WIND EROSION GRADIENT PATTERNS OF MONGOLIAN PLATEAU

YONG-QING QI\textsuperscript{1,2}, JI-YUAN LIU\textsuperscript{2}, HUA-DING SHI\textsuperscript{3}, DA-FANG ZHUANG\textsuperscript{2}, YUN-FENG HU\textsuperscript{2}

\textsuperscript{1}The Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Shijiazhuang 050021, China
\textsuperscript{2}Institute of Geographic Sciences and Resources Research, Chinese Academy of Sciences, Beijing 100101, China
\textsuperscript{3}Chinese Research Academy of Environmental Sciences, Beijing 100012, China

E-MAIL: qiyq@sjziam.ac.cn

Abstract:
Wind erosion is one of the major environmental problems in semi-arid and arid regions. Here we established a transect from northwest (Tariat, Mongolia) to southeast (Xilingol, Inner Mongolia of China) across the Mongolian Plateau, and estimated the soil wind erosion gradient patterns by using the \textsuperscript{137}Cs tracing technique. In the Mongolia section, the wind erosion rate increased gradually with vegetation type and climatic regimes, controlled by physical factors such as annual precipitation and vegetation coverage, etc. While in the Inner Mongolia section, the wind erosion rates were thrice as much as those of Bayannur of Mongolia. Besides the physical factors, higher population density and livestock carrying level should be responsible for the higher wind erosion rates in Inner Mongolia.

Keywords:
Mongolian Plateau; Wind erosion; \textsuperscript{137}Cs tracing technique

1. Introduction

As an important indicator of land desertification, wind erosion is one of the major environmental problems in semi-arid and arid regions worldwide \cite{1,2}, including the Mongolian Plateau. The main part of the Mongolian Plateau belongs to Mongolia in the north and Inner Mongolia Autonomous Region of China in the south and east. The plateau is an intracontinental region in East Asia, with rare annual precipitation and frequent drought and windy episodes during the whole winter-spring season. Wind erosion is an important geo-process that can result in regional land degradation and dust storms \cite{3,4}. Moreover, the Mongolian Plateau is also a sensitive region of global climate change \cite{5}.

The \textsuperscript{137}Cs tracing technique has been improved during the last 40 years and is currently considered as one of the major techniques for estimating soil erosion rates. This technique was originally used for water erosion studies, but has been applied to estimate wind erosion rates since the 1990s \cite{6-8}.

In this paper, we collected soil samples along the Tariat-Xilingol transect across the Mongolian Plateau, and to estimate the wind erosion rates of the sampling sites using the \textsuperscript{137}Cs tracing technique and to assess the gradient patterns of wind erosion along the sampling transect.

2. Study area

The Tariat-Xilingol transect spanned a 1,400-km spatial gradient, and traversed the main wind erosion region of the central Mongolian Plateau (Figure 1). It constitutes a spatial gradient in both climate and vegetation types. Along the transect from north to south, the vegetation type changes from forest steppe, typical steppe, desertification steppe, steppe desert, Gobi desert, typical steppe to farming pastoral grassland. Thus, the transect covers the major vegetation and ecological types of the wind erosion region on the Mongolian Plateau \cite{9,10}.

3. Sample collection and analysis

Figure 1. The Tariat-Xilingol transect and sampling sites

There are 8 sample sites were chosen (Figure 1). The Tariat site (RS1) with forest steppe is located in the north slope of Hangai Mountain where the dominant vegetation
type is typical Carex meadow steppe on the taiga forest edge. Bayannur (RS2) is located in the grazing zone of Tura River basin, with the typical steppe of the north Mongolian Plateau. The Lus site (RS3) is located in the transitional region between Hangai Mountain and Gobi desert, and vegetation type is desertification steppe with typical high drought hardness plants. Elerjet (RS4) is located in the area closer to the Gobi desert, and the dominant vegetation type is steppe desert with less annual precipitation than Lus. The Sainshand site (RS5) is located in the typical Gobi desert region with rare persistent remains on the bare ground surface. The sites of Xilinhot (RS6), Zhengxiangbai Banner (RS7) and Taipusi Banner (RS8) are located in the south section of this transect, Inner Mongolia, and the steppes are used as pastures those are under the different management and human disturbance modes. Generally, for the effective and reliable comparison on wind erosion at the transect scale, all of the sampling sites have similar topography as open and flat plain.

The soil samples were collected by using a column cylinder drill (90 mm internal diameter). At each sampling site, one section sample and 2~4 bulk samples were collected. The section sample was collected was from the top 30 cm depth of the soil profile with 3 cm increment from 0 to 12 cm and 6 cm increment from 12 to 30 cm. The bulk samples (30 cm depth) were radially distributed around the section sample point with 10~20 m away. All the samples were oven-dried, disaggregated and passed through a 2-mm sieve prior to the 137Cs activity analysis. The samples were tested in the Nuclear Physics Laboratory of Sichuan University. The 137Cs activities in soil samples were determined by gamma-ray spectrometry equipped with hyperpure germanium (HPGe) detector. The sample testing weight of about 400 g and the counting time of 25,000 s provided the results with an analytical precision of the 95% level confidence. The 137Cs activities in the samples were obtained from the peak area in the spectrum associated with 662 keV.

4. Results and discussion

4.1. Wind erosion rates at the sampling sites

The profile-distribution model was used to estimate the wind erosion rates in this study \cite{10}:

\[ X = k \cdot X_0 \cdot e^{-h \cdot (T + T_0)} \]  

\text{(eq 1)}

where \( X \) is 137Cs inventory of sampling site (Bq·m⁻²) in the year \( T \); \( X_0 \) is 137Cs reference inventory (Bq·m⁻²); \( h \) is average annual soil erosion depth (cm·a⁻¹); \( T \) is the year of sample collection; \( \lambda \) is the coefficient describing the shape of the 137Cs depth distribution in the soil that can be confirmed by the least squares fit using every layer 137Cs contents of the section sample; and \( k \) (0.95) is the coefficient of 137Cs redistribution caused by snow-blown \cite{11}.

The 137Cs inventories of the sampling sites ranged from 265.6±44.9 to 2087.1±70.2 Bq·m⁻². The highest value was measured at Site RS8-2 of Taipusi Banner in the southern typical steppe zone and the lowest one was found at Site RS5 of Sainshand in the Gobi desert zone.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
\textbf{Sampling sites} & \textbf{137Cs inventory (Bq·m⁻²)} & \textbf{Soil bulk density (t·m⁻³)} & \textbf{Erosion depth (mm·a⁻¹)} & \textbf{Erosion rate (t·km⁻²·a⁻¹)} \\
\hline
RS1 & 788.9±98.9 & 1.10 & 0.16 & 172.37 \\
RS2-1 & 1279.5±166.5 & 1.60 & 0.04 & 64.58 \\
RS2-2 & 1070.9±138.5 & 1.26 & 0.08 & 103.46 \\
RS2-3 & 846.5±100.2 & 1.24 & 0.14 & 169.07 \\
RS3 & 796.5±128.4 & 1.57 & 0.13 & 206.34 \\
RS4 & 733.7±122.3 & 1.75 & 0.16 & 276.24 \\
RS5 & 265.6±44.9 & 1.04 & 0.40 & 419.63 \\
RS6 & 661.2±101.3 & 1.29 & 0.28 & 360.02 \\
RS7 & 886.9±83.8 & 1.67 & 0.21 & 351.33 \\
RS8-1 & 1230.6±40.2 & 1.35 & 0.14 & 417.60 \\
RS8-2 & 2087.1±70.2 & 1.24 & 0.02 & 53.12 \\
RS8-3 & 1113.0±36.5 & 1.33 & 0.17 & 479.63 \\
RS8-4 & 1412.7±75.4 & 1.29 & 0.11 & 309.74 \\
\hline
\end{tabular}
\caption{137Cs inventories and wind erosion rates of the sampling sites}
\end{table}

Table 1 shows the annual wind erosion depths and erosion rates. Wind erosion depths ranged from 0.02 to 0.40 mm·a⁻¹. In the transect, soil bulk densities of some sampling sites are higher because of high gravel contents and tight soils, and the wind erosion rate accordingly ranged from 53.12 to 479.63 t·km⁻²·a⁻¹.

4.2. Analysis and discussion

The T value, the soil loss tolerance factor, is a discriminatory standard to determine whether obvious and harmful soil erosion had occurred. In China, the Ministry of Water Resources established the standard for Classification and Gradation of Soil Erosion \cite{12}, and defined the T value as “the maximum level of soil erosion that will maintain soil fertility and permit the crop productivity to be sustained in a long-time period”. In this study, we referred to the gradation of wind erosion in SL190-96 and the data of T values of water erosion in neighboring regions, and define 200 t·km⁻²·a⁻¹ as the acceptable T value of wind erosion estimation in the Mongolian Plateau region.
Figure 2 shows the wind erosion gradient patterns of the Tariat-Xilingol transect. In the north section, the wind erosion rates of Tariat and Bayannur are less than 200 t·km⁻²·a⁻¹, shows slightly eroded. The erosion process had no obvious effects on soil fertility, and steppe productivity and the structure & service of steppe ecosystem were maintained. The wind erosion rates of other sites are all beyond 200 t·km⁻²·a⁻¹, shows more severely eroded. The wind erosion has degraded soil fertility level and the primary productivity of steppe, and hence damaged the structure and service of ecosystem to some degree.

In the Mongolia section, the wind erosion rate generally increased from north to south along the transect except for Tariat. The lowest wind erosion rate was found at Bayannur in the typical steppe zone, 112.37 t·km⁻²·a⁻¹, and the highest value was found at Sainshand in Gobi desert, 419.63 t·km⁻²·a⁻¹. The gradient patterns of the wind erosion rates in the Mongolia section can be summarized as follows: from north to south, wind erosion increased with decreasing annual precipitation and decreasing vegetation coverage; wind erosion increased and biodiversity decreased when ecosystem structure was simplified from typical steppe, desertification steppe, and steppe desert to Gobi desert. The wind erosion process was mainly affected and controlled by physical factors, and the disturbance of human activities is negligible.

The south section of Xilinhot, Zhengxiangbai Banner and Taipusi Banner, is located at Xilingol region of Inner Mongolia of China. Apart from the Site of Sainshand in Gobi desert, the wind erosion rate increased gradually from north to south along the whole Tariat-Xilingol transect. The wind erosion rates of study sites in China are higher than those in Mongolia. The wind erosion rates at Xilinhot, Zhengxiangbai Banner and Taipusi Banner are thrice as much as that at Site Bayannur despite similar vegetation types. Higher wind erosion rates in these 3 Sites could be explained partially by more frequent dust storms due to stronger wind field in the windy season [13,14]. The average population density and stocking carry level is 10 per km² and is 0.6 per hm² for the sites in Inner Mongolia respectively [15]. The pasture natural condition in Site Bayannur is favorable, but the population density and stocking carry level, 3 per km² and 0.3 per hm² [16], are significantly lower than those of Sites in Xilingol, Inner Mongolia. Our results suggested that high intensity of human activity may be responsible for the more severe wind erosion in the Inner Mongolia section relative to the Mongolia section with similar natural conditions.

Except for Site Tariat and Site Bayannur, the wind erosion rate of each site is beyond the slight erosion level, the ecosystem stability and primary productivity were damaged to some extent. As an important component of the ecosystem, the steppe vegetation is in a continuous degenerate status.

5. Conclusions

In this study, we estimated the wind erosion gradient patterns of the Tariat-Xilingol transect across Mongolian Plateau using the 137Cs tracing technique, and examined causing factors of wind erosion along the transect. The 137Cs inventories of sampling sites ranged from 265.6±44.9 to 2087.1±70.2 Bq·², and the wind erosion rates ranged from 53.12 to 479.63 t·km⁻²·a⁻¹. Most of the sites were only slightly affected by human activities. All the sampling sites of the Mongolia section except Tariat, changing from typical steppe, desertification steppe, steppe desert to Gobi desert from north to south, with decreasing annual precipitation and vegetation coverage, and increasing wind erosion rates. Our results also showed that the wind erosion process was mainly controlled by physical factors in the Mongolia section of the transect. In the typical steppe zones of the north and south section, the wind erosion rates at Sites of Xilingol are thrice as much as that at Site Bayannur. The contrast between these sites could be explained by their
differences in physical factors, population density and stocking carry level. Our results also showed that intensive human activity may be responsible for the more severe wind erosion in the Inner Mongolia section. Given the acceptable T value of 200 t·km⁻²·a⁻¹ for the Mongolian Plateau, the wind erosion rate at each site is beyond the slight level except for Tariat and Bayannur. The ecosystem stability and primary productivity were damaged to some degree and the steppe vegetation was in a continuous degenerate status at these sites.

Acknowledgements

This paper is supported by the Chinese Academy of Sciences (KSCX1-YW-09-01 and KZCX2-YW-448), Chinese Ministry of Water Resources (2007SHZ090134) and the National Natural Science Foundation of China (40871021).

References