Spatial Distribution Characteristics of Surface Soil Particle Size in the Sand Barrier Belt at the Margin of Minqin Oasis (Postprint)

Authors: Zhao Peng

Date: 2021-09-14T00:00:00+00:00

Abstract

Soil particle size is an important characteristic parameter of wind-sand activity. Through field investigation and laboratory testing, the spatial distribution characteristics of surface soil particle size in windbreak and sand-fixation forests with different spatial distributions were analyzed, aiming to evaluate the windbreak and sand-fixation function of the sand-blocking belt at the edge of the Minqin Oasis. The results show that: (1) In the dam area, the surface soil particle size composition of the Haloxylon ammodendron-Calligonum mongolicum-Artemisia desertorum-Agriophyllum squarrosum sand-fixation forest is dominated by fine sand, medium sand, and very fine sand, accounting for 33.47%, 26.08%, and 18.18%, respectively; in the Spring Mountain area, the surface soil particle size composition of the Nitraria tangutorum+Artemisia desertorum+Bassia dasyphylla sand-fixation forest is dominated by fine sand, silt, and very fine sand, accounting for 29.62%, 21.17%, and 18.87%, respectively; and in the lake area, the surface soil particle size composition of the Nitraria tangutorum-Phragmites australis-Salsola collina sand-fixation forest is dominated by fine sand, silt, and very fine sand, accounting for 36.66%, 27.98%, and 22.83%, respectively. (2) The mean particle size follows the order: dam area (2.55Φ) > Spring Mountain area (3.5Φ) > lake area (3.94Φ); sorting is poor in the dam area (1.58Φ) and very poor in both the lake area (2.10Φ) and Spring Mountain area (2.29Φ). (3) The surface soil particle size frequency curves are bimodal in the Spring Mountain and lake areas, and unimodal in the dam area; the skewness is extremely positively skewed in all areas, and the kurtosis is very narrow. The cumulative particle size distribution curves reflect that wind-sand activity is more frequent and intense in the dam area than in the Spring Mountain and lake areas. The species composition of desert vegetation communities in the sand-blocking belt determines the magnitude of their windbreak and sand-fixation functions, which in turn affects the surface soil particle size distribution characteristics. It is recommended that afforestation tree species with strong sand-fixation capabilities

should be emphasized during the restoration of the ecological protection system in the sand-blocking belt.

Full Text

Spatial Distribution Characteristics of Surface Soil Grain Size in the Sand-Resistant Belt at the Edge of Minqin Oasis

ZHAO Peng[12], ZHU Shujuan[1], DUAN Xiaofeng[2], CHANG Zhaofeng[12], KANG Caizhou[1], WANG Fanglin[2], WANG Yuqi[2], GAO Decai[3]

[1]State Key Laboratory Breeding Base of Desertification and Aeolian Sand Disaster Combating, Gansu Desert Control Research Institute, Lanzhou 730070, Gansu, China
[2]Gansu Minqin National Field Observation & Research Station on Ecosystem of Desert Grassland, Minqin 733000, Gansu, China
[3]Gulang County Haizitan Forest Field, Gulang 733100, Gansu, China

Abstract

Soil particle size is a critical parameter characterizing aeolian sand activity. Through field investigation and laboratory analysis, this study examined the spatial distribution characteristics of surface soil particle size in windbreak and sand-fixation forests across different spatial configurations to evaluate the windbreak and sand-fixation functions of the sand barrier belt at the edge of Minqin Oasis. The results revealed distinct patterns across three zones: in Baqu, the surface soil of *Haloxylon ammodendron-Artemisia desertorum-Agriophyllum squarrosum* sand-fixation forests was dominated by fine sand (33.47%), medium sand (26.08%), and very fine sand (18.18%); in Quanshanqu, the surface soil of *Nitraria tangutorum-Artemisia desertorum-Bassia dasyphylla* forests consisted primarily of fine sand (29.62%), silt (21.17%), and very fine sand (18.87%); and in Huqu, the surface soil of *Nitraria tangutorum-Phragmites australis-Salsola collina* forests was dominated by fine sand (36.66%), silt (27.98%), and very fine sand (22.83%). The average particle size followed the order: Baqu (2.55 Φ) > Quanshanqu (3.5 Φ) > Huqu (3.94 Φ). Sorting was poor in Baqu (1.58 Φ) and very poor in both Quanshanqu (2.29 Φ) and Huqu (2.10 Φ). Frequency curves exhibited bimodal patterns in Quanshanqu and Huqu but a unimodal pattern in Baqu, with extremely positive skewness and very narrow kurtosis across all zones. Cumulative distribution curves indicated that aeolian sand activity was more frequent and intense in Baqu compared to Quanshanqu and Huqu. The species composition of desert vegetation communities in the sand barrier belt determines the effectiveness of windbreak and sand-fixation functions, thereby influencing surface soil particle size distribution characteristics. For restoration of the sand barrier belt' s ecological protection system, selection of tree species with strong sand-fixing capacity is recommended.

Keywords: sand-resistant belt; grain size characteristics; sand-fixation vegetation; windbreak and sand-fixation function; Minqin Oasis

Introduction

1.1 Study Area Overview

The study area is located in the Minqin sand barrier belt at the southeastern edge of the Badain Jaran Desert (102°54 47 ~102°57 3 E, 38°25 49 ~38°37 41 N), which features a typical temperate continental desert climate. According to meteorological observations from the Gansu Minqin Desert Grassland Ecosystem National Field Scientific Observation and Research Station (2006-2016), the multi-year average temperature is 7.6°C, with annual accumulated temperature $ 10°Cof3036.4°Canddailytemperaturerangeof15.2°C.Multi − yearaverageprecipitationis176mm,concentratedinJune–Septemberandaccountingforover80^{-1}$, 25.1 annual gale days, and 27.8 annual sandstorm days. Regional land cover types include natural vegetation, artificial vegetation, desert landscape, bare land, artificial oasis, fixed dunes, and semi-fixed dunes. Desert vegetation characteristics are evident with simple community structure, dominated by shrub and semi-shrub xerophytic communities and annual herbaceous "shrub-grass" associations. Artificial plants include *Haloxylon ammodendron*, *Elaeagnus angustifolia*, *Populus alba*, and *Popolus gansuensis*. Natural plants include *Nitraria tangutorum*, *Calligonum mongolicum*, *Artemisia arenaria*, *Tamarix ramosissima*, *Phragmites australis*, *Reaumuria soongarica*, *Agriophyllum squarrosum*, *Bassia dasyphylla*, and *Salsola collina*. Zonal soils are gray-brown desert soils, while azonal soils include aeolian sandy soils and meadow swamp soils, with irrigation silt soils being the primary cultivated soils.

1.2 Field Investigation and Sampling

Based on spatiotemporal characteristics of groundwater depth, Minqin Oasis can be divided into Baqu, Quanshanqu, and Huqu. Along the oasis-to-desert gradient in these three zones, six observation transects were established in the sand barrier belt, with three sample plots per transect, totaling 18 plots. In each plot, five soil samples from the 0-5 cm layer were randomly collected and mixed. Samples were air-dried, sieved to remove gravel and debris, and analyzed using a Mastersizer 2000 particle size analyzer with wet dispersion. Surface soils in all spatial distribution zones of the sand barrier belt were aeolian sandy soils. Pretreatment involved: weighing appropriate amounts (0.1 g for clay, 0.3 g for sandy soils), adding 10 mL of 10% H_2O_2, heating and boiling until bubbling ceased to remove organic matter and oxidizable salts; after cooling, adding 10 mL of 10% HCl to remove calcium salts, adding distilled water, standing, then ultrasonic dispersion for 10 mL.

1.3 Soil Grain Size Parameters

The USDA classification system was adopted, dividing soil particles into gravel (>2.0 mm), very coarse sand (1.0-2.0 mm), coarse sand (0.5-1.0 mm), medium sand (0.25-0.5 mm), fine sand (0.1-0.25 mm), very fine sand (0.05-0.1 mm), silt (0.002-0.05 mm), and clay (<0.002 mm). GRADISTATv 9.1 software was used to calculate mean grain size, sorting coefficient, skewness, and kurtosis. Parameter calculation formulas and their significance are as follows:

Mean grain size: $\bar{x}_a = \sum f \cdot m_m$
where f represents frequency percentage and m_m is the median soil particle diameter in metric units. The physical meaning is that particles larger than this diameter account for 50%, as do particles smaller than it, also called median grain size. Mean grain size indicates average particle coarseness, representing the average kinetic energy of transport forces, with particle size reflecting soil development degree and material transport distance.

Sorting coefficient: $\sigma_a = \sqrt{\sum f \cdot (m_m - \bar{x}_a)^2}$
The sorting coefficient indicates sediment sorting. When $\sigma_a < 0.35\Phi$, sorting is excellent; 0.35-0.50Φ is very good; 0.50-0.71Φ is good; 0.71-1.00Φ is moderate; 1.00-2.00Φ is poor; 2.00-4.00Φ is very poor; and $\sigma_a > 4.00\Phi$ is extremely poor.

Skewness: $SK_a = \frac{\sum f \cdot (m_m - \bar{x}_a)^3}{\sigma_a^3}$
Skewness quantitatively describes the symmetry of sediment grain distribution, reflecting the approximate position of the main peak and the relative position of mean and median grain sizes, as well as soil particle size trends. Negative skewness indicates distribution shifted toward coarser particles relative to the median; positive skewness indicates positive deviation. When SK_a is between -1.0 and -0.3, it' s negatively skewed; -0.3 to -0.1 is very negatively skewed; -0.1 to 0.1 is nearly symmetric; 0.1 to 0.3 is positively skewed; and 0.3 to 1.0 is very positively skewed.

Kurtosis: $K_a = \frac{\sum f \cdot (m_m - \bar{x}_a)^4}{\sigma_a^4}$
Kurtosis represents the peakedness of the frequency curve. When $K_a < 0.67$, it' s very wide; 0.67-0.90 is wide; 0.90-1.11 is moderate; 1.11-1.50 is narrow; 1.50-3.00 is very narrow; and $K_a > 3.00$ is extremely narrow.

1.4 Sedimentary Environment Discrimination

Sahu established empirical discriminant formulas for sedimentary environments based on grain size parameters. Using statistical analysis of numerous clastic sediments, the variation characteristics of mean grain size (M_z), standard deviation (σ), skewness (SK_a), and kurtosis (K_a) in different depositional environments were determined. Using multivariate classification analysis, empirical discriminant formulas were developed to differentiate dune sand, beach sand, river sand, etc.:

$$Y_1 = -3.5688M_z + 3.7016SK_a + 3.1135K_a$$

If $Y_1 < -2.7411$, it' s aeolian deposition; otherwise continue.

$Y_2 = 15.6534M_z + 65.7091SK_a + 18.5043K_a$
If $Y_2 < 65.3650$, it' s beach deposition; otherwise continue.

$Y_3 = 0.7215M_z - 8.7604SK_a + 0.0482K_a$
If $Y_3 > -7.4190$, it' s shallow marine deposition; otherwise continue.

$Y_4 = 0.2852M_z - 0.4030SK_a + 0.0482K_a$
If $Y_4 < 9.8433$, it's turbidity current deposition; otherwise it's fluvial deposition.

Results

2.1 Soil Grain Size Composition Characteristics

The surface soil grain size composition in different sand barrier belts at the edge of Minqin Oasis showed distinct patterns . In Baqu, the sand-fixation forest surface soil was dominated by fine sand, medium sand, and very fine sand, accounting for 33.47%, 26.08%, and 18.18% respectively. In Quanshanqu, the sand-fixation forest surface soil consisted primarily of fine sand (29.62%), silt (21.17%), and very fine sand (18.87%). In Huqu, the sand-fixation forest surface soil was dominated by fine sand (36.66%), silt (27.98%), and very fine sand (22.83%). Fine sand was the dominant fraction across all zones. The combined content of fine sand, very fine sand, and silt was 87.47% in Quanshanqu, 69.66% in Huqu, and 66.11% in Baqu. Clay content was lowest in Baqu (2.16%) and highest in Quanshanqu (4.25%) and Huqu (4.16%). Medium sand, coarse sand, and very coarse sand contents were highest in Baqu (26.09%), followed by Quanshanqu (8.37%) and Huqu (7.56%), indicating significant soil coarsening in Baqu sand-fixation forests.

2.2 Soil Grain Size Parameter Characteristics

The mean grain size (M_z) of surface soil in different spatial zones of the sand barrier belt ranged from 1.42–6.85Φ, sorting coefficient (σ) from 0.57–3.10Φ, skewness (SK) from -0.24–0.62Φ, and kurtosis (K) from 0.69–2.64Φ [Figure 2: see original paper]. In Baqu' s Longwangmiao sand barrier belt, the *Calligonum mongolicum-Agriophyllum squarrosum* community had a mean grain size of 2.53Φ, with unimodal frequency curves, poor sorting, positive skewness, and very narrow kurtosis. The Shajingzi sand barrier belt' s *Nitraria tangutorum* community showed a mean grain size of 2.45Φ, with unimodal frequency curves, very poor sorting, positive skewness, and narrow kurtosis. In Liujiadun sand barrier belt, the *Tamarix ramosissima-Reaumuria soongarica* forest had a mean grain size of 3.19Φ, with bimodal frequency curves, moderate sorting, near-symmetric skewness, and very narrow kurtosis. The Sancheng sand barrier belt' s *Nitraria tangutorum-Salsola collina* forest showed a mean grain size of 2.96Φ, with bimodal frequency curves, poor sorting, extremely positive skewness, and very narrow kurtosis. Overall, Quanshanqu sand barrier belts exhibited predominantly positively skewed bimodal frequency curves with very narrow kurtosis and poor sorting.

In Huqu, the Fugong sand barrier belt' s *Haloxylon ammodendron-Limonium aureum* forest had a mean grain size of 4.44Φ, with unimodal frequency curves, poor sorting, positive skewness, and narrow kurtosis. The Xiqu sand barrier belt' s *Nitraria tangutorum-Phragmites australis* forest showed a mean grain size of 3.91Φ, with bimodal frequency curves, moderate sorting, extremely positive skewness, and very narrow kurtosis. The Qingtu sand barrier belt's *Nitraria tangutorum-Halogeton glomeratus* forest had a mean grain size of 3.19Φ, with unimodal frequency curves, poor sorting, near-symmetric skewness, and very narrow kurtosis. Overall, Huqu sand barrier belts showed predominantly positively skewed unimodal frequency curves with very narrow kurtosis and poor sorting.

2.3 Soil Grain Size Cumulative Distribution Characteristics

Cumulative frequency curves reflect transport media and dynamic conditions of soil detritus, as well as sand sorting. Steeper curves indicate better sorting and more frequent/intense aeolian activity. Cumulative frequency curves for different sand barrier belts [Figure 7: see original paper] showed that in Baqu, creep, saltation, and suspension fractions accounted for 8.45%, 61.55%, and 30.00% respectively; in Quanshanqu, 14.62%, 59.96%, and 25.42%; and in Huqu, 26.14%, 48.44%, and 25.42%. Quanshanqu had the highest creep fraction, Baqu the highest saltation fraction, and Huqu the highest suspension fraction. Baqu' s cumulative curve was steepest, followed by Quanshanqu and Huqu, indicating more frequent and intense aeolian activity in Baqu.

2.4 Sedimentary Environment Discrimination

Under fluvial action, weathered debris from the Qilian Mountains formed alluvial-proluvial fans at piedmont areas and alluvial plains around lakes. With intensifying aridification in northwestern China during the Late Cenozoic, numerous terminal lakes in central Asia shrank or dried, while atmospheric circulation eroded loose deposits in downstream alluvial plains and terminal lakes, developing extensive aeolian landforms and forming thick aeolian accumulations downwind. Minqin Oasis lies in the lower Shiyang River basin. Discrimination results indicated that surface soils in different spatial zones of the sand barrier belt were all fluvial deposits, inconsistent with actual aeolian deposition. Research shows that Sahu' s discriminant formulas have limitations when applied to aeolian deposits on the Qinghai-Tibet Plateau, particularly for aeolian sand environment discrimination.

Discussion

3.1 Relationship Between Soil Grain Size and Vegetation

As an important component of the geographical environment, vegetation strongly influences energy conversion and transfer between the atmosphere and pedosphere, representing one of the most active factors affecting soil wind erosion. Wind erosion rates increase exponentially with decreasing vegetation cover: >60% cover results in slight wind erosion, 20-60% in moderate wind erosion, and <20% in severe wind erosion. Vegetation effects on soil wind erosion depend on vegetation layer characteristics, reflected in surface roughness and wind erosion intensity variations. In the middle and lower reaches of the Tarim River, different land types, vegetation types, and cover significantly affect soil grain size characteristics. Due to reduced vegetation cover and root density, overgrazed grasslands in Inner Mongolia’ s typical steppe show obvious wind erosion features, with surface soil coarsening directly causing decreased soil organic carbon content. During biological soil crust development in the Mu Us Sandy Land, fine particles (clay and silt) continuously increase, grain size composition optimizes, and overall distribution evolves toward uniform and symmetric patterns. Land use evolution from grassland to dunes is primarily a wind erosion desertification process characterized by decreasing very fine sand content. Windbreak and sand-fixation functions per unit area rank as: *Nitraria tangutorum* > *Haloxylon ammodendron* > *Ephedra przewalskii*. Larger shrub canopy favors accumulation of fine sand, very fine sand, and silt. This study found that in Baqu, *Haloxylon ammodendron-Agriophyllum squarrosum* sand-fixation forests had much lower contents of erodible clay and silt (2.16% and 4.25%) compared to Quanshanqu’ s *Nitraria tangutorum* (4.16% and 21.17%) and Huqu’ s *Nitraria tangutorum-Salsola collina* (21.98% and 12.46%), indicating superior windbreak and sand-fixation functions. Compared with artificial *Haloxylon* forests, shrub dunes have better windbreak and sand-fixation capacity. In Minqin’ s oasis-desert transition zone, wind transport capacity is weakest in straw checkerboard sand barriers, followed by *Nitraria* shrub dunes, then *Phragmites australis* desert belts, and strongest on dune tops with maximum sediment transport. In desert areas, annual horizontal dust flux through a 9169 kg × 50 m cross-section is 9169 kg; in oasis-desert transition zones it’ s 5318 kg, a 42% reduction; and within oases it’ s 1043 kg, an 89% reduction, demonstrating strong duststorm attenuation by shelterbelts and farmland protection networks. Thus, the species composition of desert vegetation communities in different zones determines windbreak and sand-fixation effectiveness, thereby influencing surface soil grain size distribution.

3.2 Relationship Between Grain Size and Provenance

Grain size distribution curves of different sediments can reflect material sources. The “narrow tube” topography of the Hexi Corridor is an important reason for frequent sandstorms in Minqin, with local “narrow tubes” making Minqin the most severely affected area. Sedimentary facies in the Shiyang River middle reaches show transitions from fluvial to lacustrine to aeolian deposits, indicating Holocene aridification. This study found that the lower Shiyang River’ s Minqin Oasis edge deposits are fluvial, inconsistent with actual aeolian deposition, reflecting limitations of Sahu’ s formulas for inland aeolian environment discrimination. In Baqu, sand-fixation forest surface grain size frequency curves are nearly symmetric with sharp narrow peaks and fine-particle tails, characteristic of aeolian deposits. Baqu’ s saltation fraction ranges from 1.124–3.88Φ, much larger than Quanshanqu (1.895–4.248Φ) and Huqu (1.374–4.245Φ), reflecting Baqu’ s relatively high-energy depositional environment. Huqu lacustrine deposit surface soils show positively skewed curves with wide low peaks and obvious bimodal patterns, with higher fine-particle content than aeolian deposits. Baqu and Huqu grain size frequency curve characteristics are similar to those of aeolian and lacustrine deposits in the Ulan Buh Desert and Hunshandake Sandy Land. Shrub dune grain size frequency curves show unimodal distribution, while Gobi shows bimodal or trimodal patterns. Quanshanqu *Nitraria* shrub dunes show positively skewed bimodal distribution, presenting Gobi vegetation characteristics. Sorting coefficients for sand barrier belts show Baqu (1.58Φ) < Quanshanqu (2.29Φ) < Huqu (2.10Φ), with overall poor sorting, reflecting vegetation’ s windbreak and sand-blocking effects. Different tree species’ sand-fixation forests show varying effects in reducing aeolian sand flux and wind erosion depth. In desert areas, dust release is greatest from silt and fine sand, less from medium and coarse sand, and least from very coarse sand. Baqu’ s clay content (14.62%) is much lower than Quanshanqu (25.42%) and Huqu (26.14%), suggesting greater dust release potential in Quanshanqu and Huqu. The distinct grain size distribution curves in Baqu, Quanshanqu, and Huqu are closely related to complex desert material sources, depositional environment formation mechanisms, and diverse sand material migration patterns.

Conclusion

Surface soil grain size composition in the sand barrier belt varies by zone: Baqu is dominated by fine sand (33.47%), medium sand (26.08%), and very fine sand (18.18%); Quanshanqu by fine sand (29.62%), silt (21.17%), and very fine sand (18.87%); and Huqu by fine sand (36.66%), silt (27.98%), and very fine sand (22.83%). Average particle size follows the order Baqu (2.55Φ) > Quanshanqu (3.5Φ) > Huqu (3.94Φ). Sorting is poor in Baqu (1.58Φ) and very poor in Quanshanqu (2.29Φ) and Huqu (2.10Φ). Frequency curves show bimodal patterns in Quanshanqu and Huqu but unimodal in Baqu, with extremely positive skewness and very narrow kurtosis. Cumulative distribution curves indicate more frequent and intense aeolian activity in Baqu than in Quanshanqu and Huqu. The species composition of desert vegetation communities in the sand barrier belt determines windbreak and sand-fixation effectiveness, thereby influencing surface soil grain size distribution. For restoration of the sand barrier belt’ s ecological protection system, selection of tree species with strong sand-fixing capacity is recommended.

References

[1] Hwang S I, Powers S E. Using particle size distribution models to estimate soil hydraulic properties [J]. Soil Science Society of America Journal, 2003, 67(4): 1103-1112.

[2] Zhang Junhua, Li Guodong, Nan Zhongren, et al. Research on soil particle distribution and its relationship with soil organic carbon under the effects of tillage in the Heihe oasis[J]. Geographical Research, 2012, 31(4): 608-618.

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

[4] Li Haidong, Shen Weishou, Zou Changxin, et al. Soil nutrients content and grain size fraction of aeolian sandy land in the Shannan wide valley of the Yalung Zangbo River, China[J]. Acta Ecologica Sinica, 2012, 32(16): 4981-4992.

[5] Chen Yingying, Zhang Zhenke, Xu Huaxia, et al. Stable carbon isotope and particle size characteristics in coastal saline soil with different reclamation age of Dongtai, Jiangsu Province[J]. Scientia Geographica Sinica, 2015, 35(6): 782-789.

[6] Gui Dongwei, Lei Jiangqiang, Zeng Fangjiang, et al. Fractal dimension of particle size distribution and its affecting factors in oasis farmland soils in southern marginal zones of Tarim Basin[J]. Chinese Journal of Eco-Agriculture, 2010, 18(4): 730-735.

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

[8] Dong Zhibao, Li Zhenshan. Wind erodibility of aeolian sand as influenced by grain parameters[J]. Journal of Soil Erosion and Soil and Water Conservation, 1998, 4(4): 3-5.

[9] Zhou Xin, Zuo Xiaoan, Zhao Xueyong, et al. Plant biomass and soil properties during the process of dune restoration in the Horqin Sandy Land[J]. Journal of Desert Research, 2015, 35(1): 81-89.

[10] Tian Lihui, Zhang Dengshan, Peng Jiping, et al. Grain size of land surface deposits in a vegetation restoration region of the alpine sandy land in Qinghai, China[J]. Journal of Desert Research, 2015, 35(1): 32-39.

[11] Yan Yuchun, Tang Haiping, Zhang Xinshi, et al. A probe into grassland wind erosion based on the analysis of soil particle size[J]. Journal of Desert Research, 2010, 30(6): 1263-1268.

[12] Yang Shirong, Meng Zhongju, Dang Xiaohong, et al. Grain size characteristics of surface sediments of eco photovoltaic power station in Kubuqi Desert[J]. Research of Soil and Water Conservation, 2020, 27(1): 112-118.

[13] Wang Yizhao, Yuan Weijie, Ding Guodong, et al. Concave surface and grain size characteristics in polylactic acid (PLA) sand barrier[J]. Arid Land Geography, 2020, 43(3): 671-678.

[14] Su Songling, Mao Donglei, Cai Fuyan, et al. Grain size characteristics and sedimentary environment of sediments on the surfaces of crescent shaped dunes in the desert and gravel Gobi in Cele, Xinjiang[J]. Journal of Arid Land Resources and Environment, 2020, 34(8): 124-132.

[15] Si Yuejun, Li Baosheng, Li Zhiwen, et al. A comparative analysis of grain size characteristics of modern aeolian sand and beach sand from the coast of Beibu Gulf in China[J]. Journal of Desert Research, 2020, 40(6): 1-10.

[16] Wang Zhongcheng, Qian Yibing, Zhang Haiyan, et al. Size distribution and origin of the soils on the north slopes of Karlik mountains in the Tianshan mountains[J]. Journal of Glaciology and Geocryology, 2010, 32(5): 1035-1043.

[17] Ma Qianqian, Xie Xiaosong, Xiao Jianhua, et al. Analysis of grain size characteristics and sedimentary environment of sediments in central Dubai, United Arab Emirates[J]. Journal of Arid Land Resources and Environment, 2020, 34(11): 104-109.

[18] Li Zhixing, Li Zhizhong, Jin Jianhui, et al. The significance of aeolian environment reflected by particle size parameters of coastal dunes in Changli, Hebei province[J]. Journal of Hainan Normal University (Natural Science Edition), 2020, 33(1): 92-102.

[19] Li Sen, Xia Xuncheng, Xiao Honglang, et al. Characteristics, origin and development era of eolian sand in Sahelian region, Mali[J]. Scientia Geographica Sinica, 1999, 19(2): 68-75.

[20] Wang Liqiang. Surface Deposits of the Hexi Corridor and Its Adjacent Areas and Implications for Provenance of Asian Dust[D]. Lanzhou: Lanzhou University, 2011.

[21] Zhou Dandan, Dong Jianlin, Gao Yong, et al. Grain size analysis and soil loss of surface soil during desertification process on Bayinwenduer desert[J]. Arid Land Geography, 2008, 31(6): 933-939.

[22] Zhang Zhengcai, Dong Zhibao. The effect of wind erosion on the surface particle size[J]. Journal of Arid Land Resources and Environment, 2012, 26(12): 86-89.

[23] Dong Zhibao, Chen Weinan, Dong Guangrong, et al. Influences of vegetation cover on the wind erosion of sandy soil[J]. Acta Scientiae Circumstantiae, 1996, 15(4): 437-443.

[24] Lu Huayu, An Zhisheng. Comparison of grain size of red clay and loess paleosol deposits in Chinese Loess Plateau—New evidence for eolian origin of red clay[J]. Acta Sedimentologica Sinica, 1999, 17(2): 61-67.

[25] Qiao Yansong, Guo Zhengtang, Hao Qingzhen, et al. Grain size characteristics of the Miocene loess paleosol sequence and their implications for genesis[J]. Scientia Sinica (Terrae), 2006, 36(7): 646-653.

[26] Qian Yibing, Zhou Huarong, Zhang Liyun, et al. Spatial distribution of soil granularity in the wetlands and their peripheral regions in the middle and lower reaches of the Tarim River[J]. Arid Land Geography, 2005, 28(5): 609-613.

[27] Yang Yongzhao, Li Fucun, Cao Zhihong, et al. Particle size features of Chunodun Paleosol and identification of its parent material[J]. Chinese Journal of Soil Science, 2007, 44(1): 1-5.

[28] Liu Hujun, Wang Jihe, Chang Zhaofeng, et al. Characteristics of desert flora and vegetation in lower reach of Shiyang River basin[J]. Chinese Journal of Ecology, 2006, 25(2): 113-118.

[29] Gao Junliang, Gao Yong, Luo Fengmin, et al. Response of surface soil grain size characteristics to wind erosion desertification[J]. Science & Technology Review, 2014(25): 20-25.

[30] Chang Zhaofeng, Li Yijun, Zhang Jianhui, et al. Comparison on functions of wind break and sand fixation of four plant species in Minqin desert area[J]. Pratacultural Science, 2012, 29(3): 358-363.

[31] Li Yaohui, Shen Jie, Zhao Jianhua, et al. Simulation of terrain effect to the development of sandstorm in Minqin: Take a heavy sandstorm for example[J]. Journal of Desert Research, 2014, 34(3): 849-860.

[32] Li Yu, Wang Yue, Zhang Chengqi, et al. Changes of sedimentary facies and Holocene environments in the middle reaches of inland rivers, arid China: A case study of the Shiyanghe River[J]. Geographical Research, 2014, 33(10): 1866-1880.

[33] Wang Libing, Hu Xiaolong, Yu Weili, et al. Spatial heterogeneity of granule diameter and its relation with shrub size and soil erosion[J]. Arid Land Geography, 2006, 29(5): 688-693.

[34] Wang Yanwu, Luo Ling, Zhang Feng, et al. Windbreak effect of sand fixation forest on the edge of oasis in Minqin[J]. Journal of Northwest Forestry University, 2018, 33(4): 64-70.

[35] Zhang Yalu, Chun Xi, Zhou Haijun, et al. Grain size discriminant method for eolian and lacustrine sediments of deserts and its environment indication[J]. Journal of Desert Research, 2020, 40(5): 1-9.

[36] Wang Ping, Wang Yan. Characteristics of aeolian sediment under different underlying surfaces in oasis desert transitional region of Minqin[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(11): 138-145.

[37] Zhao Mingzhu, Zu Ruiping, Wang Junzhan, et al. Grain size characteristics of sediment along the Haro railway[J]. Journal of Desert Research, 2021, 41(1): 1-9.

[38] Yang Xinghua, Kang Yongde, Zhou Chenglong, et al. Characteristics of soil particle size distribution and its effect on dust emission in Taklimakan Desert[J]. Transactions of the Chinese Society of Agricultural Engineering, 2020, 36(5): 167-174.

[39] Zhao Ming, Zhan Kejie, Yang Zihui, et al. Study on the structure characteristics of low altitude sandstorm in Minqin desert oasis[J]. Scientia Sinica (Terrae), 2011, 41(2): 234-242.

[40] An Qing, An Ping, Xu Ruru, et al. Comparative study on grain size characteristics of sediments in different regions of the Tibetan Plateau and the applicability of sedimentary environment discriminant formulas[J]. Journal of Liaocheng University (Natural Science Edition), 2017, 30(4): 37-47.

[41] Gao Guanglei, Ding Guodong, Zhao Yuanyuan, et al. Effects of biological soil crusts on soil particle size characteristics in Mu Us sandland[J]. Transactions of the Chinese Society for Agricultural Machinery, 2014, 45(1): 115-120.

[42] Folk R L, Ward W C. Brazos River bar: A study in the significance of grain size parameters[J]. Journal of Sedimentary Research, 1957, 27(1): 3-26.

[43] Sahu B. Depositional mechanisms from the size analysis of clastic sediments[J]. Journal of Sedimentary Research, 1964, 34(1): 73-83.

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

Source: ChinaXiv —Machine translation. Verify with original.