Wind Erosion on Field in a Semiarid Area of China

Xuewen Huang, Halin Zhao, Bin Xu

Introduction

Wind erosion is a frequent phenomenon in Northern China where climate ranges from arid and semiarid to dry subhumid. The total area affected by wind erosion is 33 million hectares. Serious wind erosion occurs in the semiarid region, where overgrazing and ploughing of rangeland have dramatically increased since early in the 20th century (Zhu, and Wang, 1993). Every year desert encroachment caused by wind erosion buries 210,000 hectares of produce land in China (PRC, 1994).

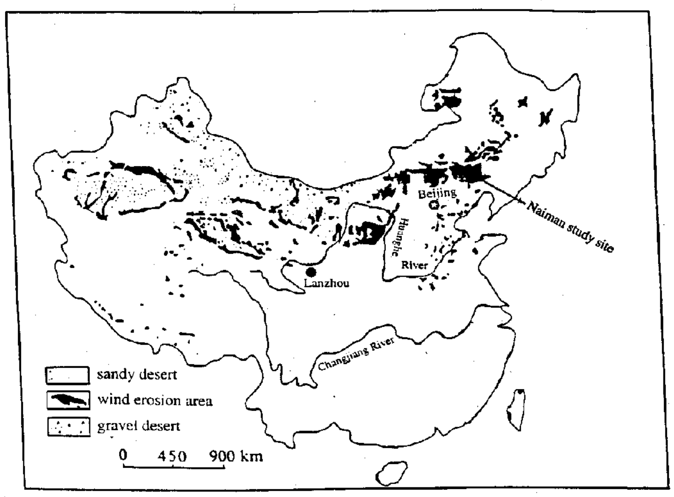

Figure 1.Desert and wind erosion area in China

Most research on wind erosion in China focuses on erosion control practices and/or descriptive studies in the field. This paper reports soil loss rates in fields under different conditions using sampler and grid methods. Also, changes in soil quality caused by wind erosion are discussed.

Environmental description of study area

The study area is located at Horqin sandy land, Naiman Banner, Inner Mongolia, which was formerly a prairie. Unfortunately, a rapidly increasing population and intensive human activities in this area have changed the landscape from prairie to sandy land since the middle of this century.

The topography is categorized into sand dunes, gentle undulating slopes, and some nearly level areas which occupy a small part of the total area which is used for agriculture. The ground surface is covered by abound Quaternary alluvia and lacustrine deposits. The main soil groups belong to meadow and aeolian sand soil. Sand particles account for 80% of the soil texture. Annual rainfall is 360 mm. Annual temperature is about 6.5 °C. It is dry and windy in winter and spring. The average wind speed is 3.5 m/s, but in spring it reaches 4.4 m/s. The prevailing wind is northwest. The wind direction frequency distribution is illustrated in Figure 1. All observation fields were in local condition, where land was in winter fallow, with little standing residue.

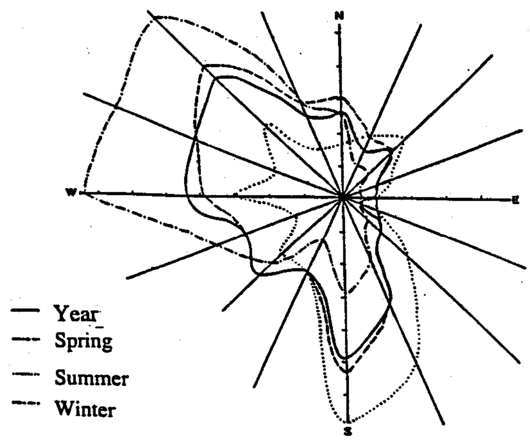

Fig.2. Wind direction frequency distribution in study area

Methods for Wind Erosion Study in Field

Two methods were used to measure the soil loss over time. The IDEAS segmented dust sampler (see Figure 2), which is 20 cm tall with 10 square openings of 4 cm^2 (2 cm by 2 cm), was installed on the field surface and faced toward the wind direction. This sampler was used to measure the soil flux during wind erosion events. This sampler only catches the surface creep, saltation and some of the low level suspension. The bottom of the lowest opening was at the ground surface, so that the transported materials from surface creep to the lower suspension layer could be collected. A three-cup 1-minute average anemometer was installed on a pole erected 1 m away and parallel to the sampler to measure wind speed at two heights of 0.5 and 2 m. The sampling time varied from 10 to 30 minutes depending on the wind speeds; the higher the wind speed, the shorter the sampling time. Zhao and Huang (1993), Hasi (1994) measured the soil loss in arable land using the sampler. Chen *et al*.(1996) studied the distribution of grain-size parameter of drifting sand flux collected by the sampler.

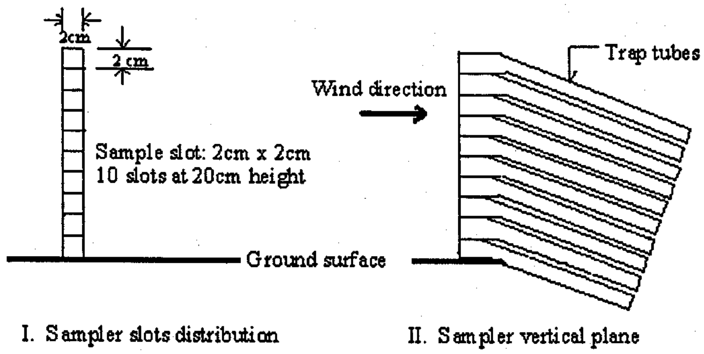

Fig.3. Installation and structure of segmented sampler

Figure 3 illustrates the field condition and location of eight samplers in the field. We divided the field into three areas: eroded area, also called negative sediment balance; transit area, also called neutral sediment balance; and deposition area, also called positive sediment balance. The dashed line is the original ground level before erosion took place. In addition, we collected soil samples at the eight sites in order to study the soil properties affected by wind erosion.

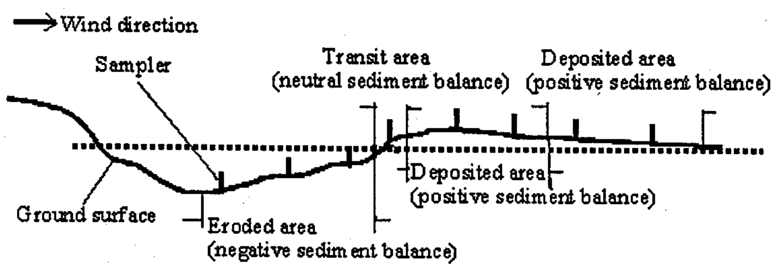

Fig.4. Field condition and samplers installation

Another method, called the grid method (Xu *et al.*, 1993), was used to survey the depth of erosion or deflation and deposition during the wind erosion season. Figure 4 shows the structure of the apparatus. The grid board which is 150, 15, and 2 cm in length, width and thickness, respectively, is made of smooth wood. There are fourteen holes on the board. The space between the holes is 10 cm. After selecting the sites, we established 2 fixed reference points, one meter apart. At each site, we buried two pins as the reference points under the ground surface and marked the location. The level of the grid is determined by the top of the reference points.

Changes in the relief of the ground surface are measured with a scale through each of 14 holes in the grid. After the measurement, the grid is removed. Through replicate measurements over different periods, the erosion or deposition amount was determined using this method.

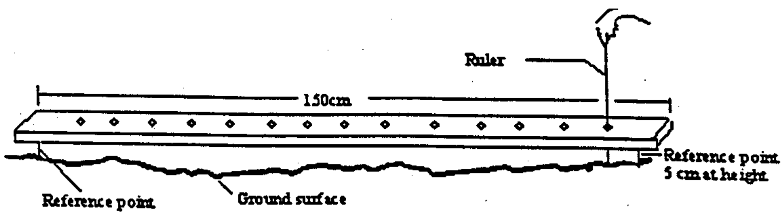

Fig. 5. Grid method for measurement of depth of wind erosion

Results and Analysis

Soil loss rate and vertical distribution during wind erosion event

The sample data were analyzed to determine the distribution and transport of eroded material with height and distance. During an erosion event in spring 1992, wind speed was about 7 to 11 ms^{-1}. Figure 5 shows soil flux in different height segments. Obviously, soil flux decreases with the height above the surface. However, values for soil flux in the 0 to 4 cm segment at the four sites are different. Deposition areas have greater values than either the eroded area or transit area. The reason is that there were fewer erodible soil particles, a higher water content, and a harder surface in the eroded area than in the other areas. In contrast, many erodible particles and/or loose fine particles existed in deposition areas which helped to promote soil drifting. Distribution of soil flux by percentage at different sites is illustrated in Figure 6. The average percentages of 40, 30, 13, 10, and 7 eroded material distributes at 0-4, 4-8, 8-12, 12-16, and 16-20cm heights, respectively.

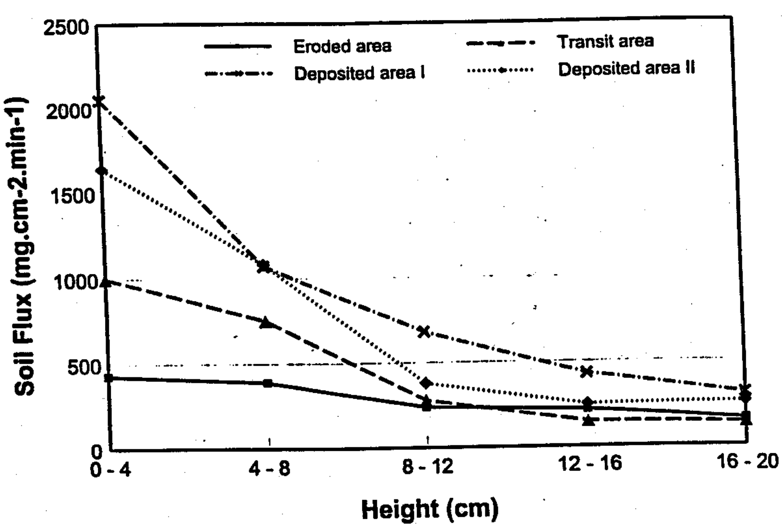

Fig. 6. Soil flux in different height segments

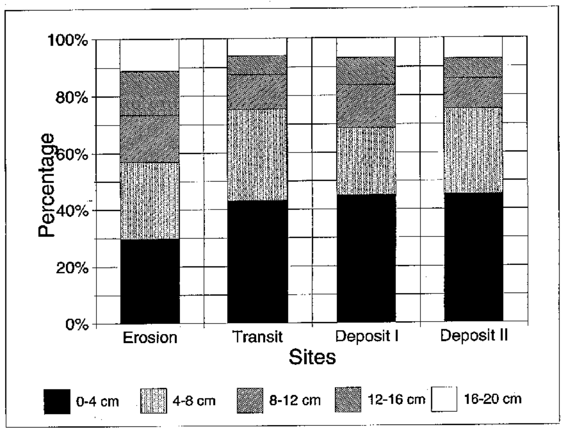

Fig.7. Vertical distribution of sampler soil flux at different sites

Residue and wind erosion

Table 1 shows the relationship between residue and soil loss. The residue was standing, and a typical amount on local farmland. Soil loss rate in Horqin Sandy Land is tremendous. Annually, about 0.5 to 1.8 cm of top soil is removed by wind from arable land. Residue after harvesting can beneficially reduce wind erosion on cropland. In general, the more residue, the less soil loss. But, characteristics of the root systems also influence the cohesion between soil and root; for instance, millet and corn have more hairy roots than sorghum, soybean and buck wheat. The hairy roots aggregate the soil and help prevent soil from blowing. Although sorghum has large roots, the soil loss in sorghum residue land is still considerable. Unfortunately, the residue amounts reported in Table 1 are too low to provide wind erosion control on Horqin Sandy Land.

Table 1. Relationship Between Residue and Soil Loss by Wind

Residue	Residual Amounts ($kg \cdot ha^{-1}$)	Erosion in Depth(cm)	Soil Loss ($t \cdot ha^{-1}$)
corn[a]	1875	0.5	72
sorghum[a]	975	1.5	217
millet[a]	825	0.8	116
millet[b]	725	0.21	30
wheat[b]	305	1.42	204
black soybean[b]	188	1.8	216
buck wheat[a]	150	1.5	217
buck wheat[b]	298	1.1	158

[a]: measured from October 17, 1988 to April 28, 1989; [b]: measured from October 22, 1989 to May 14, 1990.

Topography and wind erosion

Soil losses by wind erosion in different topography are illustrated in Table 2. In gentle slope topography, wind erosion occurred everywhere, including base, lower, upper and dome of slopes. However, the results are complex because sometimes wind erosion exhibited deflation, but at other time deposition occurred in the same place. For example, October 17, 1987 to April 23, 1988, at four slope locations (base, lower, upper and dome), displayed soil deposition except the middle. On the other hand from April 23 to May 5, 1988, all slope locations, except upper, displayed soil loss. Only the middle part of gentle slope always suffered soil loss.

Table 2. Soil Loss by Wind in Different Topography

Topography		Soil Loss at depth(cm) in measured dates		
		April 23	May 5	May 14
Gentle Slope:	base	0.40*	0.21	missing data
	lower	0.1*	0.01	0.11
	middle	3.43	0.93	0.67
	upper	0.49*	0.26*	0.13*
	dome	2.03	0.07	0.27*
Gentle Slope Related to Wind Direction				
Windward face:	lower	0.22	0.09	0.23*
	middle	5.86	0.90	missing data
	dome	2.47	0.66	0.73
Downwind or slip face		2.33*	0.66	0.46
Plain Cropland		1.08	0.10	0.30
Plain Grassland		0.42*	0.5*	0.35*

*soil deposit depth. Above data were measured from October 17th, 1987 to May 14th, 1988.

When location was identified relative to wind direction, the maximum soil deflation occurred in the middle and dome on the windward side of moderate-slope cropland, whereas the downwind slope showed deposition. Level cropland always exhibited soil loss, but nearby level grassland caused deposition.

Wind erosion is particularly severe on newly developed cropland. On this land, wind erosion generally resulted in trough-shaped depressions on the windward slope and patch-shaped deposits on the leeward, forming a fragmented field. This kind of cropland soon became too rough and degraded for cultivation; therefore, it has to be abandoned. Generally, these newly developed croplands were located on the grassland with a gently sloping ground surface and sandy soil. Due to the uneven ground surface, the sandy soil texture, and the destruction of vegetation by ploughing, the new cropland is highly susceptible to wind erosion. Finally, it becomes a blowout or poor quality crop land. Table 3 shows soil erosion on disturbed land because of ploughing. The soil loss in new cropland is tremendous. The volume reached 1400 tons per hectare in depression, 900 tons per hectare in the windward middle area of the slope, whereas 58 tons per hectare deposition and 14 tons per hectare of soil loss occurred in grassland at corresponding locations.

Table 3. Soil Erosion on Disturbed Land After Ploughing

Location and Topography	Slope(E)	Erosion at depth (cm)	Soil Loss($t \cdot ha^{-1}$)
Depression			
New Cropland	0	9.6	1392
Grassland	0	0.4*	58*
Windward middle areas			
New Cropland	5.0	6.2	899
Grassland	3.0	0.1	14
Windward upper areas			
New Cropland	2.0	3.2	464
Grassland	2.0	3.7*	536*

*soil deposition at depth, measured from October 17, 1987 to May 30, 1988.

Soil quality and wind erosion

Wind erosion significantly alters soil physical and chemical properties (see Table 4). Through selective removal of soil particles, there is enrichment of organic matter, soil nitrogen, and phosphorus in wind-eroded sediment compared to the eroded area. In addition to soil organic matter and nutrients, soil particles on the surface changed dramatically. Fine particles (<0.005mm) doubled in the deposited area compared to the eroded area. On the other hand, pH value increased in eroded area, and decreased in deposited area. This result is due to the fact that local parent soil and ground water contain saline and alkaline components. When the topsoil was removed, exposure of a high pH parent soil or subsoil led to an increase of pH value at the surface.

Table 4. The Changes of Soil Properties due to Wind Erosion

	Eroded land				Transit land		Deposition land I			Deposition land II
sites	1	2	3	mean	4	5	6	7	mean	8
Soil Organic Matter ($g \cdot kg^{-1}$)										
	2.45	3.66	5.22	3.78	4.80	6.28	7.50	6.86	6.88	8.50
pH	8.92	8.90	8.83	8.88	8.77	8.77	8.71	8.73	8.73	8.66
Total Nutrient($g \cdot kg^{-1}$)										
N	0.15	0.24	0.29	0.23	0.29	0.36	0.42	0.36	0.38	0.46
P_2O_5	0.35	0.38	0.40	0.38	0.40	0.45	0.44	0.44	0.44	0.51
Available Nutrient ($g \cdot kg^{-1}$)										
N	0.0236	0.0255	0.0314	0.0268	0.0410	0.0421	0.0227	0.0316	0.0321	0.0665
P_2O_5	0.0063	0.0106	0.0127	0.0990	0.0156	0.0116	0.0134	0.0109	0.0120	0.0103
Fine particles(<0.005 mm)										
%	4.01	4.16	5.69	4.62	6.50	8.55	9.74	9.92	9.40	9.92

Conclusion

Wind erosion in field conditions is complex and influenced by climate, surface cover, topography, and soil characteristics. In semiarid cropland, soil flux reached 1.4 to 4.5 $g\cdot cm^{-2}$ per minute on eroding and deposition areas during an erosion event. Soil flux decreases with the height above the surface. The amount of erodible particles and surface situation influence the soil transport. Using the grid method, measured soil loss from fall to next spring reached 44 to 260 tons per hectare on cropland. Such severe erosion results in broken landscape. Soil loss in newly developed cropland was particularly severe and reached 1400 tons per hectare. Undoubtedly dry, windy weather, loose soil, and less residue and ploughing of grassland accelerates wind erosion. Wind erosion significantly alters soil physical and chemical properties by removing topsoil and fine particles. Soil organic matter, nutrients, and fine particles decrease, but pH values increase in eroded compared to deposition areas.

Due to sever soil degradation from wind erosion in this area, erosion control is the first concern by local community. We suggest that returning cropland to grassland, establishing windbreak, and increasing standing residue after harvest are the effective measures.

Acknowledgment

The authors greatly appreciate helpful suggestions on the manuscript from Ed. Skidmore and L. Hagen.

References

Chen, W., Yang, Z., and Dong, Z., 1995. Vertical distribution of grain-size parameters of drifting particles during sand storms in the Taklimakan Desert, Central Asia. Physical Geography, 16 (6): 503-532.

Gao, A. and Wu, S., 1996. Study on wind erosion of sandy lands in Huang-Huai-Hai Plain, Acta Pedologica Sinica. 33(2): 184-190.

Hasi, 1994. Effects of unerodible soil particles and tillage way on wind erosion on Bashang Highland. J. of Desert Research, 14(4):72-97.

People's Republic of China (PRC), 1994. China 21st Agenda, China Environmental Science Press, Beijing, China.

Xu, B., Liu, X., and Zhao, X., 1993. Soil wind erosion in farmland and its control in the Middle Part of Naiman Banner, Inner Mongolia Autonomous. J. of Soil and Water Conservation, 7(2): 75-88.

Zhao, H., Huang, X., and He, Z., 1996. Study on desertification of farmland soil in Horqin Region, Inner Mongolia, Acta Pedologica Sinica, 3(3):242-248.

Zhu, Z., and T. Wang.1993. Trends of desertification and its rehabilitation in China. Desertification Bulletin, N0.22:27-30.