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Research Article

A New Instrument for Testing Wind Erosion by Soil Surface Shape Change

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Wind erosion, a primary cause of soil degeneration, is a problem in arid and semiarid areas throughout the world. Many methods are available to study soil erosion, but there is no an effective method for making quantitative measurements in the field. To solve this problem, we have developed a new instrument that can measure the change in the shape of the soil surface, allowing quick quantification of wind erosion. In this paper, the construction and principle of the new instrument are described. Field experiments are carried out using the instrument, and the data are analyzed. The erosion depth is found to vary by 11% compared to the average for measurement areas ranging from $30 \times 30\,\text{cm}^2$ to $10 \times 10\,\text{cm}^2$. The results show that the instrument is convenient and reliable for quantitatively measuring wind erosion in the field.

1. Introduction

Soil erosion is a global disaster, especially in northern China [1]. Erosion studies have been widely carried out around the world, and many measuring methods have been developed [2, 3]. Wind erosion is often observed by iron rod and digital cameras in the field. The rod measuring method has high precision, but only one point can be measured. Taking photographs is affected by the camera support and its stabilization and is difficult to operate [4, 5]. Also, the computing process is complex for obtaining measurements from the photographs. Furthermore, the measured results can be of low precision when the soil surface is covered by vegetation. Remote sensing and GIS are macroscale methods used in soil erosion research and are inadequate in precision research [6–8]. In recent years, laser-scanning instruments have been used to observe changes in soil surface shape. Laser scanning has certain disadvantages. Firstly, it is affected by vegetation, and the measurements have large errors. Secondly, the installation is complex, causing difficulty for field observation [9]. To avoid these various difficulties, we have designed a new mechanical measurement tool, the soil surface shape change measurement instrument, which is not affected by vegetation and has high precision [10]. The new tool also has a simple construction and is convenient for field measurement of wind erosion.

2. Materials and Methods

2.1. Construction of the Instrument. This instrument is designed by Liu et al. [11]. A schematic illustration of the instrument is shown in Figure 1. In this figure, box B holds the measuring rods. At the top of the box is the holding board B1. At the bottom is the holding board B2, and in the middle is the holding board B3. The box also has lateral boards B4 and B5. The three boards parallel to the ground are connected with lateral boards. Under the bottom holding board B2 is a notch B6. There is a splint board B7 in the lead notch that can be pushed in or pulled out to let the rods down. Those mechanical rods could be fall down to soil surface freely and not affected by vegetation. The case has four stable feet at every corner of the bottom box B8.

Figures 2 and 3 show the rods arranged in a matrix held by holes in two horizontal boards. The holes in the boards

Table 1: The data of different erosion areas recorded in field.

Erosion area (cm^2)		10×10	12×12	14×14	16×16	18×18	20×20	22×22	24×24	26×26	28×28	30×30
Erosion depth (cm)	First	0.279	0.291	0.293	0.288	0.278	0.297	0.271	0.279	0.269	0.259	0.261
	Second	0.235	0.238	0.249	0.249	0.248	0.25	0.251	0.257	0.244	0.245	0.236
	Third	0.194	0.218	0.232	0.216	0.224	0.236	0.228	0.238	0.222	0.198	0.214
	Average	0.236	0.249	0.258	0.251	0.25	0.261	0.25	0.258	0.245	0.234	0.237

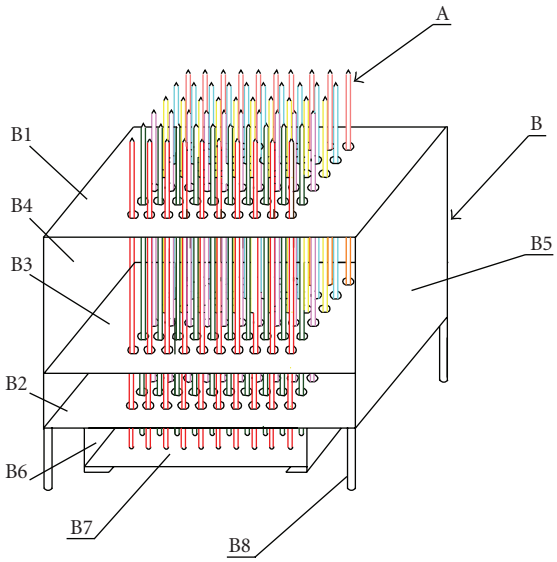

Figure 1: Schematic of the soil surface shape change measurement instrument.

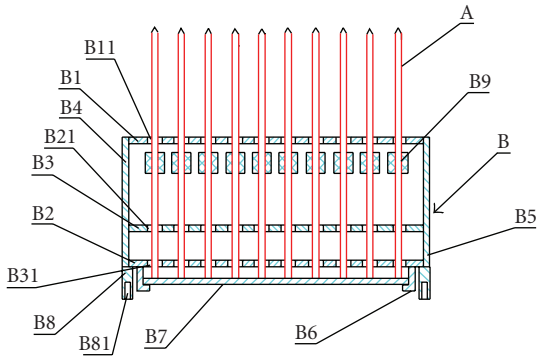

Figure 2: Schematic of the instrument Section 1.

are vertical and parallel. Splint B7, below the rods, holds all the rods in place. Rods A can move freely in the holes.

The holes B81 (Figure 2) in the four feet of the instrument are placed over nails which have first been buried in the soil. When the splint is pulled from the lead notch, all rods fall down on the soil surface D (Figure 3). The soil surface shape is measured according to the falling distance of each rod.

The box holds a total of 100 rods, each marked with a ruler to measure the falling distance. The rods are hollow and made from metal. Each rod has a plastic cushion pad at its bottom which reduces damage to the soil surface

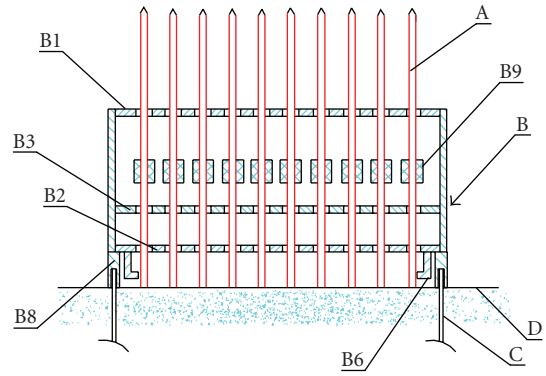

Figure 3: Schematic of the instrument Section 2.

when the rods fall on it. Between two boards is a fixing ring B9 (Figure 3) on each rod which keeps the rods in place. Without these rings, the rods might fall on the soil surface when the instrument is removed after the initial measurement, affecting subsequent measurements of the area.

To take measurements in the field, the instrument is first placed on the nails in the ground. When the instrument is stable, the splint is pulled out and the height of each rod is recorded. The instrument is then removed, and the soil is eroded by an artificial wind. A second measurement is then carried out.

The artificial wind is a level 7 velocity (13.9–17.1 $m \cdot s^{-1}$) acting on the soil for 3 minutes. The wind is produced by a brand 130FLJ5 centrifuge wind instrument. Figure 4 is a photograph showing the experimental setup. The measured area is 10 cm × 10 cm = 100 cm^2. The wind blows in the same direction as the rows of rods, and so the shape change of the soil surface between the rows is very small. The change between the columns, however, is substantial. To simplify the calculations, we only measure every other row, such that the data for one row represent two adjacent rows. We monitor erosion as a function of wind velocity and direction. Other wind characteristics are held constant.

2.2. Experimental Design. In these experiments, the size of the measurement area may affect the precision of the data. Nails C (Figure 3) drove into soil according to instrument bottom four feet when measure area is decided. The instrument could be put on or take away from the nails easily. Since the measurement area of the instrument is fixed, we needed to determine how large an area is needed to simulate real erosion. Therefore, we have tested the effect of measured area on the erosion results.

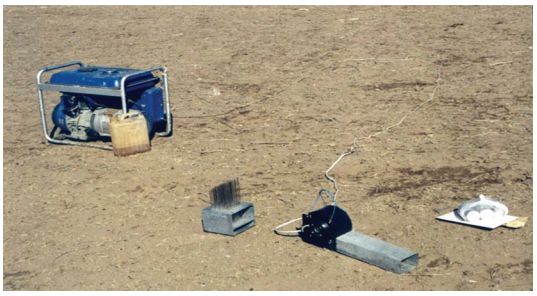

Figure 4: Photograph of the experiment setup in the field.

In the field, we take erosion depth data using different soil areas. We then compare the results to determine what size area is adequate for the test instrument. The method is to start with an area of $30 \times 30\,\text{cm}^2$, then systematically reduce the area by two rows and two columns (1 cm) at a time. Erosion depth is measured for each area. The bottom area of the instrument is $10 \times 10\,\text{cm}^2$, and so in order to test the larger soil areas, we take multiple measurements of adjoining areas.

The erosion time for each tested area is 3 minutes. A longer erosion time may be needed for experiments in grassland and artificially forested areas, which have large canopies, making erosion slow. For a cultivated field, the wind exposure time must be shorter because the soil is loose and erodes easily.

3. Results and Discussion

The data of different erosion areas recorded in field are listed in Table 1.

In this experiment only one wind (artificial wind) speed is used, so does the soil types (only one soil type in this area). Erosion depths were recorded for eleven soil areas from $10 \times 10\,\text{cm}^2$ to $30 \times 30\,\text{cm}^2$. Values are averages over the half set of rods. The results are shown in Figure 5. The maximum erosion depth measured was 0.261 cm at an area of $20 \times 20\,\text{cm}^2$, and the minimum was 0.234 cm at an area of $28 \times 28\,\text{cm}^2$, a difference of 0.027 cm. This difference is 11% of the average depth, which is 0.248 cm.

For the smallest tested erosion area of $10 \times 10\,\text{cm}^2$, the erosion depth was measured to be 0.236 cm. This depth is about 4.5% smaller than the average depth measured for all soil areas. This variation is small enough that we expect this instrument is suitable for field study of wind erosion.

4. Conclusion

To quick quantification of wind erosion measurements in the field, a new instrument that measures the change in the shape of the soil surface was designed. It can test erosion area range from $10 \times 10\,\text{cm}^2$ to $30 \times 30\,\text{cm}^2$. Erosion depths using the instrument measured were recorded in field experiments. The results show that the instrument is convenient and reliable for quantitatively measuring wind erosion in the field.

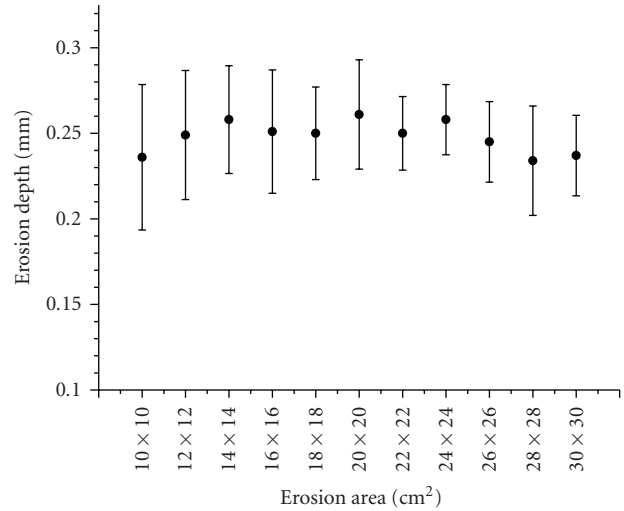

Figure 5: The measured wind erosion depth versus the measurement area.

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