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Wind erosion risk in agricultural soils under different tillage systems in the semiarid Pampas of Argentina

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ABSTRACT

The effect of plant residues, plant canopy and non-erodible soil aggregates on wind erosion has been mostly evaluated under controlled wind tunnel conditions. Little is known about their combined effect under field conditions. Wheat of different growth lengths are widely cropped in the semiarid Pampas of Argentina (SAP) under different tillage systems. Aim of this study was to measure the soil cover in wheat types of different growth lengths, cropped under three tillage systems, and their effects on wind erosion in a semiarid environment of Argentina. Measurements of the soil coverage with crops canopy, stubble and soil aggregates were done 15 days each during a wet (2005) and a dry (2006) year on a sandy loam Entic Haplustoll of the semiarid Pampas. On the basis of climatic and soil coverage data wind erosion was estimated with the Revised Wind Erosion Equation (RWEQ). Results showed that wind erosion was lower in no-till (NT) than in vertical- (VT) or conventional tillage (CT) in all wheat types due to high soil coverage with plant residues (83% of total soil cover during fallow). In contrast, during fallow in CT and VT, a 16% of soil was covered with non-erodible aggregates (64% of total cover) and plant residues (32%). As a result, the hazard of wind erosion was high in CT and VT (899 and 1002 kg ha^{-1}, respectively). Regarding the wheat types, wind erosion amounts of CT and VT were, in average of both sampling years, lower in long cycle wheat (LCW, 635 kg ha^{-1}) than in intermediate cycle wheat (ICW, 980 kg ha^{-1}) and short cycle wheat (SCW, 1237 kg ha^{-1}). The higher wind erosion of SCW was produced by the simultaneous occurrence of minimum soil coverage and high climatic erosivity just after crop seeding. In NT wind erosion was low in all cases (between 0 and 31 kg ha^{-1}). However, high wind erosion amounts (1500 kg ha^{-1}) can occur in NT after crop seeding. SCW cropped with CT and VT must be avoided in the studied region, in order to make an efficient wind erosion control. No-till was the best system for controlling wind erosion, though, moderate wind erosion amounts can occur in this system during short periods of time after seeding of all wheat types.

1. Introduction

Wind erosion is an important soil degradation process in arid and semiarid regions of the world (Peterson et al., 2006), including the semiarid Pampas of Argentina (SAP) (Buschiazzo et al., 1999). In cultivated fields wind erosion depends mostly on the soil coverage with plant canopy or plant residues and on the soil surface roughness produced by tillage practices. The effectiveness of these parameters in controlling wind erosion has been mostly quantified separately and under controlled conditions (Fryrear, 1984; Bilbro and Fryrear, 1994; Armbrust and Bilbro, 1997). Little is known about their combined effect under natural field conditions.

Soil coverage of 30% with plant residues or canopy is effective in controlling wind erosion, since this soil coverage lying residues control 70% of wind erosion and crops canopy a 90% (Fryrear et al., 1998). Nevertheless, other authors stated that wind erosion control effectivity depends on crop type, management system and climatic conditions (Mendez and Buschiazzo, 2008). In some regions it can be seen that the susceptibility of the soil to wind erosion during winter crops fallows is high (López et al., 2003). Therefore, small grain crops like wheat are important in these systems for controlling wind erosion (Krupinsky et al., 2007).

Wheat is an important crop in the semiarid Argentinian Pampas (SAP) (REPAGRO, 2005), where it is seeded at different dates and cropped under different tillage systems (Buschiazzo, 2006). Little is know about the wind erosion risk of different wheat canopies and tillage systems on wind erosion in SAP.

The available models to predict wind erosion, like the Revised Wind Erosion Equation (Fryrear et al., 1998) or the Wind Erosion Prediction Model (Hagen, 1991), include crop subroutines for

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wheat with spring and winter wheats. Such wheat types do not have the same growth habits than wheat cropped in the semiarid Pampas and other parts of the world.

NT has been mostly described as an efficient system in controlling wind erosion because it left a large amount of plant residues on the soil surface (Thorne et al., 2003; Merrill et al., 2004). Though, these authors showed that after wheat seeding a short period with high soil susceptibility to wind erosion existed, even in NT. Tillage systems which include residue removal with ploughs can leave the soil bare but rough by the formation of clods. This can occur mostly in the fallow and during plant emergence. A question can be therefore stated regarding the efficiency of each tillage system in controlling wind erosion.

It is known that plant residues provide an effective control of wind erosion, but their temporal variation with time, as a function of seasonal climatic changes, and its relation to wind control efficiency provided by plant canopy and clods formed by ploughs which increase the soil surface roughness, have been less studied. According to that it is expected that wind erosion will be mostly controlled by plant residues in NT and by soil aggregates in tillage systems where the soil is disturbed. Wind erosion control will be more efficient in NT than in the other tillage systems.

The aim of this paper was to evaluate the amount of soil cover under variable wheat types and different tillage systems and its effects on wind erosion amounts.

2. Materials and methods

This study was carried out in a long-term tillage experiment developed since 1996 in the Faculty of Agronomy of the University of La Pampa, Argentina (S36°46′; W64°16′; 210 m a.s.l.). The mean annual precipitation of this semiarid study site is 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). The soil of the studied site was an Entic Haplustoll with an A horizon containing 2.37% organic matter, 12.8% clay, 62.0% sand, 25.2% free lime, pH of 6 and P (extractable Bray) 19 mg kg^{-1}.

Measurements of soil cover were carried out on three 4.5 ha plots, each submitted to conventional tillage (CT), vertical tillage (VT) and no-tillage (NT). Before experiment starts, all plots were planted with sunflower (*Helianthus annus*) which was harvested in March 2005 and 2006. Weeds were controlled with disk in CT and with disk and chisel in VT. Weeds were always controlled with herbicides in NT (Glifosate and 2–4 d) and after wheat seeding in VT and CT.

Each 4.5 ha plot was divided into three 1.5 ha subplots. In each subplot a different wheat type was seeded: long cycle wheat (LCW), intermediate cycle wheat (ICW) and short cycle wheat (SCW). The combination of three tillage systems and three wheat types produced nine treatments.

In each treatment the soil coverage with plant rests (including stubble mulch and weed rests), wheat canopy, weeds (living weeds) and non-erodible aggregates (greater than 10 mm in diameter) were measured each 15 days by triplicate during 2005 and 2006.

Soil cover was measured by means of digital photographs of the soil surface, taken in different moments since fallow start and wheat growth. The photographs were randomly taken at each sampling subplot from three 1 m^2 soil surfaces, perpendicularly to the soil surface from 1.5 m height. The Paint Shop Pro 7 PC program was used to determine the soil coverage as follows: each digital photograph was divided into a 4 cm × 4 cm grid in the PC screen, producing a total of 126 crossing points; the percentage of soil cover was then determined as the quotient between the number of crossing points with flat residues, non-erodible aggregates, weed and canopy cover and the total amount of crossing points of the grid.

A meteorological station was installed close to the experimental field in order to register wind speed at 2 m height, as well as air temperature and precipitation. Based on the averaged wind speeds, monthly temperatures and rains, the climatic erosivity of the Wind Erosion Equation represented by the *C*-factor, which combines the effect of monthly rains and temperatures of a given region, was calculated (WEQ, Woodruff and Siddoway, 1965) (Eq. (1)). Such data are listed in detail in Table 1.

Wind erosion was estimated with the stand alone version of RWEQ (Fryrear et al., 1998), developed by Zobeck (personal communication) in an Excel spreadsheet. This model was found to be adequate to predict wind erosion in the semiarid Pampas of Argentina (Buschiazzo and Zobeck, 2008).

$$C\text{-factor} = 386\left[\frac{U^3}{((P/2.54)/(1.8T+32))^{10/9}}\right] \qquad (1)$$

where U is the mean monthly wind speed at 10 m height expressed in m s^{-1}, P is the mean monthly precipitation expressed in mm and T is the mean monthly temperature expressed in °C.

Wind erosion was calculated for each individual storm and treatment by loading the model with the following information: contents of soil organic matter, clay, silt, and, one minute wind speed averages (m s^{-1}) and soil coverage with plant residues, wheat canopy, weeds and non-erodible aggregates. The humidity factor was 1 in all cases and no erosion was calculated during the first three days after a rain event. Wind erosion amounts were calculated for periods of time when wind speeds were higher than 5 m s^{-1} at 2 m height, the threshold wind velocity considered by RWEQ (Fryrear et al., 1998).

The wind value considered by the RWEQ was calculated with Eq. (2) for each single storm.

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

Table 1
Main climatic conditions during the sampling periods.

	Year	April	May	June	July	August	September	Total	Mean
Temperature (°C)	2005	14.7	10.9	8.4	8.5	9.7	11.9	–	10.7
	2006	16.1	10.1	9.2	5.7	10.4	13.1	–	10.8
Precipitation (mm)	2005	0.2	29.3	20.9	6.8	13.6	58.4	129	–
	2006	28	0.4	2.4	1.8	0	23.6	56	–
Wind speed at 2 m height (m s^{-1})	2005	2.1	1.5	1.0	2.2	2.4	3.0	–	2.1
	2006	1.3	3.4	2.9	3.3	3.8	3.9	–	3.1
C-factor	2005	17.0	7.1	1.9	20.6	27.4	50.6	–	20.7
	2006	3.9	73.6	45.3	66.5	105.1	109.8	–	67.4