to assess the temporal variation of wind erosion as a function of the soil cover on summer crops under contrasting tillage systems.

2. Materials and methods

The study was conducted on the long term experimental plots of the Faculty of Agronomy of the University of La Pampa, Argentina (S36° 46′; W64° 16′; 210 m a.s.l.) where different tillage systems are compared (Fig. 1). The Faculty of Agronomy of the University of La Pampa is located in the center of Argentina, inside of the central semiarid pampas. This region represents the frontier between cultivated areas (eastward) and grassland areas (westward). This semiarid region has a mean annual precipitation of 764 mm and the mean annual temperature is 15.5 °C for the period 1971–2001. Prevailing winds blow from the north and the south, with higher speeds and gusts up to 60 km h^{-1} during the spring and the summer (Casagrande and Vergara, 1996).

Soil losses by wind erosion were estimated with the spreadsheet version of RWEQ in order to reach the aims of the paper.

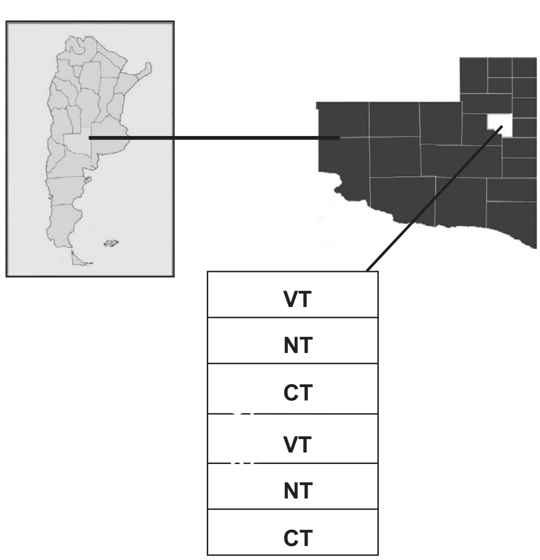

Fig. 1. Location of the study site and layout of the experimental plots. CT, conventional tillage; NT, no-tillage; and VT, vertical tillage.

2.1. RWEQ model description

RWEQ is an empirical model used to estimate long-term soil loss due to wind erosion (Fryrear et al., 1998). Soil movement is presented by a steady state equation that assumes the existence of a wind transport capacity. Soil transported by the wind is estimated with the following equation (Fryrear and Saleh, 1996).

$$Q(x) = Q_{max}\{1 - \exp[-(x/s)^2]\} \quad (1)$$

where $Q(x)$ is the amount of soil transported by the wind past a point x, Q_{max} is the maximum amount of soil that can be transported downwind and s is critical field length at which the transported load is 63.2% of Q_{max}.

The parameter Q_{max} and s are determinate by equation:

$$Q_{max} = 109.8\,x\,(WF \times EF \times SCF \times K \times COG) \quad (2)$$

$$s = 150.71\,x\,(WF \times EF \times SCF \times K \times COG)^{-0.3711} \quad (3)$$

Where WF is the weather factor, EF is the erodible fraction (aggregates <0.84 mm), SCF is the soil crust factor, K is the soil roughness factor and COG is the combined residues-plant materials factor.

The factor WF, SCF, K and COG are expressed as soil loss ratio (SLR) which is the quotient between the soil loss with the factor and without the factor. The SRL values are between 0 and 1. The weather factor (WF) is the product of a wind-erosivity factor and two wind-erodibility factors, one for soil water content and the other for snow cover. The weather factor is estimated with the follow equation:

$$WF = Wf\frac{\rho}{g}(SW)SD \quad (4)$$

Where WF Weather Factor kg m^{-1}, Wf wind factor (m s^{-1})^3, air density kg m^{-3}, g acceleration due to gravity m s^{-1} s^{-1}, SW soil wetness dimensionless and SD snow cover factor.

In the spreadsheet version of RWEQ the wind factor is equal to wind value (W) that is calculated with the following equation:

$$W = \sum_{i=1}^{N} U_2(U_2 - U_t)^2 \quad (5)$$

Where W wind value (m s^{-1})^3, U_2 wind speed at 2 m meters height, U_t threshold wind speed at 2 m (assumed 5 m s^{-1}) and N number of wind speed observations (i) in a time period of 1–15 days.

The snow cover factor was 1 (no snow limitation) in all cases because snow does not falls in the study region. The soil wetness factor was 1 (no wetness limitation) in all cases and no erosion was calculated during the first three days after a rain event. The equation to calculate snow cover factor and soil wetness factor can be consulted in the RWEQ user manual.

The erodible fraction (EF) is represented by the aggregates <0.84 m which can be transported by the wind (Chepil, 1942). The erodible fraction was estimated by the RWEQ model by the following equation:

$$EF = (29.09 + 0.31Sa + 0.17Si + 0.33Sa/Cl - 2.59OM - 0.95CaCO_3)/100 \quad (6)$$

where Sa sand content (%), Si silt content (%), Sa/Cl sand to clay ratio, OM organic matter and $CaCO_3$ calcium carbonate.

Soil crust factor (SCF) was calculated with the following equation:

$$SCF = 1/(1 + 0.0066(CL)^2 + 0.021(OM)^2) \quad (7)$$

Where CL is percent clay and OM is percent organic matter.

The soil roughness factor (K) is the product of the random roughness and oriented roughness. The random roughness is caused by clods or non-erodibles aggregates over soil surface and