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Abstract. *Field data need to be collected to test wind erosion models under a broad range of climate, soil, and management conditions. The objective of this study was to test the USDA-ARS Wind Erosion Prediction System (WEPS) for a field with winter wheat plants in a modest amount of flat residue. A 600 m by 415 m field was selected near Burlington, CO, USA. Big Spring Number Eight (BSNE) samplers were used to measure wind blown sediment flux and automated devices (Sensits) for continuous detection of saltation. A weather station recorded relevant meteorological data. Detailed measurements of the field surface were taken on three dates. The experiment was conducted from 25 November, 2000 through 12 April, 2001.*

One dust storm occurred during this experimental period, with a net field sediment loss of 0.06 kg/m^2. Spatial variability of sediment discharge was high and could be explained by spatial differences in field conditions. WEPS overestimated the protective power of small wheat plants. It needs a provision to account for standing biomass that is not uniformly spaced, such as wheat plants in the field. Wind erosion (and WEPS) is very sensitive to soil surface water content, which is difficult to measure. Albedo is a good indicator of soil wetness right at the soil surface, but additional research is needed to use albedo for quantifying soil surface water content.

Keywords. wind erosion, field experiment, winter wheat, soil surface water content

Introduction

Agricultural producers in the Central High Plains of the USA have expressed the wish to locally develop strategies for conservation of natural resources, which resulted in the High Plains Pilot Project (HPPP), covering extreme Northwestern Kansas (Cheyenne, Rawlins, Sherman, Thomas and Wallace counties) and adjacent counties (Sedgwick, Phillips, Yuma and Kit Carson) in Eastern Colorado. The most common cropping system in the HPPP region is a wheat-fallow system with a 14 month fallow period, and winter wheat in the remaining 10 months of the 2 year cycle. This system is vulnerable to wind erosion, especially in early spring with high wind speeds, small wheat plants, and a soil structure weakened by freeze/thaw cycles of the previous winter. There are also concerns about wind erosion during the summer fallow period following sunflower harvest (Nielsen and Aiken, 1998). Alternative cropping systems have been proposed in conjunction with reduced tillage. It has been demonstrated that reduced tillage, especially no-till, improves water storage in the soil, thus opening the way for more intensive cropping systems, such as a wheat-corn-millet-fallow cropping system and even continuous cropping systems (Peterson et al., 1993; Peterson et al., 1996; Farahani et al., 1998; Anderson et al., 1999). These more intensive systems promise to be both economically and environmentally more attractive, including the benefit of reduced wind erosion. Farmers, who have adopted continuous cropping systems in no-till, report that on their fields wind erosion is a thing of the past. However, these producers are still a minority. For fields under more traditional management, erosion of soil by wind is still a serious threat in this region.

Agricultural producers and the USDA-Natural Resources Conservation Service (NRCS) need to know what can be expected in terms of wind erosion, resulting from different management practices. The USDA-ARS Wind Erosion Research Unit (WERU) in Manhattan, KS is developing a process-based Wind Erosion Prediction System (WEPS, Hagen, 1991; Wagner, 2001), that is able to simulate wind erosion and dust emission for different management scenarios such as different cropping and tillage systems and thus has the potential to meet this need. WEPS, however, needs to be tested in the field (Hagen, 1991). Until recently, actual measurements of wind erosion under field conditions were virtually nonexistent (Fryrear, 1995). Fryrear (1986) developed a field dust sampler and named it the Big Spring Number Eight (BSNE). Fryrear et al. (1991) describe a setup for wind erosion measurements on a circular field with a radius of 91 m. Wind erosion was measured at sites in five different states to be used for the verification of WEPS (Fryrear, 1995). Sterk (1997) measured wind erosion on a rectangular field of 60 m by 40 m in Niger, West Africa. His measurements showed that spatial soil loss/deposition can be highly variable.

A sensor used by Fryrear et al. (1991) and others is the Sensit (Gillette and Stockton, 1986), which is a piezoelectric device that produces a signal upon impact of saltating soil particles. It has been used both in the open field and in wind tunnels. The instrument has proven useful for the determination of the threshold friction velocity at which erosion by wind starts. Use of the Sensit to measure horizontal sediment mass flux has not been very successful, but would be useful since it will provide a much better time resolution of mass flux during a single storm than one can obtain from sediment samplers such as the BSNE.

More data need to be collected to verify wind erosion models under a broad range of climatic, soil, and management conditions (Fryrear, 1995a). The Wind Erosion Customer Focus Meeting organized by WERU in December 1998 listed the completion of an extensively field tested WEPS as the number one priority for WERU to work on. The objective of this study was to test WEPS in the HPPP area for a field with winter wheat in a modest amount of flat residue.

Methods

A field was selected 10 miles south of Burlington, CO (39.13 N, 102.30 W, elevation = 1292 m). The 1720 m by 810 m field was planted to wheat with a 305 mm row spacing (oriented east-west) on August 29, 2000. A sunflower crop was grown on the field in the summer of 1999 and a corn crop in the summer of 1998. Only the NW corner (600 m by 415 m, Figure 1) of the field was instrumented. To the north was a field with standing corn residue. The western border was a dirt road flanked on both sides by ditches and a wheat field to the west. The southern and eastern borders were extensions of the same field with wheat. BSNE sampler stations were placed not at regular distances, but according to field topography: stations 4, 9 and 17 were placed on a ridge, stations 2 and 5 on another ridge, 10-13 and 18 on a flat part of the field, 3, 6, 14, and 19 on yet another ridge, and stations 7, 15, and 20 on a slope. Stations 1, 2, 3, 8 and 16 were positioned on the field boundaries for measurement of 'background' movement of sediment originating from adjacent fields. The difference between the highest and the lowest point on the instrumented field was about 7 m. Each BSNE station consisted of 6 BSNE samplers with their openings at 0.05, 0.10, 0.35, 0.60, 1.00, and 1.50 m above the soil surface. The two lowest samplers had openings of 20 mm wide and 10 mm high; the other four samplers had openings of 20 mm wide and 50 mm high.

The field instrumentation setup was similar to that of Fryrear et al. (1991). A major difference was the field size: 600 m by 415 m instead of a circle of 91 m radius. This was done in order to obtain a longer distance from a (non-erodible) boundary, so that the field would be large enough to reach transport capacity. Other differences were that our field was one with winter wheat, flat residue and some topography, whereas Fryrear worked mostly with bare, flat, sandy plots.

At the weather station (Figure 1) wind speed was measured at 2.0 m, using a cup anemometer (1005DC, Sierra Misco, Berkeley, CA[1]), wind direction at 3.5 m using a wind vane (WSD330, RM Young, Traverse City, MI), air temperature and relative humidity at 0.2 m and at 2.0 m (CS500, Campbell Scientific, Logan, UT), incoming and reflected shortwave radiation at 1.5 m using a double sided pyranometer or albedometer (3023, Qualimetrics, Sacramento, CA), net radiation at 1.5 m using a net radiometer (Q7.1, Radiation and Energy Balance Systems, Seattle, WA), soil temperature at –0.03 m (107, Campbell Scientific), and rainfall with a tipping bucket rain gauge (6010, Qualimetrics). A vertical wind profile was taken at the weather station on 12 and 13 April, measuring wind speed at 0.26, 0.41, 0.67, 1.08, 2.00, and 3.10 m above the soil surface. Profile measurements were not taken during the entire experimental period, because of the risk of fouling bearings of anemometers close to the ground with moving soil.

At each of the BSNE stations 10 – 13 (Figure 1) the occurrence of saltating soil particles was measured with a Sensit (Sensit Company, Portland, ND) at 0.05 m, and wind speed was measured at 2.0 m, using a cup anemometer (1005DC, Sierra Misco). Figure 2 shows the setup at one of the four stations that were configured this way. All sensors were calibrated before being deployed in the field.

Data were measured and recorded with equipment from Campbell Scientific: a data logger (CR10X), a solid state multiplexer (25AMT), and a 8 channel interval timer (SDM-INT8). Sensors were sampled every 10 s and data were recorded for 15 minute periods. Recorded data

[1] Mention of brand names is for information purposes only and does not imply endorsement by ASAE or USDA-ARS.

were transmitted twice a day from the data logger to a PC at WERU in Manhattan, KS, using a mobile phone system: a cellular transceiver with RJ11 interface (Alltel, Manhattan, KS) and a telephone modem (COM200, Campbell Scientific). The system was powered using 2 solar panels (MSX20R, Campbell Scientific) and a sealed, lead acid battery with a capacity of 115 Amphours. The site was operational from 25 November, 2000 through 12 April, 2001.

On 19 December, one day after the only wind erosion event during the experimental period, BSNE samplers were emptied in plastic bags and weighed in the laboratory. For each BSNE station, measured mass from the samplers was fitted to

$$q = a\,(z+1)^{b} \tag{1}$$

Where q is sampler mass (kg/m^2), z is height of the BSNE sampler opening above the soil surface (m), and a and b are fitting parameters. Sediment discharge was determined by integrating equation 1 from 0 to 2 m. Net soil loss from the field was calculated from sediment crossing the field boundaries. Sample aggregate size distribution was determined using a sonic sifter (ATM Corporation, Milwaukee, WI) with 5, 10, 20, 53, 106, 250 µm sieves.

Field conditions were recorded near every BSNE station, not located on a field boundary, on three dates: 19 December, 8 March, and 12 April. Recorded were the status of wheat, residue, topsoil, soil roughness, soil surface moisture, and crust condition. Wheat plants occupying 0.10 m within a row were dug up and placed in a plastic bag with a wet paper towel to keep the plants from drying out. In the laboratory the number of plants were counted and their heights (as standing in the field; not stretched out) measured. Leaves and stems were separated. Leaf area and stem silhouette area were measured using a leaf area meter (LI-3000, LI-COR, Lincoln, NE). Leaf area index (LAI) and stem area index (SAI) were calculated from these measurements. In addition, leaf and stem dry mass (in oven for 24 hours at 70 ^{o}C) was determined. Flat residue cover was measured using a 15.2 m (50 ft) long measuring tape and counting the foot marks that covered pieces of residue. Above ground flat residue was collected within a rectangular frame of 305 mm by 584 mm. Residue was air dried and weighed in the laboratory. No standing residue was present on the field.

A few kg of soil were collected from the top 0.05 m using a shovel. In the laboratory this soil was used for the following analyses: soil texture using the pipette method (Gee and Bauder, 1986), aggregate size distribution using a rotary sieve (Chepil, 1962; Lyles et al., 1970) for sizes down to 420 µm and using a sonic sifter (ATM Corporation, Milwaukee, WI) with 5, 10, 20, 53, 106, 250 µm sieves for the finer material. The aggregate size distribution was described according to Wagner and Ding (1994). Dry aggregate stability (Boyd et al., 1983) and wet aggregate stability (Kemper and Rosenau, 1986) were also determined.

Soil roughness was measured using a pinmeter (Wagner and Yu, 1991; Skidmore et al., 1994). One measurement was taken perpendicular to the ridges (ridge roughness) and one parallel with a ridge (random roughness). Pinmeter photographs were taken using a digital camera and analyzed using SigmaScan Pro (SPSS Inc., Chicago, IL) software. The standard deviation of pin positions was corrected for trends, i.e. downward or upward trends of pin positions from one side of the pinmeter to other. Such trends increase the standard deviation without contributing to soil roughness. Ridge heights were measured using a 1 m long straight edge.

Surface (top 8 mm) soil moisture was measured gravimetrically using the sampling method described by Reginato (1975) and practiced by Durar et al. (1995). Note that for a rough surface the top 8 mm is not well defined, making sampling quite challenging. Pieces of crust were placed in plastic bags. Back in the laboratory, crust (consolidated zone) thickness was measured using a calipers.

On 8 March the same field variables were recorded as described above for 19 December, except for the texture analysis. In addition, loose material covering the crust was collected from an area of 305 mm by 305 mm, using a soft brush and dustpan. On 12 April the same measurements were taken as on 8 March, except for soil roughness and residue cover because the wheat had grown and by this time was covering a substantial portion of the residue and the soil. Aggregate size distribution and dry aggregate stability were determined for only 3 BSNE stations: 5, 12, and 17.

Results and discussion

The Sensits produced high output on many days, although the storm of 17/18 December was the only wind erosion event (Figure 3). High Sensit particle count on most other days can be traced back to snowfall or blowing snow, to which the Sensits are very sensitive. The highest winds during the period were on 11 April, but there was no significant soil movement, because it was raining at the same time. The wet soil surface, together with growing wheat, caused the soil not to move, despite the very strong winds.

Figure 4 shows the condition of the field surface at 4 different points in time. Wheat cover in December (Figure 4b) had decreased compared to that in November (Figure 4a), because of dormancy setting in. On 8 March (Figure 4c), the wheat cover was very similar to that of December: dormancy had not been broken yet. On 12 April (Figure 4d), the wheat had been growing for a while, providing much more protection from wind erosion than before. The soil was crusted most of the time (Figure 4). Table 1 shows field conditions on the three measurement dates. Wilting point (-1.5 MPa) water content, calculated from texture (Saxton, 1986), was 0.077 kg/kg.

Only one significant wind erosion event occurred, on 17/18 December, during the period of the experiment. Figure 5a shows soil and dust moving in the distance (but still on the experimental field). In the foreground hardly any soil is moving. Ridges abraded in areas with heavy soil movement (Figure 5b). Most of the field, however, looked like Figure 4b with the ridges largely intact. Soil movement on the field had high spatial variability (Figure 6). This was confirmed by visual observation on the afternoon of 18 December (Figure 5a). At this time soil was moving heavily only in two narrow ‘corridors’, (Figure 6). High spatial variability is probably typical for many agricultural fields. Even experimental fields that were made uniform for purposes of the experiment, frequently showed large spatial variations in erosion (Hagen, 2001).

For the erosion event of 17/18 December, the northern field boundary was non-erodible, but the western boundary (dirt road) did not prevent sediment from moving in from an adjacent field, as evidenced by the large soil discharges of the BSNE stations located on this boundary (Figure 6). More soil movement in the western part of the field may be explained by field conditions less favorable than average (Table 1): lower residue cover (8, 10, and 8% cover at BSNE stations 4, 9, and 17 respectively and 530 and 827 kg/ha at stations 4 and 9 respectively), lower LAI at stations 9 and 11, higher sand fraction (50% at station 4) and drier surface soil

(0.027 kg/kg at station 4). Field loss for the 600 m by 415 m experimental site was about 0.06 kg/m^2.

Figure 7 depicts the wind erosion event of 17/18 December in more detail. Winds picked up very rapidly arount 5 pm on 17 December, then died down during the night and picked up again on the 18th. Wind direction was rather constant throughout the event coming from the NNW (328 degrees from North). Sensit response, indicating soil movement, followed the wind speed closely. Threshold wind speeds, as indicated by Sensit, were around 12 m/s (Figure 8a). At wind speeds higher than this, soil movement became significant. Wind power density was calculated as

$$WPD = \rho \ (u_i^2 - u_t^2)^{3/2} \quad (2)$$

where WPD is wind power density (W/m^2), ρ is air density (kg/m^3), u_t is threshold wind speed (m/s) and u_i is measured wind speed (m/s). The relationship between particle count, which closely approximates mass flow rate, and wind power density (Figure 8b) illustrates the near-linear dependence of saltation impacts on wind speed cubed after the threshold wind speed is reached.

Albedo (short wave reflection coefficient) indicated the presence of a snow cover (Figure 9). Vertical lines represent night, dawn, and dusk, when albedo values are not valid. February started with a snow cover as indicated by an albedo of more than 0.6 on 1 February. The first week of February albedo gradually decreased from 0.6 to less than 0.2 on 7 February, indicating a gradual snow melt. On 7 February, the soil surface was no longer covered with snow and it was wet (a dry surface typically had an albedo of about 0.26 in this field). Then on 9 February, fresh snow fell as shown by the albedo jumping back up to almost 0.6. Fresh snow also fell on 14 and 27 February. This kind of information is important in wind erosion field research, since a snow cover may make the difference between soil moving or not. Snow and snow cover are difficult to measure directly in an automated fashion. A regular tipping bucket rain gage does not capture snow very well.

Albedo is also a good indicator of soil surface wetness, (Figure 10). The soil surface was dry on 8, 9 and 10 April, with albedo around 0.25. It was wetted by rain on the evening of 10 April and on 11 April. The albedo on 11 April had decreased from 0.25 to about 0.17. On 12 April the soil surface dried and the albedo went back up to about 0.25. Soil surface wetness is very important in wind erosion. If the surface is wet, much greater friction velocities are needed to move the soil. For this reason, wind erosion was insignificant on 11 April, although wind speeds were much greater than during the dust storm of 17/18 December. Measurement of soil moisture right at the surface is difficult, making the albedo information quite valuable. This has been recognized by other researchers, such as Idso et al. (1975).

WEPS simulations

Simulation of the 17/18 December storm with WEPS, using the 19 December field conditions shown in Table 1, yielded no erosion (Table 2). Assuming a totally dry soil surface still produced no erosion. Reducing the wheat to very small plants (Table 2) of about one fourth the size of the real wheat cover (Figure 4b) produced no erosion. A simulation entirely without wheat produced a field loss of 1.75 kg/m^2, which is much larger than the measured loss. Apparently, WEPS is very sensitive to small changes in standing biomass. This component of WEPS is based on laboratory wind tunnel experiments with simulated standing biomass uniformly spaced on a flat surface. In our experimental field the wheat plants were not uniformly spaced, and stems and leaves are 'clumped' together for each wheat plant. This makes them much less effective in preventing wind erosion. Furthermore, our field was not flat, but ridged with the small wheat plants in the furrows and barely taller than the ridges (Figure 4b, Table 1).

Simulation without wheat and a surface soil moisture content of 0.036 kg/kg (Table 1) yielded a field loss of 0.13 kg/m^2, down from 1.75 kg/m^2 for a dry soil surface. This shows that WEPS is very sensitive to surface soil moisture, probably correctly so. This raises the question of accurate and timely measurement of surface soil moisture in field experiments like this. Automated sensors (TDR, dual probe, etc.) are timely (continuous), but don't function well near the surface. Soil moisture at the surface would have to be estimated using soil moisture measured deeper in the soil, in conjunction with other data, such as evaporation. Albedo is timely and gives an indication of soil moisture right at the surface, but does not quantify soil moisture, so it can not be used directly in simulation models. Gravimetric measurements are not timely and sampling right at the surface is a challenge. The surface soil moisture of 0.036 kg/kg in Table 1 came from gravimetric measurements on samples taken from the top 8 mm of the soil, one day after the erosion event. Therefore, it is questionable that this represents soil moisture right at the surface during the event.

The 11 April wind event was simulated using the measured field condition data of 12 April as inputs (Table 1), yielding no erosion (Table 2). A simulation without wheat and with a dry soil surface still produced no erosion, because no loose material was present on the surface crust to initiate erosion through abrasion. When a very small amount (0.01 kg/m^2) of loose material was introduced in the simulation, field loss was 8.31 kg/m^2, which is a very large loss. By comparison, the largest measured field loss in the study by Zobeck et al. (2001) was 5.62 kg/m^2, out of 41 storm events. This indicates that WEPS may overestimate the abrasive power of loose material.

When introducing very small wheat plants (h = 10 mm, LAI = 0.1, SAI = 0.01) field loss came down to 0.12 kg/m^2. Again, it appears that the model overestimated the protective power of small wheat plants. It is not likely that a wheat cover much smaller than that of 19 December (Figure 4b), would have reduced field loss by this much. WEPS needs a provision to account for standing biomass that is not uniformly spaced. The necessary information may be obtained using a portable wind tunnel on surfaces with different configurations of standing biomass. An extension of WEPS along similar lines is also needed for simulating wind erosion on range lands, where standing elements, such as bushes and shrubs, are not spaced uniformly.

Conclusions

One dust storm occurred during the experimental period (November 2000 – April 2001), with a net field sediment loss of 0.06 kg/m^2. Spatial variability of sediment discharge was high and could be explained by spatial differences in field conditions. WEPS overestimated the protective power of small wheat plants. A simulation without wheat produced a field loss of 1.75 kg/m^2, whereas very small wheat plants (h = 10 mm, LAI = 0.1, SAI = 0.01) totally stopped erosion. WEPS needs a provision to account for standing biomass that is not uniformly spaced, such as wheat plants in the field. Albedo is a good indicator of soil wetness right at the soil surface. Additional research is needed to use albedo for quantifying soil surface water content.

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Table 1. Measured field conditions on three dates. Average and standard deviation are for 15 samples, one near each of the 15 BSNE stations, not located on a field boundary, except as indicated in the footnotes below. The last column indicates whether a variable is used in WEPS or not.

Variable	19 December		8/9 March		12 April		WEPS
	avg	stdev	avg	stdev	avg	stdev	
Surface soil moisture (kg/kg)	0.036	0.007	0.061	0.039	0.120	0.020	
Plant height h (mm)	43	11	57	6	149	22	X
LAI (m^2/m^2)	0.32	0.12	0.34	0.14	1.03	0.33	X
SAI (m^2/m^2)	0.05	0.02	0.04	0.02	0.11	0.04	X
Population (plants/m^2)	203	88	173	77	157	62	
Leaf dry mass (g/m^2)	30.0	11.4	25.6	11.3	60.8	18.7	
Stem dry mass (g/m^2)	9.5	4.5	2.4	2.0	15.1	7.3	
Residue cover (%)	14.0	7.9	9.7	3.5	9.8†		X
Air dry residue mass (kg/ha)	1710	698	1685	489	1411	579	
Sand (%)	31	7					X
Silt (%)	53	6					X
Clay (%)	16	5					X
Aggregates < 84 μm (%)	59	6	48	12	56*	15*	
Minimum aggregate size (mm)[1]	0.019		0.044		0.020*		X
Maximum aggregate size (mm)[1]	79.5		77.9		44.4*		X
GMD (mm)[1]	0.62		1.32		0.75*		X
GSD (mm/mm)[1]	12.0		18.7		14.7*		X
Crust thickness (mm)	11&	3&	21!	6!	21‡		X
Loose material on crust (kg/m^2)	0.65‡		0.65~	0.61~	0	0	X
Dry aggregate stability (ln[J/kg])	3.11#	1.00#	2.54#	0.90#	2.51¶	1.22¶	X
Wet aggregate stability (%)	23	6					
Ridge height (mm)	42	7	36	7	34	6	X
Ridge roughness (mm)	12.5	2.2	12.1	1.8			
Random roughness (mm)	5.8	1.9	5.2	1.1			X

[1] Obtained by fitting the cumulative distribution function (Wagner and Ding, 1994) to the average of the measured cumulative aggregate size distribution using Tablecurve (SPSS Inc. Chicago, IL) software

GMD = Geometric Mean Diameter
GSD = Geometric Standard Deviation
* n = 3 (one sample near each of 3 BSNE stations)
~ n = 30 (two samples near each of 15 BSNE stations)
& n = 92 (several samples near each of 15 BSNE stations)
! n = 86 (several samples near each of 15 BSNE stations)
n = 300 (twenty samples near each of 15 BSNE stations)
¶ n = 60 (twenty samples near each of 3 BSNE stations)
† estimated from residue mass
‡ used March measurement

Table 2. Simulation results from the WEPS erosion submodel for the 17/18 December dust storm and the 11 April wind storm.

SIMULATION INPUT **Simulation of 17/18 December event using…**	Field soil loss (kg/m^2)
19 December conditions (Table 1)	0.00
Dry soil surface	0.00
Dry and very small wheat plants†	0.00
Dry and no wheat plants	1.75
Soil surface moisture as in Table 1 and no wheat plants	0.13
Measured	0.06
Simulation of 11 April event using…	
12 April conditions (Table 1)	0.00
Dry and no wheat plants	0.00
Dry and no wheat plants, loose material on crust = 0.01 kg/m^2	8.31
Dry and very small wheat plants†, loose material on crust = 0.01 kg/m^2	0.12
Measured	0.00

†very small wheat plants: height = 10 mm, leaf area index = 0.1, stem area index = 0.01

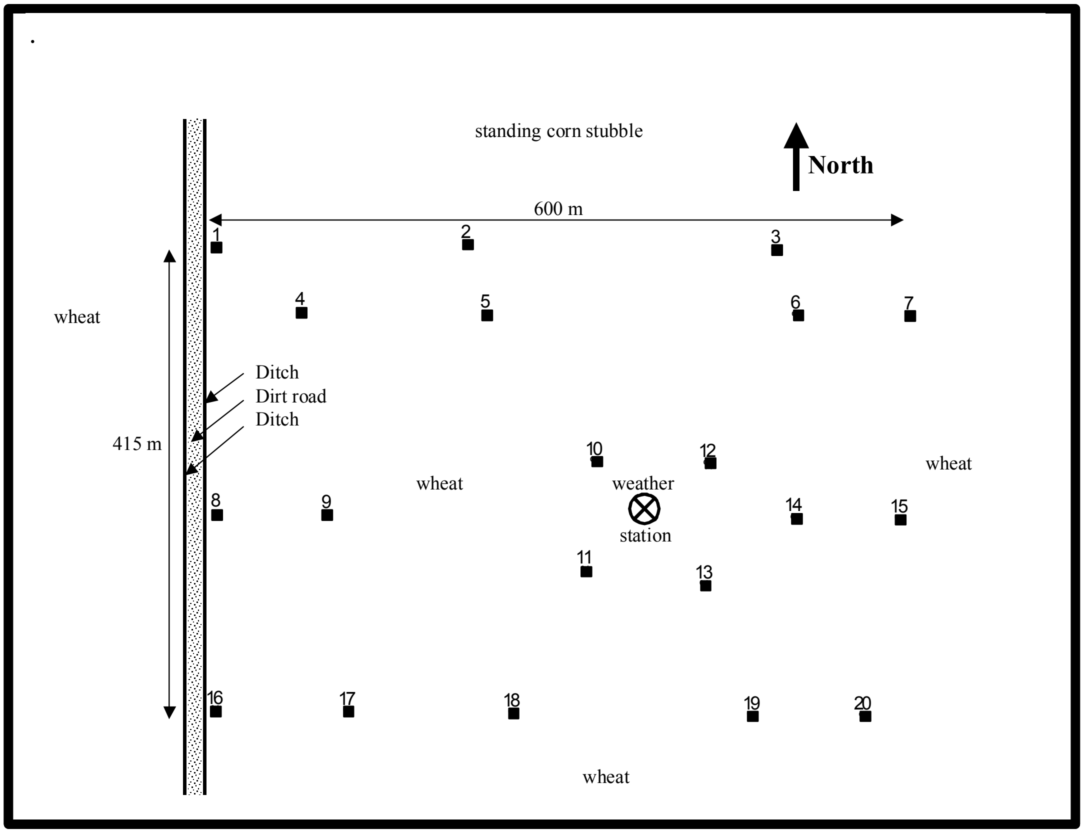


Figure 1. Placement of BSNE stations on the experimental field. Numbers are station ID's. Each station consists of 6 BSNE samplers with openings at 0.05, 0.10, 0.35, 0.60, 1.00, and 1.50 m.

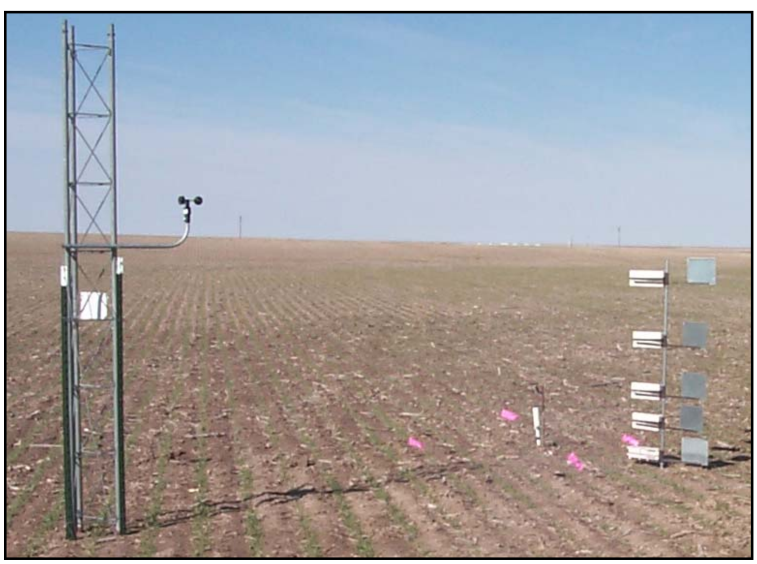


Figure 2. Station 11 was one of four stations (10-13) instrumented with BSNE samplers, a Sensit and an anemometer.

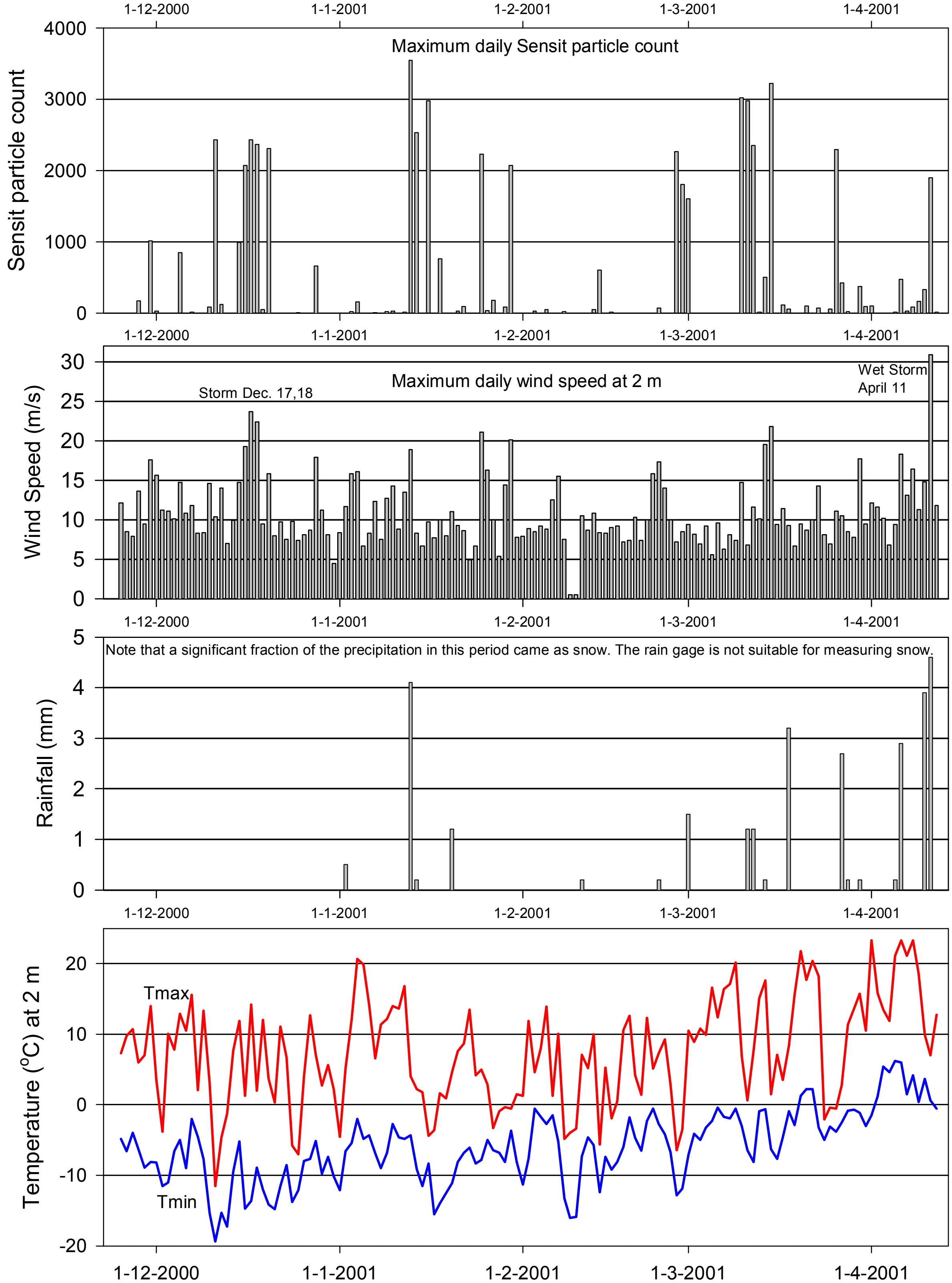


Figure 3. Overview of daily weather and Sensit data for the experimental period, November 2000 - April 2001.

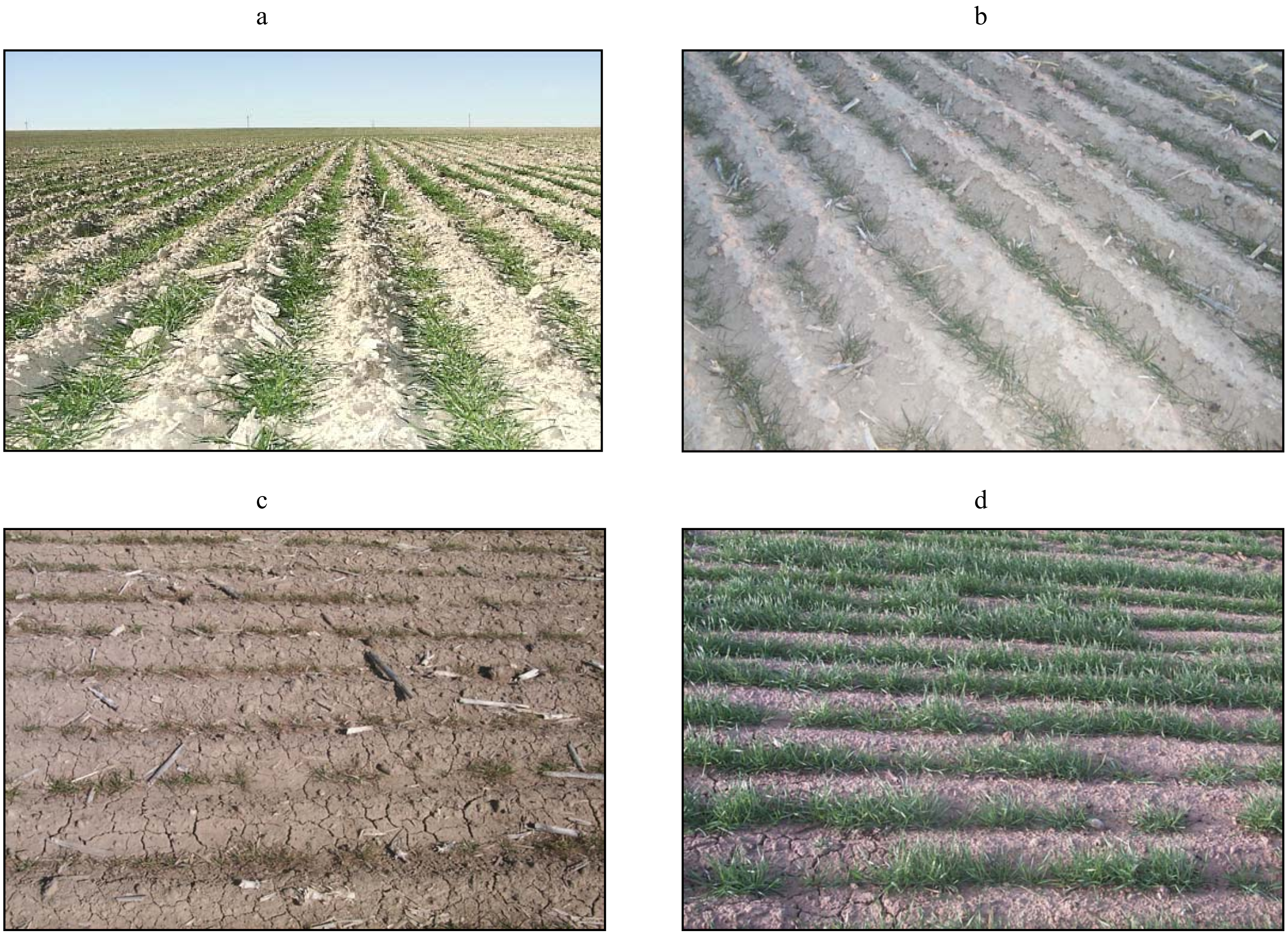
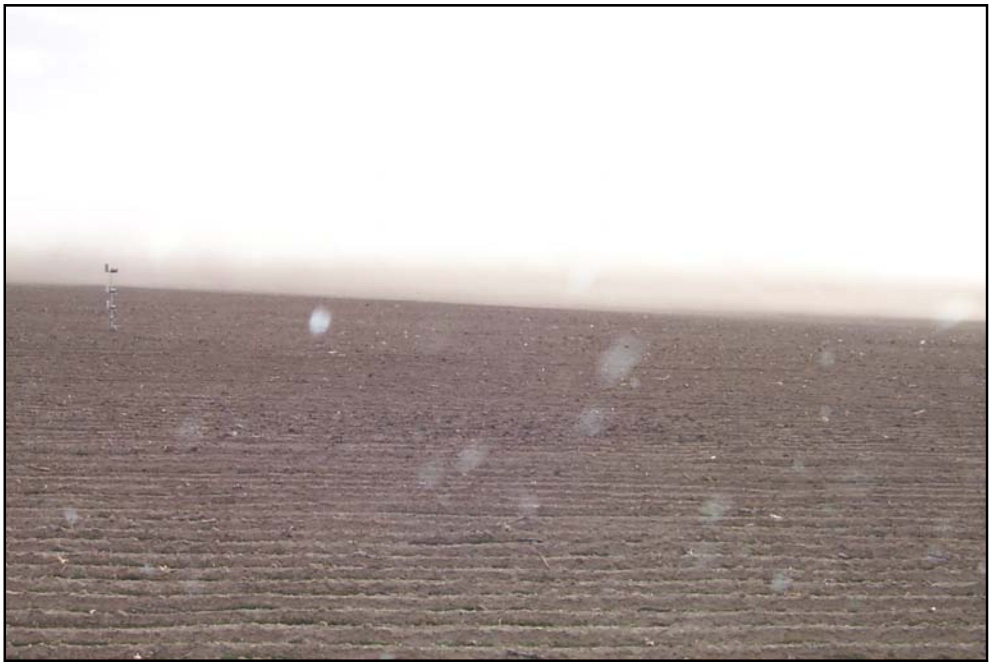


Figure 4. Condition of the field surface on 9 November, 2000 (a), 19 December, 2000 (b), 8 March, 2001 (c), and 12 April, 2001 (d).

a



b

Figure 5. Wind erosion on 18 December, 2000. Soil and dust are moving in the distance. In the foreground hardly any soil is moving (a). Abraded soil ridges after the storm in areas of heavy soil movement (b).

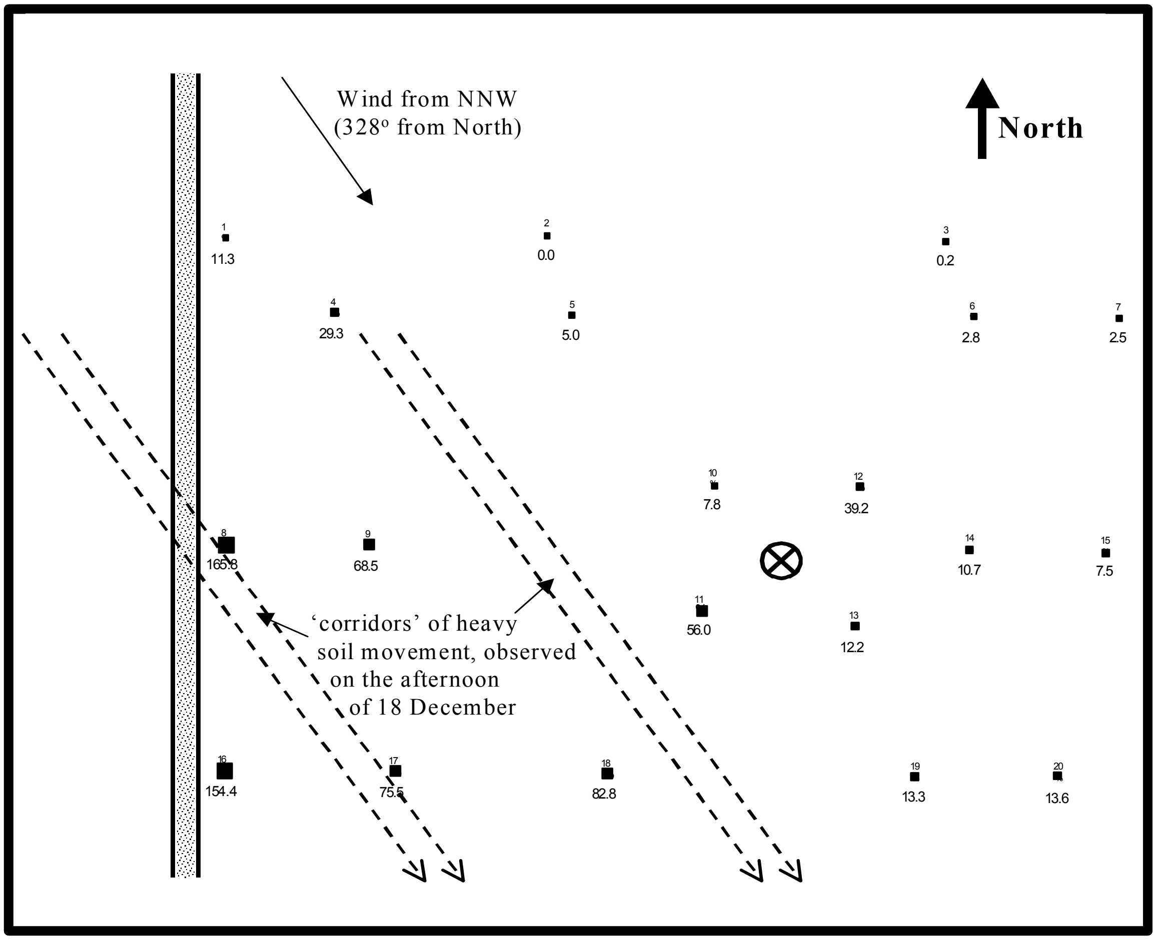


Figure 6. Soil discharge (kg/m) associated with the storm on 17/18 December, 2000. Numbers in small print are station ID's.

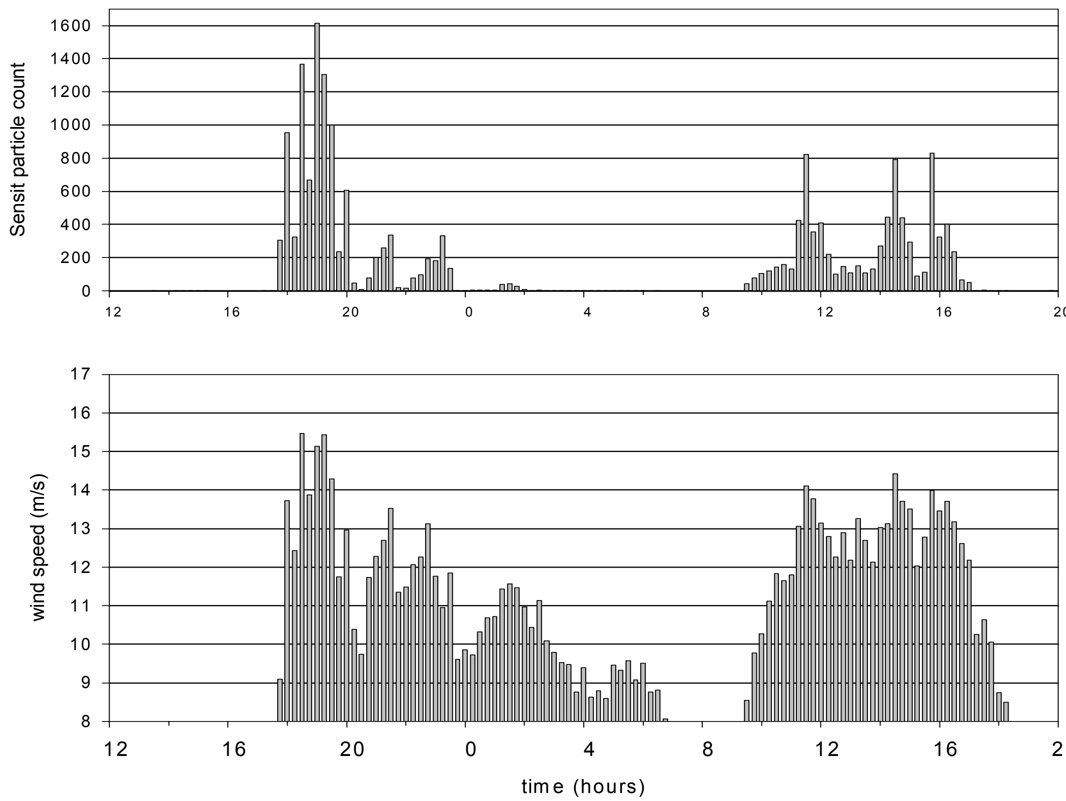


Figure 7. Detail of wind erosion event on 17/18 December. Data are 15 minute averages, measured at station 12.

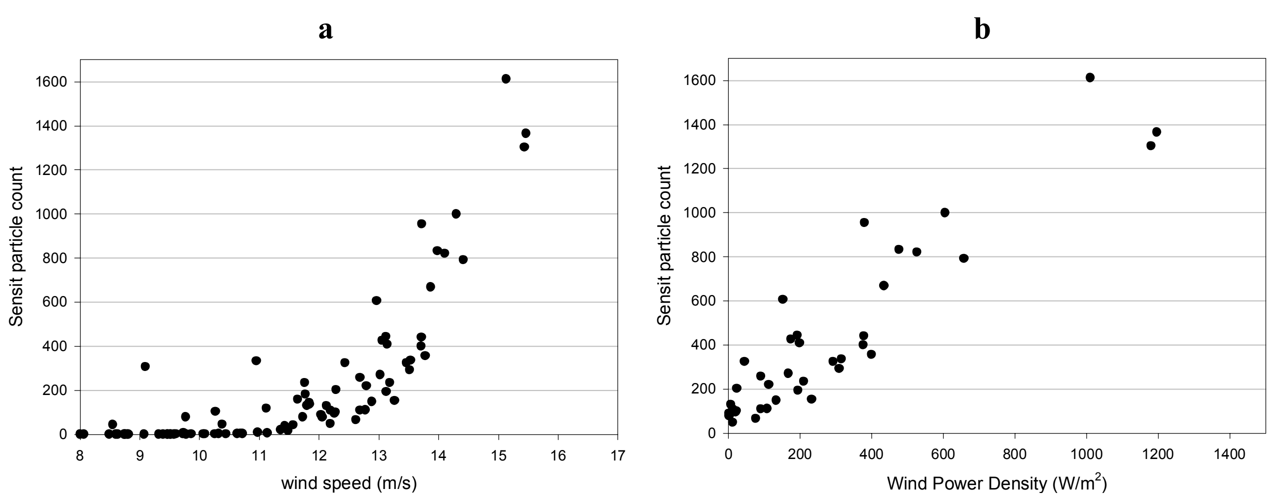


Figure 8. Determination of threshold wind speed from Sensit and wind speed data (a) and Sensit particle count as influenced by wind power density (equation 2) using a threshold wind speed of 12 m/s (b). Data are 15 minute averages, measured at station 12 on 17/18 December.

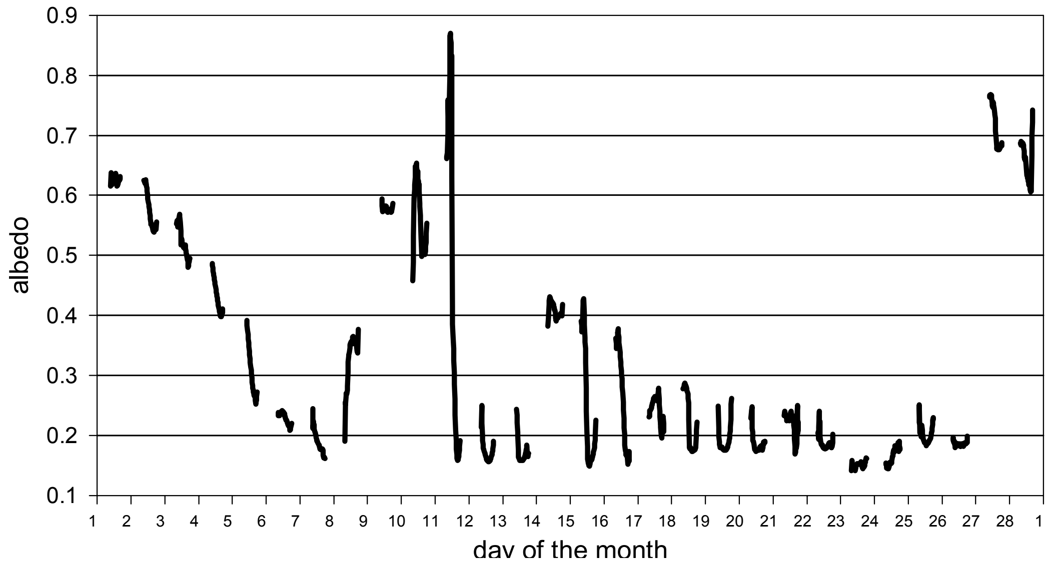


Figure 9. Albedo (short wave reflection coefficient) for February 2001. High albedo indicates the presence of a snow cover.

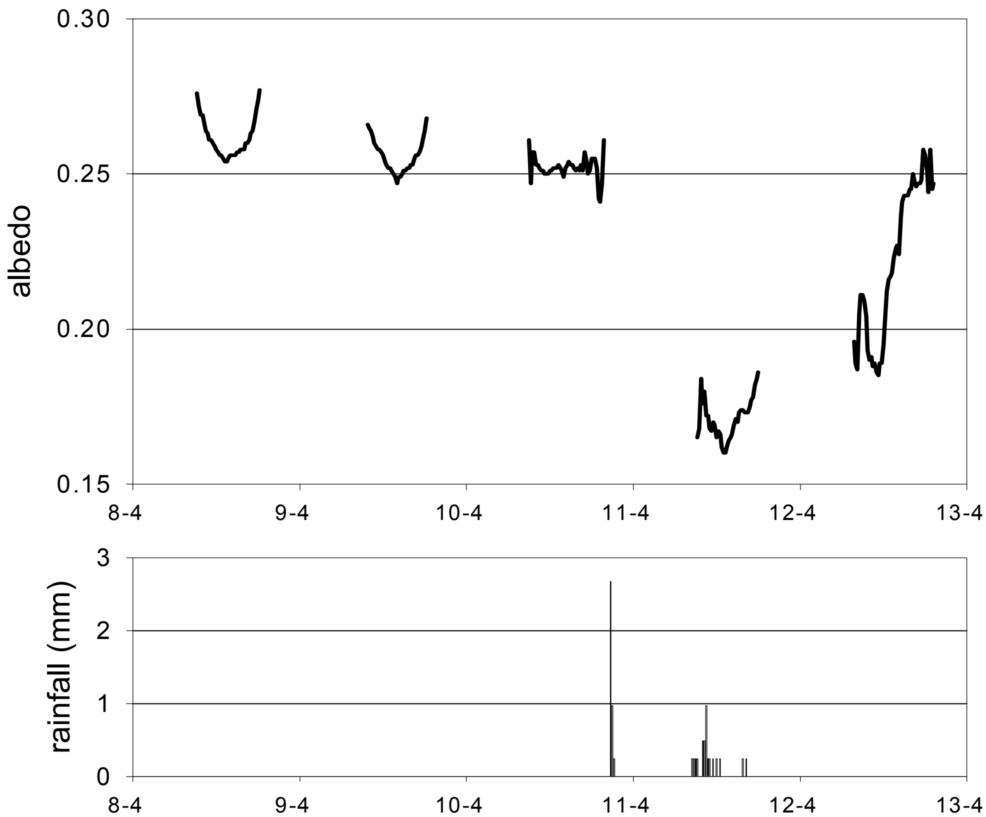


Figure 10. Albedo and rainfall for 8 April through 12 April, 2001. Albedo decreases after rain has wetted the soil surface. It increases again on 12 April, as the soil surface is drying.