Influence of Snow on Wind Erosion Processes in the Chinook Belt of Southern Alberta

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Introduction

Chinook is the name applied to strong, warm dry winds that sweep down the eastern slopes of the Rocky Mountains. They are the dominant climatic factor in southern Alberta but also influence parts of Saskatchewan, Montana, Wyoming and Colorado. Definitive characteristics of a winter chinook include a sharp temperature rise (by up to 20°C) and westerly winds with speeds from 60-120 km hr^{-1}. With the onset of a chinook, snow cover melts rapidly and the high wind speeds may cause widespread soil erosion. The chinook phenomenon ensures frequent freeze/thaw cycles over the winter period which breakdown soil aggregates and contribute to the pool of loose erodible material (LEM).

The Wind Erosion Prediction System (WEPS) currently being developed by the United States Department of Agriculture (Hagen, 1991) has a validation network of instrumented field-scale sites (Fryrear et al., 1991). One such site was established in the chinook belt near Lethbridge, Alberta in 1990. This paper describes and discusses some of the processes observed and thought to be contributing to the severity of erosion events at this site.

Materials and Methods

The WEPS validation site was located about 17 km SE of Lethbridge, Alberta. The site was established November 1990 on a 7 year continuous cropped field. The field was cropped to canola in 1990 and direct seeded to winter wheat in the fall of 1990. The soil is a clay loam dark brown chernozem with 1.83 % total C and 0.16 % total N. A circular plot (200 m diameter) was staked and the surface was tilled to leave the surface in an erodible state. A meteorological tower was erected at the centre of the plot and wind speed and direction, soil and air temperatures, precipitation, solar radiation, vapour pressure, and relative humidity were measured. A SENSIT sensor was installed near the meteorological tower. The SENSIT sensor monitored the start and stop of particulate movement across the soil surface by measuring the impact energy of particles near ground level (5 cm).

Benchmark soil clods were identified within the plot area. Detailed observations, including a photographic journal, were made of the benchmark clods to monitor temporal physical changes.

Observations and Discussion

Since wind erosion in this region is largely associated with processes induced by numerous chinook events we will focus on one particular chinook of March 7, 1991.

Abrasion of aggregates by wind-transported soil particles is a documented phenomenon (Hagen, 1984). Observations at the Lethbridge site on the morning of March 7, 1991 showed that blowing snow has a similar abrasive capacity. Abrasion and aggregate detachment from benchmark clods was apparent and using a SENSIT sensor (Gillette and Stockton, 1986) it was shown to be related to blowing snow. The SENSIT determines the exact moment snow or soil movement begins and also computes the kinetic energy of the particles.

Prior to 1300 hours, the air temperature was less than 1°C (Fig. 1a) and the wind speed was about 8 m sec^{-1} (Fig. 1b). Snow drifted across the site, striking the windward faces of clods, abrading them, and chipping off soil particles. These detached particles were then carried by the wind across the snow surface in distinct patterns not unlike the pattern of the leading edge of water gently washing up on a sandy beach.

After 1300 hours, the air temperature was greater than 1°C (Fig. 1b) and the soil temperature increased (Fig. 1c). Drifted snow against the windward face of the warming clods became discoloured and muddied as a result of melting and soil splash caused by abrading snow particles, while the snow on the leeward side of the clods remained clean. The soil aggregate detachment during frozen conditions and subsequent soil splash as the soil thawed both contributed to the pool of LEM.

After the clods had dried, evidence of the disruptive force on the windward face of the clods was observed. These clods were aligned so that parts of them were sheltered from the wind by neighbouring clods. A demarcation line existed between the exposed upper surfaces of the clods which were smooth and light coloured in appearance and the sheltered lower surfaces which were rougher and darker. These same clods showed no evidence of abrasion earlier in the winter.

These observations illustrate a new concept of describing soil surface microrelief and its effect on erodibility (Potter et al., 1990; Zobeck, 1991). The cumulative shelter angle distribution (CSAD) is used to estimate the unsheltered portion of the soil surface that will be susceptible to wind erosion and takes into account the protection or sheltering of surfaces from abrasive impact.

With the onset of the chinook, areas with shallow snow cover became exposed to the forces of the wind much quicker than areas with deeper drifts. This uneven drifting effect caused variability in surface moisture content across the site as the snow melted in the week following the chinook event. Being in a saturated state would allow for low aggregate bond strength to be manifest as moisture tension approaches the free state allowing slaking to occur (Bullock et al., 1988). These weak bonds may be attributed to late fall tillage, freeze/thaw events or possibly wetting rate as the snow melted. The slaked areas crusted and cracked upon drying (Uehara and Jones, 1976) and the crust offered resistance to movement by wind.

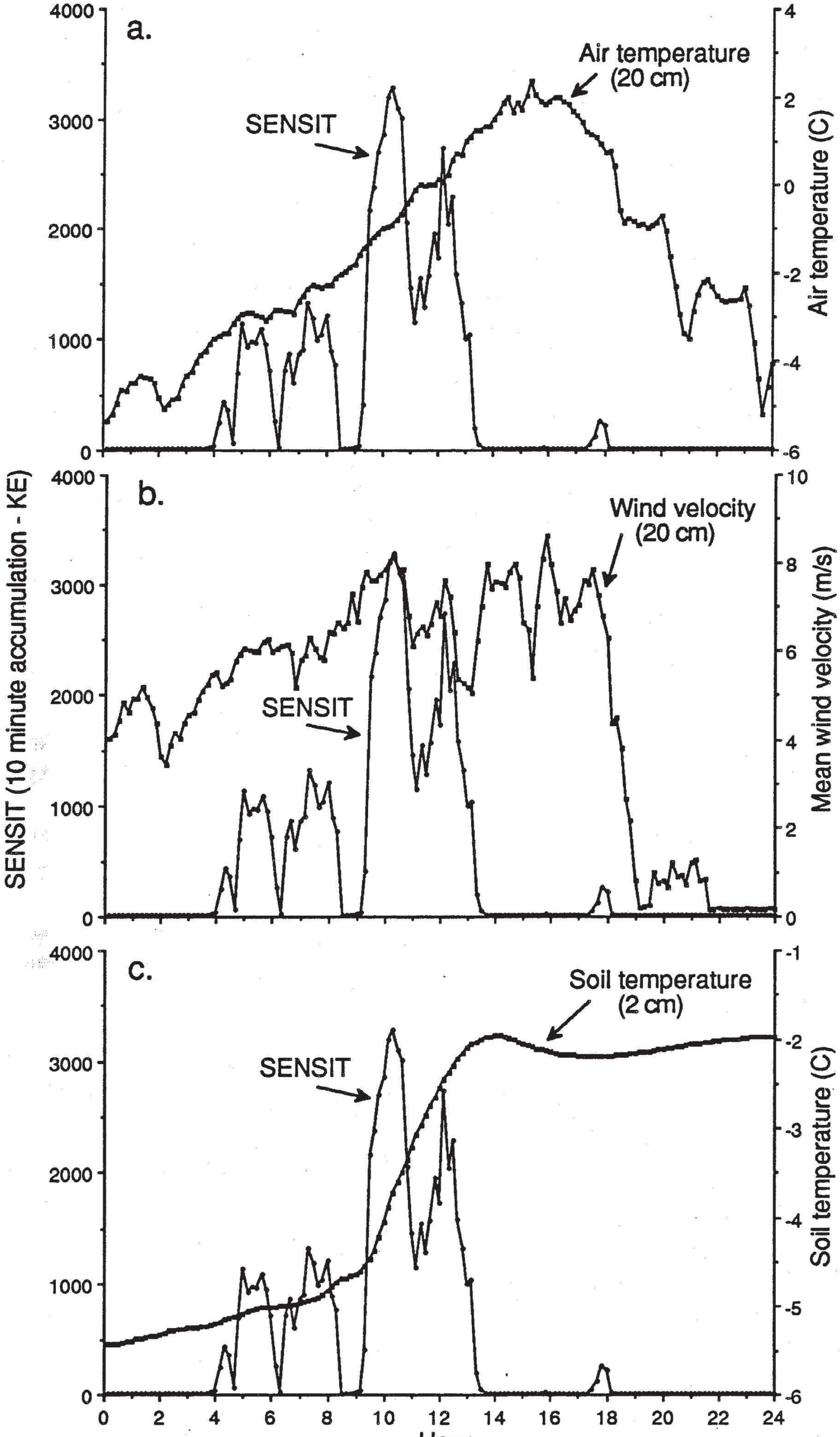

Figure 1. SENSIT kinetic energy (KE) count and a) air temperature at 0.2 m, b) mean wind velocity at 0.2 m, and c) soil temperature at 2 cm, March 7, 1991.

Conclusions

1. Blowing snow plays an important role in the wind erosion process in the chinook-dominated environment of southern Alberta.

2. Blowing snow contributes to the pool of loose erodible material by abrading soil aggregates. It occurs under different meteorological conditions than blowing soil abrasion and the magnitude of its contribution to the LEM pool compared with blowing soil is not known.

3. Differential snow cover caused by random drifting exerts a significant effect on soil surfaces following a chinook. Shallow snow cover sublimates allowing the soil surface to dry fast and become erodible. Meltwater from deeper snow cover saturates the soil surface, causing it to slake and crust. The subsequent crust offers some resistance to soil movement by wind.

Acknowledgement

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