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Quantifying Wind Erosion Losses in Alberta

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Problem

The correct and reliable estimation of wind erosion losses is important in the evaluation of erosion control systems (e.g. conservation tillage, chemical fallow, crop residue management, shelterbelts). However, until recently, quantifying soil losses from wind erosion in terms of weight of topsoil per unit area was not possible. Now, recently developed methods[3] and field equipment are providing mechanisms to describe field erosion losses on a single storm basis.

Literature Review

In the past, wind erosion losses have been estimated by the Wind Erosion Equation[7]. The Wind Erosion Equation was derived in laboratory wind tunnels from measurement of basic physical processes in the 1960s. Field verification was not possible as field erosion measurement equipment was not available at that time. To investigate field wind erosion processes, information on meteorological variables, soil flux variables and temporal soil surface properties for individual erosion events is required. New equations have been developed to describe the vertical and horizontal components of soil mass flux during wind erosion events[2,6]. New methodologies for measuring temporal soil properties affecting erodibility have been reported[8]. These measurements and procedures will be needed to test the process-based Wind Erosion Prediction System (WEPS)[4] which is being developed by the Agricultural Research Service of the United States Department of Agriculture (USDA-ARS) and is set to replace the Wind Erosion Equation.

Study Description

The quantification of wind erosion losses was conducted at two WEPS validation sites near Lethbridge (Table 1) and on 14 monitoring and characterization sites in Alberta (Table 2). Once the WEPS model has been delivered, measured soil losses from the Lethbridge validation sites and the monitoring and characterization sites will be compared to WEPS-predicted losses.

Table 1. Dates and soil losses for 16 erosion events at WEPS Site 1 and 13 at WEPS Site 2

WEPS Site 1		WEPS Site 2	
Event	Soil loss (t/ha)	Event	Soil loss (t/ha)
Apr. 4, 1991	7.0	Feb. 9, 1994	1.1
Apr. 8, 1991	2.7	Feb. 13, 1994	4.4
Apr. 25, 1991	0.3	Feb. 15, 1994	2.1
Dec. 6, 1991	27.9	Mar. 13, 1994	5.4
Dec. 9, 1991	24.4	Mar. 16, 1994	1.3
Dec. 10, 1991	17.0	Mar. 17, 1994	2.3
Dec. 11, 1991	16.7	Mar. 20, 1994	1.2
Dec. 16, 1991	6.9	Mar. 21, 1994	17.3
Apr. 3, 1992	29.0	Mar. 26, 1994	0.3
Apr. 4, 1992	6.8	Apr. 12, 1994	0.8
Apr. 5, 1992	7.7	Apr. 13, 1994	19.6
Apr. 9, 1992	0.8	Apr. 17, 1994	0.3
Apr. 13, 1992	1.9	Apr. 24, 1994	0.5
Apr. 18, 1992	1.8		
Apr. 27, 1992	0.5		
May 11, 1992	0.8		
TOTAL	152.2		56.6

Table 2. Wind erosion monitoring and characterization sites in Alberta

Year	Site	Soil texture	Organic C (%)	Management history	Erosion events
1991	Taber	sandy loam	0.81	potatoes, irrigated crops	2
	Retlaw	loam	1.22	wheat-fallow	2
	Champion	sandy loam	1.42	wheat-fallow	4
	Beiseker	silt loam	3.75	continuous wheat	1
	Vegreville	sandy loam	0.82	wheat-oilseeds	1
	Two Hills	sandy loam	1.50	wheat-oilseeds	0
1992	Retlaw	loam	2.13	wheat-fallow	6
	Crossfield	clay loam	3.64	wheat-oilseeds	2
1993	Taber East	sandy loam	1.08	sugar beets, irrigated crops	4
	Taber West	sandy loam	1.24	sugar beets, irrigated crops	4
	Beiseker	loam	3.88	wheat-barley-fallow	0
	Drumheller	clay	2.73	wheat-oilseeds-fallow	0
1994	Beiseker	loam	-	wheat-canola-fallow	2
1995	Turner Valley	clay	-	broken pasture	2

In November 1990, WEPS Validation Site 1 was selected on a clay loam soil 15 km southeast of Lethbridge. A single, 200-m diameter circular plot was established on land that had been under zero tillage for six years. The objective of the site was to encourage erosion events and ascertain soil losses for the given set of soil surface conditions at the onset of each erosion event and the wind speeds occurring during the event. The site was tilled to bury residue and render the surface erodible. Thirteen clusters of soil collectors[1] at 10-, 25-, 50- and 100-cm heights and meteorological instrumentation (wind speeds at four heights and wind direction) and a wind erosion sensor (SENSIT) were installed. Sixteen erosion events were monitored between April 1991 and May 1992 (Table 1). Using equations for vertical distribution of material moving in saltation and surface creep[2,3] and horizontal distribution of material across an eroding surface[3,6], soil losses from individual erosion events were calculated. Soil losses, wind speeds and soil surface conditions for these erosion events have been summarized and quantified previously[5].

WEPS Validation Site 2 was established in April 1993 about 3 km from WEPS Site 1. Erosion was induced at Site 1 by over-cultivation. However, Site 2 was managed conventionally, being fallowed with a heavy-duty cultivator+rodweeder attachment (tillage on May 11, June 28 and August 2, 1993). Thirteen erosion events were monitored between February and April 1994 (Table 1).

The objective of the monitoring and characterization sites was to provide data on measured wind erosion losses for cropping systems typical of Alberta. These sites were essentially less sophisticated validation sites. They were usually set up in April/May and were managed by the producers in their normal fashion. No attempt was made to induce erosion. The sites were chosen to represent common management systems both on dryland and irrigated land. Wind erosion is a very apparent problem that occurs each spring on land to be seeded to irrigated specialty crops such as potatoes, pulses or sugar beets in southern Alberta.

The sites were rectangular in shape and established in fields that had a history of erosion or were deemed at high erosion risk. Four clusters of windblown sediment samplers (each cluster with samplers at 10-, 25-, 50- and 100-cm heights) were erected at each site on the downwind side of the erodible surfaces. At each site, surface soil samples (0 to 2.5 cm) were taken for aggregate size distribution analysis and this was related to soil loss.

Soil losses were calculated for each erosion event at each site using a modified version of the equations of Fryrear et al.[3] Modifications were required to handle rectangular sites rather than circular ones. Since wind speeds were generally below normal for the period in question, the number of erosion events monitored was lower than anticipated. At Lethbridge, only three of the 60 months between January 1991 and December 1995 had mean monthly wind speeds which were above normal.

Major Findings

For the first time, actual soil losses due to wind erosion were calculated on a single storm basis. At WEPS Site 1, individual storm losses varied from 0.3 to 29 t/ha (Table 1). The total soil loss (152.2 t/ha) during the summerfallow period points to the fragility of the soil surface, after six years of continuous zero tillage. The loss is roughly equivalent to 15.2 mm of topsoil depth.

The magnitude of erosion losses was closely related to temporal soil properties. Precipitation events increased threshold wind velocities for the onset of erosion by crust formation and increased surface moisture. Management factors, such as seeding perpendicular to the prevailing wind, also increased threshold wind velocity. Based on the fastest rate of natural soil renewal reported for cultivated land, and assuming no further erosion occurred, it would take about 17 years to restore topsoil lost during this one injudiciously managed fallow period.

At WEPS Site 2, the first erosion event occurred on February 9, 1994 with two more on February 13 and 15, 1994 (Table 1). There was snow cover on the site from February 16 to 28. Air temperatures at Lethbridge increased from -33°C on February 25 to +15°C on March 1, resulting in rapid snowmelt and some ponding on the site. Even though high wind speeds were recorded on March 1 and 2, erosion did not occur due to the moist surface. Additionally, wind speeds were below normal at Lethbridge in early 1994. Mean monthly wind speeds were 13.8 km/h for January (normal 21.2 km/h); 17 km/h for February (normal 20.2 km/h); 15.7 km/h for April (normal 20.7 km/h); and 15.4 km/h for May 1994 (normal 19.3 km/h). However, the total loss of 56.6 t/ha (Table 1) is substantial considering that the land was conventionally fallowed rather than over-cultivated to induce erosion and that wind speeds were below normal.

Table 2 gives details of the 14 monitoring and characterization sites established in Alberta between 1991 and 1995. Dry aggregate size analysis (data not shown) revealed that all of the monitoring and characterization sites were at high erosion risk during the assessment period. Erosion losses at Retlaw (1992) were calculated as follows:

April 3	0.3 t/ha	April 9	0.5 t/ha
April 18	7.1 t/ha	April 27	0.2 t/ha
April 30	1.9 t/ha	May 11	0.6 t/ha

The site had loam textured soil and very little crop residue cover.

Wind speeds in spring 1993 were well below normal. At Lethbridge, the mean wind speed for April 1993 was 15.2 km/h versus the long-term average of 20.8 km/h. May had a mean speed of 15.1 km/h versus the long-term average of 19.3 km/h. Precipitation was also higher than normal especially in the Drumheller area. Consequently, wind erosion events were small and soil losses were negligible.

Two minor erosion events occurred at the Beiseker site on May 6 and 12, 1994. On May 24, 1994 the monitoring site was terminated as 50 mm of rainfall caused severe crusting which left the surface in a non-erodible condition. Two minor events were recorded at Turner Valley in 1995, where very high rainfall precluded major erosion losses.

In summary, soil losses were quantified intensively (WEPS validation sites) and less intensively (monitoring and characterization sites) for a range of Alberta cropping systems.

These losses will be compared with WEPS-predicted losses when the model becomes available. When the Alberta research was initiated in 1990, the delivery of the WEPS model was imminent. However, some seven years later, the WEPS model has not been delivered by USDA-ARS.

Applied Questions

What do the soil losses measured in tonnes per hectare mean in terms of soil depth loss?

If we assume a soil bulk density of 1 Mg/m^3, then 10 tonnes/ha soil loss is equal to 1 mm of soil depth. Therefore, at Site 1, the 152.2 tonnes/ha of soil loss over the fallow season translates into an average loss of 15.22 mm of topsoil over the entire hectare.

How can we use these measured soil loss values in the future?

The measured soil losses will be used to verify soil losses predicted by the WEPS model for the various soil management systems investigated. Models continuously require comparison with real data so that their output can be validated. If the measured and predicted losses are close, then it may be possible to use the model to predict losses over a larger area.

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