Soil & Tillage Research 153 (2015) 112–119

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Wind erosion control utilizing standing corn residue in Northeast China

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ARTICLE INFO

Article history:
Received 20 March 2015
Received in revised form 18 May 2015
Accepted 19 May 2015

Keywords:
Soil wind erosion
Standing corn residue
Conservation management
Aerodynamic roughness length
Saltation probability

ABSTRACT

Soil wind erosion is a serious concern in agricultural regions. Wind erosion is of particular concern in Northeast China where a north continental monsoon climate is prevalent and land is prepared for seeding using an ancient ridge culture technique. Cultural reluctance to adopting a cropping strategy that leaves residues is also based on local population use of corn stalks as animal fodder and fuel. In order to evaluate the conservation effects of standing residue on controlling soil wind erosion, a 4-year study (2011–2014) was conducted near Changchun city in Northeast China. Four experimental treatments were used: un-fixed corn residue coverage (shattering/cutting the corn stalks into small sections and spreading them on the soil surface) and three treatments with the standing corn residue of different height for each treatment; 30-, 40- and 50-cm.[1] The corn stalk residue above that which remained in each treatment was removed from the field as much as practical. The standing residue treatments also resulted in some soil coverage by fugitive leaves and small stalk pieces. The experimental design was four treatments replicated four times, with years as replicates. Soil loss from the un-fixed corn residue coverage treatment and soil sediment from the standing residue coverage treatments was measured. Standing residue with the heights of 30-, 40- and 50-cm increased mean aerodynamic roughness length (equivalent to the height at which the wind speed theoretically becomes zero) by 19.87, 43.77 and 61.62, respectively, and increased mean threshold wind speed by 11, 25 and 33%, respectively. Mean monthly soil loss mass balance for un-fixed corn residue was 1.27 Mg ha^{-1}, and the mean monthly values for soil sediment mass balance were 0.725, 1.088 and 1.967 Mg ha^{-1} for 30-, 40- and 50-cm standing residue treatments, respectively. These experiments indicate that standing residue conservation management can act as an effective way to control soil wind erosion, while providing a portion of corn stalks for the local population to continue using as animal fodder and fuel.

1. Introduction

Soil loss from wind erosion is the result of transportation of soil particles by suspension, saltation, and surface creep. The mode of transport of soil particles during wind erosion is governed by soil particle size. Small particles (<0.1 mm) from pulverized soils are preferentially transported in suspension, medium-sized particles (0.1–0.5 mm) by saltation, and large particles (0.5–2 mm) by surface creep (Blanco-Canqui and Lal, 2008). Among the three methods of particle transport, saltation accounts for about 50 to 80% of total soil particle transport, and saltation particles commonly rise less than 120 cm; most saltation particles rise less than 30 cm (Lyles, 1988).

Soil wind erosion is a worldwide phenomenon (Li et al., 2014). It not only pollutes air and decreases visibility, but also damages crops through wind-blasts, buries roads and fences, as well as damages human health and causes desertification (Churchman et al., 2010; Lal, 2001). Soil wind erosion causes land degradation, and accounts for about 28% of world's degraded land (Oldman, 1994). Soil loss from wind erosion occurs primarily in arid, semiarid climates and windy regions (Lu et al., 2014). In China, wind erosion is a significant problem for about 16.7% (about 1.6×10^6 km^2) of the country (Hao-ming et al., 2005). Serious soil erosion in Northeast China, also called the 'Black Soil Zone' has

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[1] The treatment with soil surface covered with small pieces of un-fixed, loose corn residue is designated as PA. The 30-cm high standing corn residue treatment is designated as PB; 40-cm treatment as PC; and 50-cm treatment as PD. Saltation probability is designated as Pi.

http://dx.doi.org/10.1016/j.still.2015.05.009
0167-1987/

occurred since the large-scale cultivation of native prairies beginning after the end of the revolution in 1949 and extending into the early 1950s. Tillage in the region is dominated by a 'ridge culture'. The field soil is tilled several times, both fall and early spring and ridges are formed from the pulverized soil prior to seeding, with about 40 cm height difference from the bottom to top of the ridges. The ridges are different widths and distances apart depending on farmer experience and choice of crop. This region has a relatively dry, monsoon climate, and there are usually strong winds in spring and autumn. Portions of the dark prairie surface soil is eroded by wind year by year, so the overall soil productivity has declined (Honglei et al., 2005). The average annual thickness of soil lost in the dark surface epipedon is 0.3–1 cm; consequently, the thickness of this originally black horizon has decreased from 60 to 70 cm in the early 1950s to 20 to 30 cm by 2003 (Hao-ming et al., 2005). In order to control soil erosion, 'conservation management' has been proposed to halt land degradation. The main methods of soil conservation are minimum tillage or no-tillage, and covering the land surface with crop residue. These conservation methods produce a more granular structure within the topsoil and increases the soil's moisture retention abilities (Fa-peng et al., 2006). These conservation methods are suitable for corn, wheat and other staple crops (Reberg-Horton et al., 2011), and its history in America goes back more than 60 years (Jia et al., 2010). Soil organic matter content using these conservation techniques has increased by nearly 3% and grain production has increased by about 4.6% in Iowa State located in Midwest section of North America (Xing-tu and Bai-xing, 2009).

In Sahel, Africa, where pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a major crop, (Sterk and Spaan, 1997) found that covering the soil with 1500 kg ha^{-1} pearl millet residue effectively controlled wind erosion. Bielders et al. (2000) observed that the application of 2000 kg ha^{-1} of millet residue as mulch was highly effective at controlling wind erosion, and the efficiency of broadcast residue was independent of wind direction. Amadou et al. (2011) showed that a crop residue density of about 800 kg ha^{-1} was necessary during the most intense wind erosion period. However, there are few reports that investigate wind erosion control using standing corn residue in Northeast China. Corn is the major crop in Northeast China. The predominate corn harvest method is to use corn-ear harvesters that shatter and cut the corn stalks into small sections while harvesting corn ears at the same time, leaving un-fixed, loose corn residues on the field. However, simply spreading un-fixed corn residue on the field may not be practical to growers in this region. Wind tends to blow loose residue away from the field, leading to environmental pollution and leaving the soil bare, leading to further soil loss from wind erosion. In addition, Northeast of China has a climate with very cold winters, leaving insufficient time for all the returning stalks to decay, which has a negative impact on sowing the following spring. Culturally, corn stalks is one of the main winter feeds for livestock in most rural areas of Northeast China. In addition, corn stalks are compressed and stacked behind many houses to be use for winter fuel for home heating. Therefore, shattering and cutting corn stalks into small pieces and leaving them on the field is not economically or socially practical. Standing residue is different from traditional crop residue coverage (un-fixed crop residue coverage); the standing stems are anchored in the field. Standing residue involves cutting and removing the top stalk but leaving the bottom stalk standing. This technique not only promotes soil organic-matter level stabilization similar to the un-fixed crop residue technique, but also has its own special advantages in controlling soil loss from wind erosion by slowing wind velocity at the soil surface. Our hypothesis is that standing residue conservation management can reduce soil loss from wind erosion compared with un-fixed crop residue coverage, because the corn stalks can form a windbreak to slow wind velocity and block soil particles from being blown away (Bilbro and Fryrear, 1994). The objective of this paper was to compare soil coverage with un-fixed corn residue and standing residue, and test the influence of standing residue' height on the control of wind erosion in Northeast China.

2. Materials and methods

2.1. Study site

All of the experiments were conducted at Agricultural Testing Farm (44°15′N; 125°18′E; elevation of 239 m) of Jilin University in Changchun, China. The sites are located in a region with a north temperate continental monsoon climate with high winds in the spring and autumn. It is common that wind gusts exceed 16 m s^{-1}, the frequency of wind direction rose diagram (hereafter referred to as wind rose diagram) of spring and autumn of the experimental location is shown in Fig. 1. The winter period is from middle November to late March with temperatures as cold as −33 °C, but the summer temperatures range from 5 °C to 35 °C. Temperature at the experimental location varies with the seasons, with temperature below 0 °C for more than 5 months in winter. The temperature slowly rises in late winter above 0 °C, when in April, the wind becomes very strong every year. The average maximum temperature over the past 30 years was 23.1 °C in July, and the average minimum temperature over the past 30 years was −15.1 °C in January. The total precipitation from June to August ranges from 350 to 400 mm, which represents more than 60% of the whole year's precipitation. More detailed climate data in the experimental location over the past 30 years are shown in Table 1.

The dark prairie topsoil at the Agricultural Testing Farm of Jilin University has an organic carbon content of 7% for the surface soil (0–30 cm depth), with soil pH value ranges from 6.5 to 7.

2.2. Experimental design and approach

The experiments were conducted from 2011 to 2014. The experimental design was four stationary treatments replicated over 4 years. Four field areas for treatments were selected to compare conservation effects on wind erosion control with different heights of standing residue (locally referred to as 'high-stubble') and un-fixed (traditional) corn residue coverage. The plots, each containing a different treatment were all 400 m long (from east to west) and 250 m wide (north and south) (Fig. 2). In order to reduce the mutual interference among the four plots, they were surrounded by uncultivated buffer areas of dimensions 400 m long and 250 m wide where natural fallow-type vegetation

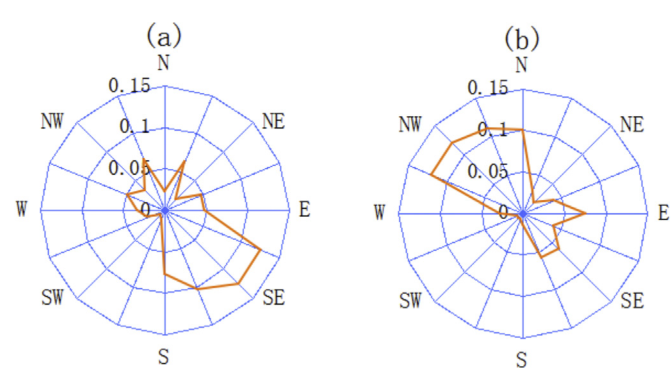

Fig. 1. The frequency of wind direction rose diagram (hereafter referred to as wind rose diagram) of the experimental location, the spring and autumn always have strong winds, but summer and winter seldom have winds; (a) represents the wind rose diagram of spring, (b) represents the wind rose diagram of autumn.