Soil Particle Size Distribution Characteristics under Different Land Use Patterns in the Agro-Pastoral Ecotone: A Case Study of Wuchuan County, Hohhot City (Postprint)

Authors: FU Dongsheng

Date: 2022-09-26T00:00:00+00:00

Abstract

Taking different farmlands and natural grasslands in Wuchuan County, Hohhot City as the research object, this study employed a combination of in-situ field monitoring and laboratory experiments to investigate soils from four typical farmland types: wheat stubble fields, sunflower stubble fields, tilled land, and abandoned farmland. By analyzing mean particle size, standard deviation, skewness, and kurtosis, the wind erosion resistance of lands under different utilization patterns was discussed. The research results indicate: (1) Soils in the study area are dominated by fine sand, very fine sand, and silt, accounting for 80%–85% of the total composition. (2) The soil particle size composition from fine to coarse follows the order: tilled for 1 a > natural grassland > tilled slope > wheat stubble > tilled for 15 a > abandoned for 5 a > sunflower stubble, with an average sand particle size of 2.12–2.61. (3) Soils in all layers exhibit poor sorting, with skewness showing positive values and being nearly symmetrical, and kurtosis belonging to a platykurtic state. The particle size range of wind-erodible soil particles is 200–400 m. (4) Compared with natural grassland, farmland cultivation leads to an expanded soil particle size distribution range, with an overall trend toward coarsening.

Full Text

Distribution Characteristics of Soil Particle Size Under Different Land Use Patterns in the Farming-Pastoral Ecotone: A Case Study of Wuchuan County, Inner Mongolia

FU Dongsheng[1], REN Xiaomeng[2], WANG Yanling[3], ZHANG Cuiying[4], MENG Zhongju[1]

[1]College of Desert Control Science and Engineering, Inner Mongolia Agricultural University, Hohhot 010018, Inner Mongolia, China
[2]Inner Mongolia Meteorological Institute, Hohhot 010051, Inner Mongolia, China
[3]Water Conservancy Development Center, Xilin Gol League Water Conservancy Bureau, Xilinhot 026099, Inner Mongolia, China
[4]Jishengtai Town, Siziwang Banner, Ulanqab City, Inner Mongolia, Ulanqab 011826, Inner Mongolia, China

Abstract

This study investigates different farmland types and natural grassland in Wuchuan County, Hohhot, using a combination of in-situ field monitoring and laboratory experiments. Four typical farmland soil types were examined: wheat stubble land, sunflower stubble land, plowed land, and abandoned farmland. The wind erosion resistance of land under different utilization patterns was evaluated through analysis of mean particle size, standard deviation, skewness, and kurtosis. The results indicate that: (1) Soil in the study area is dominated by fine sand, very fine sand, and silt, accounting for 80%–85% of the total content. (2) The soil particle size composition from fine to coarse follows the order: tillage 1 a > natural grassland > tillage slope > wheat stubble > tillage 15 a > abandoned 5 a > sunflower stubble. The average sand particle size ranges from 2.12 to 2.61. (3) Soils in all layers exhibit poor sorting, with skewness showing positive but near-symmetric distribution and kurtosis belonging to the broad-flat category. The particle size range susceptible to wind erosion is 200–400 m. (4) Compared with natural grassland, farmland reclamation and utilization lead to expanded soil particle size distribution and overall coarsening.

Keywords: farming-pastoral ecotone; farmland; soil particle size; tillage methods; Wuchuan County

Introduction

The northern foothills of the Yinshan Mountains in Inner Mongolia represent one of China' s most typical semi-arid to semi-humid transitional zones, experiencing the fastest desertification development and most fragile ecological environment. This region also serves as an "ecological barrier" for central and eastern China, possessing dual functions of ecological protection and agricultural production. Over the past half-century, the prevailing philosophy of "prioritizing agriculture over animal husbandry" and "production over ecology," combined with arid climate conditions, water resource shortages, and strong winds during autumn and winter, has left surface soils loose and vulnerable. Wind erosion destroys the cultivated layer, causing thinning of the surface horizon, nutrient loss, and significant declines in soil fertility, making this area a typical wind erosion desertification zone.

Soil particle size, as a stable natural attribute of soil, plays a crucial role in assessing soil erodibility, reflecting changes in aeolian environments, determining wind erosion intensity, and identifying land desertification extent. It also indirectly characterizes soil variability in complex environments and reflects current soil erosion status. The wind erosion process primarily involves the gradual removal and sandification of fine particles in the soil, with long-term water and wind erosion causing enormous ecological damage and economic losses. Different tillage methods create significant variations in surface coverage and roughness, subsequently affecting soil particle size distribution. Previous studies have found significant differences in fractal dimensions among different land use types, with significant correlations to various particle size fractions. Research has shown that spring plowing with 10 cm stubble retention can improve certain soil physical properties and reduce wind erosion to some extent, with clay and silt content increasing more noticeably after the windy season. Long-term conservation tillage practices have been found to significantly increase soil clay content and enhance soil structural stability, while deep loosening with straw incorporation reduces soil uniformity.

Given this context, this study focuses on the farming-pastoral experimental zone in Wuchuan County, analyzing changes in particle size parameters and frequency curves under different tillage methods, with natural grassland as a control. The objective is to identify suitable tillage patterns for the farming-pastoral ecotone on the northern foothills of the Yinshan Mountains, providing valuable theoretical and practical guidance for improving soil management and promoting sustainable agricultural development in the region.

1.1 Study Area Overview

The study area is located in the transition zone from Xilamuren Grassland to Hohhot, with geographical coordinates of 110°31 -111°53 E and 40°47 -41°23 N. The region features a mid-temperate continental monsoon climate with abundant sunshine, large diurnal temperature variations, long winters, short and cool summers, and precipitation concentrated in July–September. The average annual precipitation is approximately 300 mm, with frequent wind activities. Northerly and northwesterly winds dominate, with an average annual wind speed of 4.5 $m \cdot s^{-1}$ and 35–50 windy days annually, primarily occurring in spring. Soils are mainly chestnut, gray-cinnamon, and lithosolic soils, characterized by high porosity, poor structure, and organic matter content below 1%. The natural vegetation has a simple composition, dominated by *Artemisia frigida*, *Stipa glareosa*, *Stipa grandis*, and *Stipa krylovii*, suitable for cultivating short-season crops with one harvest per year. The main dryland crops include potatoes (*Solanum tuberosum*), naked oats (*Avena chinensis*), and buckwheat (*Fagopyrum esculentum*). This typical farming-pastoral ecotone features diverse land use types and severe erosion, including farmlands cultivated for different durations, natural grasslands, and abandoned fields.

1.2.1 Sample Plot Selection and Sample Collection

Based on the principle of similarity and comparability, the study area has flat terrain with an east-west orientation. From north to south, the plots are arranged as: natural grassland, sunflower stubble, wheat stubble, wheat plowed land, and abandoned farmland. There are no obvious boundaries between plots. Considering edge effects, sampling was conducted in the middle of each plot in mid-September and mid-October 2020. An additional sampling point was established at the exposed profile at the boundary between wheat plowed land and natural grassland. Each plot was sampled in triplicate at depths of 0-5 cm, 5-10 cm, 10-20 cm, and 20-30 cm. The collected soil samples were spread out in the laboratory to air-dry naturally before particle size analysis using a laser diffraction analyzer.

1.2.2 Soil Sample Measurement

After removing roots, litter, and other impurities, soil organic matter was removed using 30% H_2O_2 solution, and carbonates were removed by boiling with 10% HCl solution. Samples were then diluted with deionized water, allowed to settle, and the supernatant was decanted. This dilution process was repeated until the pH reached 6.5-7.0. Soil particle size distribution was measured using a Mastersizer 3000 laser particle size analyzer. According to the USDA classification system, soil particles were categorized as: clay (<0.002 mm), very fine sand (0.002-0.005 mm), fine sand (0.005-0.01 mm), medium sand (0.01-0.25 mm), coarse sand (0.25-0.5 mm), very coarse sand (0.5-1.0 mm), and extremely coarse sand (1.0-2.0 mm). The cumulative volume percentage corresponding to 5%, 16%, 25%, 50%, 75%, 84%, and 95% was calculated for determining particle size parameters.

The particle size parameter models used are as follows:

The Φ values were calculated using the Krumbein (1934) logarithmic transformation method based on the Udden (1914) particle size scale:

$$\Phi = -\log_2 d$$

where d is the soil particle diameter (mm).

Particle size characteristic parameters were calculated using formulas from Folk and Ward (1957) based on the cumulative frequency distribution curve:

Mean particle size (d_m): Reflects the average condition of soil particle size distribution, representing the average kinetic energy of transport forces and indicating soil development degree and material source:

$$d_m = \frac{\Phi_{16} + \Phi_{50} + \Phi_{84}}{3}$$

Standard deviation (σ_i): Reflects the dispersion degree of soil particle size distribution:

$$\sigma_i = \frac{\Phi_{84} - \Phi_{16}}{4} + \frac{\Phi_{95} - \Phi_5}{6.6}$$

Skewness (S_k): Reflects the symmetry of soil particle size distribution:

$$S_k = \frac{\Phi_{16} + \Phi_{84} - 2\Phi_{50}}{2(\Phi_{84} - \Phi_{16})} + \frac{\Phi_5 + \Phi_{95} - 2\Phi_{50}}{2(\Phi_{95} - \Phi_5)}$$

Kurtosis (K_g): Reflects the concentration degree of soil particle size distribution:

$$K_g = \frac{\Phi_{95} - \Phi_5}{2.44(\Phi_{75} - \Phi_{25})}$$

The specific classification standards are shown in Table 2 .

2 Results and Analysis

2.1 Soil Particle Size Composition and Distribution Characteristics Under Different Tillage Methods Soil particles are an indispensable component of soil composition and play an extremely important role in soil succession processes alongside crop growth. The surface soil (0–5 cm) particle size composition is dominated by sand and silt, with extremely low clay content. Clay volume percentage ranges from 2.04% to 3.36%, while silt volume percentage varies between 22.26% and 32.63%. Among sand particles, fine sand (0.1–0.25 mm) is the most abundant, with an average volume percentage of 35.3%, followed by very fine sand, medium sand, and minimal coarse sand.

Across different soil depths, farmland soils under various tillage methods show considerable variation in particle size, with sand and silt as the main components, of which fine sand is the most abundant with an average volume percentage of 32.95% (ranging from 25.81% to 37.11%). Silt averages 28.44% (ranging from 21.58% to 37.28%). Clay content shows a slight overall increase compared to the surface layer, with an average volume percentage increase of 0.88%. In the 20–30 cm layer, stubble lands show 2.73% higher silt content than abandoned farmland. Wheat stubble land contains 14.54% more silt than sunflower stubble land at the same depth, while its sand content is lower than other farmlands, with fine sand accounting for 29.79% and coarse sand only about 0.75%—higher than natural grassland.

In the 10–20 cm layer across different tillage methods, soil particle content becomes more uniform compared to the layer above, with overall particle coarsening. Silt content decreases significantly, accounting for 34.43% in natural grassland, 29.37% in plowed farmland, and 21.88% in wheat stubble land. In the 20-30 cm layer, abandoned farmland shows the highest mean particle size at 2.61, higher than natural grassland and stubble lands. Stubble lands overall show lower values than plowed land, with the order: abandoned 5 a > wheat stubble > sunflower stubble.

2.2 Soil Particle Size Parameter Characteristics Under Different Tillage Methods Mean particle size characterizes the average distribution of soil particles, representing transport energy and reflecting soil development degree and material source. As shown in Table 4 , surface layer (0-5 cm) farmland soils show little variation among plots, ranging from 2.21 to 2.50. The order is: tillage slope > natural grassland > stubble land > abandoned farmland, with tillage slope showing the highest value, differing from natural grassland by only 0.01.

In the 5-10 cm layer, mean particle size ranges from 2.12 to 2.58 among different tillage methods, with wheat stubble land showing the highest value and abandoned farmland the lowest, indicating particle coarsening compared to the upper layer. In the 10-20 cm layer, variations are greater, ranging from 2.14 to 2.41, with stubble lands overall lower than plowed land. The order is: sunflower stubble > abandoned farmland > plowed land > wheat stubble. In the 20-30 cm layer, the range is 2.20-2.47, with abandoned farmland showing the highest value, exceeding natural grassland and stubble lands.

Standard deviation across different tillage methods ranges from 1.23 to 1.37, indicating poor sorting throughout the 0-30 cm profile. In the 0-5 cm layer, tillage slope and plowed land show the highest values, while natural grassland is lowest. In the 5-10 cm layer, wheat stubble land shows the highest standard deviation. In the 10-20 cm layer, natural grassland is highest, while in the 20-30 cm layer, abandoned farmland reaches its maximum value, with stubble lands showing lower sorting than plowed land.

Skewness across different tillage measures ranges from -0.09 to 0.25, indicating overall positive skewness with fine particles dominating over coarse particles. In the 0-5 cm layer, tillage slope and plowed land show near-symmetric skewness, while other plots are positively skewed. In the 5-10 cm layer, wheat stubble land shows negative skewness. In the 10-20 cm layer, natural grassland shows near-symmetric skewness, while other plots are positively skewed. In the 20-30 cm layer, natural grassland and plowed land show near-symmetric skewness, with other plots positively skewed.

Kurtosis values range from 0.70 to 0.83, corresponding to broad-flat distributions. In the 0-5 cm layer, wheat stubble land shows the highest peak at 300 m. In the 10-20 cm layer, natural grassland and abandoned farmland show higher peaks at 200-250 m. In the 20-30 cm layer, wheat stubble land shows the maximum kurtosis value of 0.83, with some plots showing bimodal distributions.

2.3.1 Soil Particle Size Frequency Distribution Characteristics As shown in Figure 2 [Figure 2: see original paper], the particle size frequency distribution curves for different tillage methods within the same soil layer reveal that in the 0-5 cm layer, plowed land and tillage slope show bimodal distributions with similar peak heights. The first peak occurs at 30-45 m and the second at 100-120 m. Natural grassland and wheat stubble land show bimodal distributions, with wheat stubble land having the finest particle composition and abandoned farmland showing the smallest curve slope.

In the 5-10 cm layer, the particle size frequency curves are essentially consistent across plots. Natural grassland and wheat stubble land show bimodal distributions, with wheat stubble land' s main peak at 50 m and natural grassland' s at 100-130 m. In the 10-20 cm layer, plowed farmland and tillage slope show similar uniformity, slightly lower than natural grassland. All curves show slow initial growth, then steepen dramatically around 100 m, rapidly reaching 100% cumulative volume, indicating most soil particles are <100 m.

In the 20-30 cm layer, significant differences in particle distribution exist among plots. Abandoned farmland shows the most uniform distribution with the smallest kurtosis value. Overall, differences in particle size composition among plots are relatively small.

2.3.2 Soil Particle Size Cumulative Frequency Distribution Characteristics Figure 3 [Figure 3: see original paper] shows the cumulative frequency distribution curves for different tillage methods within the same soil layer. The slope of each curve indicates particle distribution uniformity. All curves steepen gradually between 30-50 m and 105-120 m. In the 0-5 cm surface layer, plowed land shows the most frequent and intense wind erosion activity, with stubble land showing the least. The cumulative curves intersect at 130 m, dividing the fine sand fraction (100-250 m) into two portions. In the 0-5 cm layer, the finer fraction (100-130 m) shows the order: plowed land > tillage slope > natural grassland > wheat stubble > abandoned farmland > sunflower stubble, while the coarser fraction (130-250 m) shows the opposite trend, making the overall difference in fine sand content smaller.

Research indicates that soil particles in the 120-140 m range are most susceptible to wind erosion. The frequency curves also show significant variation among plots in the 200-400 m range, with curves becoming notably steep, indicating substantial particle size changes. The 200-400 m range can be considered as representing soil particle size distribution characteristics, with particles in this range being erosion-prone. Particle size parameters show that all tillage methods cause soil coarsening, with expanded distribution ranges and overall particle size coarsening.

3 Discussion

Analysis of farmland soil particle size under different tillage methods in the Yinshan northern foothills farming-pastoral ecotone shows that all plots are dominated by fine sand content (25.81%-39.56%), with minimal coarse sand content (0.62%-2.87%), and large differences in particle size fractions. This aligns with research showing that wind erosion reduces clay and silt content while increasing average particle size. However, the degree of change differs because the experimental plots run parallel to the main wind direction, and furrows from plowing do not increase surface roughness but instead accelerate wind erosion. Field investigations show annual plowing depth of 25-30 cm brings subsoil to the surface, maintaining relatively uniform particle composition across layers. With increasing cultivation years, fine particle content decreases significantly, likely due to continuous wind erosion.

Stubble lands effectively protect farmland surface soil. After autumn harvest, the protective stubble cover during the non-cultivation winter period prevents fine particle loss by wind, significantly enhancing wind erosion resistance. Crop height and coverage increase surface roughness, reducing near-surface airflow' s ability to erode soil and protecting fine particles. Compared with abandoned farmland, stubble measures effectively intercept fine particle loss.

Soil particle size composition from fine to coarse is: plowed 1 a > natural grassland > plowed slope > wheat stubble > plowed 15 a > sunflower stubble. Particle size parameter distribution shows small differences among tillage methods, with poor sorting overall. Skewness ranges from -0.09 to 0.25, being positive with fine particles dominating. Kurtosis shows broad-flat distributions across all plots, indicating dispersed particle size distribution.

The cumulative distribution curves reflect more frequent and intense wind erosion activity in plowed land compared to stubble land. Tillage methods and crop selection determine wind erosion control effectiveness, affecting surface soil particle size distribution. Different tillage methods cause relative changes in soil environment and particle content, representing the fundamental cause of soil particle coarsening. Plowed farmland exposes the surface to wind erosion, removing fine particles. Plowing mixes soil layers uniformly, while stubble land protects surface soil, with varying protection effects depending on crop type and coverage. These results provide scientific basis for selecting appropriate post-harvest tillage methods and reflect actual conditions after natural grassland conversion to farmland, offering theoretical support for natural land restoration.

4 Conclusion

(1) Under different tillage methods, farmland soil particle size composition in all layers is dominated by fine sand, very fine sand, and silt, accounting for 80%-85% of total content. Long-term plowing causes extensive loss of fine particles without replenishment, leading to soil coarsening, while

stubble retention effectively protects fine particles.

(2) Soil particle size parameters show poor sorting across all layers, with positive near-symmetric skewness and broad-flat kurtosis. The 200–400 m particle size range is most susceptible to wind erosion.

(3) Compared with natural grassland, farmland reclamation expands soil particle size distribution and causes overall coarsening. Plowed land shows more uniform particle size distribution across layers due to tillage mixing, while stubble land provides effective surface protection.

(4) The particle size distribution characteristics and parameter analysis demonstrate that different tillage methods significantly impact soil wind erosion resistance. Stubble retention is recommended as an effective conservation practice for sustainable agriculture in this farming-pastoral ecotone.

References

[1] Liu Mengzhu, Zhang Hongjuan, Ren Heyu, et al. Spatiotemporal variations of the soil conservation in the agro-pastoral ecotone of northern China under grain for green program[J]. Research of Soil and Water Conservation, 2021, 28(5): 172-178.

[2] Du Yaxian, Fan Jin, Li Shiyao, et al. Fractal dimension characteristics of soil particle size distribution under different vegetation patches in desert steppe and its relationship with soil nutrients[J]. Chinese Journal of Applied Ecology, 2019, 30(11): 3716-3724.

[3] Gao Junliang, Luo Fengmin, Gao Yong, et al. Ecological soil C, N, and P stoichiometry of different land use patterns in the agriculture-pasture ecotone of northern China[J]. Acta Ecologica Sinica, 2019, 39(15): 5594-5602.

[4] Dai Luwei, Tang Haiping, Zhang Qin, et al. The trade-off and synergistic relationship among ecosystem services: A case study in Duolun County, the agro-pastoral ecotone of northern China[J]. Acta Ecologica Sinica, 2020, 40(9): 2863-2876.

[5] Su Yongzhong, Yang Rong, Liu Tingna. Effects of long-term different fertilization on soil fertility and soil organic carbon accumulation in psamments of oasis farmland[J]. Journal of Desert Research, 2019, 39(3): 1-6.

[6] Zheng Shun' an, Liu Daili, Zhang Mingkui, et al. Effects of long-term straw returning on heavy metals of soil and agricultural products in the polluted farmland[J]. Journal of Soil and Water Conservation, 2020, 34(2): 354-359.

[7] Zhang Xin, Ning Xiaoli, Tong Baoquan. Spatial differentiation of residential areas in the farming-pastoral ecotone on the north foot of Yinshan Mountain[J]. Journal of Arid Land Resources and Environment, 2020, 34(5): 78-84.

[8] Guo Ting, Xu Xianying, Chai Chengwu, et al. Soil moisture and grain size characteristic of micro area in oasis-desert of Minqin[J]. Chinese Agricultural Science Bulletin, 2015, 31(5): 157-163.

[9] Fan Lijuan, Hu Guanglu, Liao Yaxin, et al. Spatial variability of soil particle size and its fractal dimension of patchy vegetation in Hexi Corridor[J]. Arid Zone Research, 2015, 32(6): 1068-1075.

[10] Jia Mengmeng, Zhang Zhongliang, Lei Jiaqiang, et al. Fractal characteristics of soil particle size distribution in protection forest of Tarim Desert highway[J]. Arid Zone Research, 2015, 32(4): 674-679.

[11] Sun C, Liu G, Xue S. Natural succession of grassland on the Loess Plateau of China affects multifractal characteristics of soil particle size distribution and soil nutrients[J]. Ecological Research, 2016, 31(6): 891-902.

[12] Liu X, Zhang G C, Wang Y Q, et al. Fractal features of soil particle size distribution as affected by plant communities in the forested region of Mountain Yimeng, China[J]. Geoderma, 2009, 154(1): 123-130.

[13] Li Xuanshu, Chang Chunping, Wang Rende. Influence of land use ways on the farmland soil wind erosion in Bashang area, Hebei, China[J]. Journal of Desert Research, 2014, 34(1): 23-28.

[14] Wang Jingzhe, Ding Jianli, Wang Fei, et al. Particle size distribution (PSD) and erodibility of soils under different salinization degrees in Ebinur Lake Wetland[J]. Soils, 2018, 50(3): 598-605.

[15] Qi Shuai, Wang Dang, Dang Xiaohong, et al. Grain size characteristics of surface sediments in three low vertical sand barriers[J]. Arid Zone Research, 2021, 38(3): 875-881.

[16] Du Ji, Zhou Zhibin, Liu Fengshan, et al. Variation of fractal dimension of soil particle size distribution in the Aral reclamation area in oasis development[J]. Arid Zone Research, 2013, 30(4): 615-622.

[17] Yan Y C, Xin X P, Xu X L, et al. Quantitative effects of wind erosion on the soil texture and soil nutrients under different vegetation coverage in a semiarid steppe of northern China[J]. Plant and Soil, 2013, 369(1/2): 585-598.

[18] Xu Zhiwei, Lu Huayu. Aeolian environmental change studies in the Mu Us Sandy Land, North-central China: Theory and recent progress[J]. Acta Geographica Sinica, 2021, 76(9): 2203-2223.

[19] Li Y, Kalnay E, Motesharrei S, et al. Climate model shows large-scale wind and solar farms in the Sahara increase rain and vegetation[J]. Science, 2018, 361(6406): 1019-1022.

[20] Abell J T, Pullen A, Lebo Z, et al. A wind-albedo-wind feedback driven by landscape evolution[J]. Nature Communications, 2020, 11(1): 96.

[21] Huang J P, Li Y, Fu C B, et al. Dryland climate change: Recent progress and challenges[J]. Reviews of Geophysics, 2017, 55(3): 719-778.

[22] Donald Margaret R, Hazelton Pamela A, Clements Anne Marie. Potential for using soil particle size data to infer geological parent material in the Sydney Region[J]. Soil Research, 2013, 51(4): 301-310.

[23] Wang Shaobo, Cao Yaqian, Feng Qianqian, et al. Impacts of conservation tillage on soil particulate composition and distribution of soil carbon and nitrogen in brown soil[J]. Journal of Plant Nutrition and Fertilizers, 2019, 25(5): 792-804.

[24] Nan Ling, Du Lingtong, Zhan Xiuli. Advances in study on soil erodibility for wind erosion[J]. Soils, 2014, 46(2): 204-211.

[25] Gao Tianming, Zhang Ruiqiang, Huang Jianguo. Damage of reclamation on grassland slope in farming-pastoral interleaving areas, North Yinshan Mountains[J]. Journal of Agricultural Science and Technology, 2014, 16(1): 125-130.

[26] Liu Hantao. An Experimental Study of Anti-wind Erosion Capacity of Conservation Farming System in the Northern Foot of Yinshan Mountain[D]. Hohhot: Inner Mongolia Agricultural University, 2006.

[27] Li Xiaojia, Hai Chunxing, Liu Guangtong. Spring soil erodibility for different land use patterns in the north piedmont of the Yinshan Mountains[J]. Arid Land Geography, 2007, 30(6): 926-932.

[28] Yue Gaowei, Jia Huina, Lin Haixiao. Release mechanism of soil particles in soil wind erosion process[J]. Arid Land Geography, 2012, 35(2): 248-253.

[29] Li Xiaoli, Shen Xiangdong. Experimental study on the distribution characteristics of the saltation particle of aeolian sediment in bare tillage[J]. Transactions of the Chinese Society of Agricultural Engineering, 2006, 22(5): 74-77.

[30] Tong Chunyu, Yan Yixiao, Wang Rende, et al. Protective effect of cropland conversion with different years on soil in Bashang district, North China[J]. Journal of Arid Land Resources and Environment, 2018, 32(9): 84-89.

[31] Wang Hai, Li Gangtie, Lu Lina, et al. Distribution of soil size and fractal characteristics under low-efficiency poplar forests[J]. Bulletin of Soil and Water Conservation, 2019, 39(5): 308-315.

[32] Qiu Jie, Wang Hongde, Zheng Yipeng, et al. Fractal features of soil particles under different land uses in a coastal reclamation area[J]. Research of Agricultural Modernization, 2020, 41(5): 882-888.

[33] Cui Xiao. Layout of Farmland Conservation Tillage and Its Impacts on Soil Physical and Chemical Properties in Jieba Mountainous Area in Northern Hebei Province, China[D]. Beijing: Beijing Forestry University, 2019.

[34] Xu Yan, Zhang Renzhi. Dynamics of soil phosphorus as affected by tillage on the Loess Plateau in central Gansu, China[J]. Acta Pedologica Sinica, 2017,

54(3): 670-681.

[35] Ge Yongxiao, Ma Long, Zhang Dengqing. Response of granularity distribution to wind erosion in the playa of the Ebinur Lake, Xinjiang, Northwest China[J]. Arid Zone Research, 2014, 31(4): 636-642.

[36] Wang Rende, Xiao Dengpan, Chang Chunping, et al. Estimation on farmland soil loss by single wind erosion using improved particle size distribution comparison method[J]. Transactions of the Chinese Society of Agricultural Engineering, 2014, 30(21): 278-285.

[37] Mohammadi M H, Meskini Vishkaee F. Predicting soil moisture characteristic curves from continuous particle size distribution data[J]. Pedosphere, 2013, 23(1): 70-80.

[38] Hu H C, Tian F Q, Hu H P. Soil particle size distribution and its relationship with soil water and salt under mulched drip irrigation in Xinjiang of China[J]. Science China Technological Sciences, 2011, 54(6): 1568-1574.

Note: Figure translations are in progress. See original paper for figures.