Postprint: Preliminary Study on Large Sand Ripples in the Horqin Sandy Land

Authors: Han Guang, Long Xian, Ding Zhanliang, Feng Jingxue, Ding Zhanliang

Date: 2023-02-27T00:00:00+00:00

Abstract

Through field investigation, observation, and sampling, and utilizing Google Earth remote sensing imagery and laser particle size analyzer, this study investigated the spatial distribution, basic morphology of individual and population units, and grain size characteristics of large-scale ripples (LSR) in the Horqin Sandy Land, and explored the sources of coarse particles in LSR as well as their differences from ordinary sand ripples and ordinary aeolian sand in grain composition, morphological characteristics, and internal sedimentary structure. The results indicate that: (1) LSR in the Horqin Sandy Land are mainly distributed in the central and northern regions of Ongniud Banner. (2) The spatial morphology of LSR spatial units exhibits three types: sheet-like, patch-like, and belt-like, which develop in three types of topographic positions: broad interdune areas, middle to upper parts of dunes, and trough-shaped lowlands. (3) The average length of LSR is 6.32 m, the overall orientation is northeast–southwest, the average wavelength is 1.68 m, with relatively obvious spatial differentiation; individual LSR exhibit asymmetry between windward and leeward slopes. (4) LSR particles are of medium to coarse sand grade, with coarse particles primarily derived from fluvial alluvial layers of old river channels, underlying Q3 lacustrine-fluvial strata, weathering crusts of eroded residual hills, and piedmont proluvial deposits. (5) LSR show significant differences from ordinary sand ripples in appearance, material composition, geometric morphology, and internal sedimentary structure. This research will contribute to advancing the theoretical development and practical application of aeolian geomorphology.

ChinaRxiv

Full Text

Preliminary Study of Large-Scale Ripples in the Korqin Sandy Land

HAN Guang[1], **LONG Xian**[1], **DING Zhanliang**[2], **FENG Jingxue**[1]

[1] College of Geographical Sciences, Hunan Normal University, Changsha 410081, Hunan, China

[2] School of Resources and Environment, Baotou Teachers College, Baotou 014030, Inner Mongolia, China

Abstract: Through field investigations, observations, and sampling, combined with remote sensing imagery and laser particle size analysis, this study examines the spatial distribution, fundamental morphological characteristics of individual and collective forms, and grain size features of large-scale ripples (LSRs) in the Korqin Sandy Land. The research explores the sources of coarse particles and distinguishes LSRs from common sand ripples and typical wind-blown sands in terms of particle composition, morphological characteristics, and internal sedimentary structures. Results indicate: (1) LSRs in the Korqin Sandy Land exhibit patch, patchy, and stripe-shaped spatial patterns across three types of terrain positions. (2) The average length of individual LSRs is 6.32 m, with asymmetric stoss and lee slopes. (3) LSRs are mainly distributed in the central and northern regions of Ongniud Banner. (4) The particles are primarily medium to coarse sand, with coarse grains mainly derived from old river channel deposits, underlying fluvial-lacustrine strata, weathering crusts of denuded residual mountains, and piedmont alluvial materials. (5) LSRs differ significantly from common ripples in appearance, material composition, geometry, and internal sedimentary structure. This research contributes to advancing theoretical development and practical applications in aeolian geomorphology.

Keywords: Korqin Sandy Land; large-scale ripple (LSR); morphological characteristics; grain size features; coarse grain sources

---

1 Study Area Overview

The Korqin Sandy Land is broadly located southeast of the Greater Khingan Mountains, north of the Yanshan-Liaoxi mountainous region, west of the Liao River line, and south of the Taoer River, covering a total area of approximately 4.23×10^{4} km^2. The main body is concentrated on the plains along the middle and lower reaches of the Xilamulun River and the West Liao River. Most of the area lies within the Songliao subsidence zone, where weathering products from surrounding mountains and hills have been transported by well-developed drainage systems and deposited here, resulting in abundant surface loose sand deposits. The terrain generally slopes from west to east and from north and south toward the central Xilamulun and West Liao Rivers.

The study area experiences a temperate semi-arid to semi-humid continental monsoon climate, with an average annual temperature of 6.2 °C and average annual precipitation of 284.4 mm, concentrated primarily in June through August. Influenced by the fluctuation between the Mongolian cold high-pressure system and the Pacific warm low-pressure system, northwest and north winds prevail in winter and spring, while southeast and southwest winds dominate in summer. The average annual wind velocity ranges from 2–4 $m \cdot s^{-1}$, decreasing from west to east. The number of days with sand-driving winds (\$ $5m \cdot s^{\{-1\})exceeds200, andduststormdays(17m \cdot s}$ {-1}\$) are also numerous.

Major rivers in the Korqin Sandy Land include the West Liao River and its main tributary, the Xilamulun River, as well as the Xiangshui, Laoha, Jiaolai, Chaganmulun, Wulijimulun, Haihaer, and Huolin rivers. For various reasons, the middle and lower reaches of the West Liao River and its main tributaries are currently in a state of flow interruption. Major lakes and reservoirs such as Xihu and Shelihu in Naiman Banner, and Molimiao Reservoir in Kailu County, have mostly dried up.

Except for areas characterized by sparse forest-steppe, dry steppe, and marsh wetland landscapes, most of the Korqin Sandy Land is occupied by farmland, shelter forests, and various types of sand dunes. Due to climate humidification and sand fixation afforestation, dunes in most areas tend to be stabilized, with mobile dunes concentrated only in Ongniud Banner in the west. Mobile dunes are sparsely vegetated with *Salix gordejevii*, *Artemisia halodendron*, *Pennisetum flaccidum*, and *Agriophyllum squarrosum*, while stabilized and semi-stabilized dunes support *Caragana microphylla*, *Corispermum macrocarpum*, *Setaria viridis*, *Cleistogenes squarrosa*, and *Polygonum amphibium.* Soils are predominantly aeolian sandy soils, soft soils, moisture-affected soils, and anthropogenic soils.

---

2 Methods

2.1 Field Investigation and Sampling

2.1.1 Field Investigation Field investigations were conducted annually during spring and summer from 2015 to 2020. The work focused on: (1) key areas in the core zone of the Korqin Sandy Land, including the lower Laoha River, middle and lower Xilamulun River, Xiangshui River, middle and lower Jiaolai River, West Liao River, and upper Xiushui River (eastern Kezuohou Banner); (2) marginal zones including the Chaganmulun River (including its source and main tributary Galadasitai River), middle and lower Wulijimulun River, middle and lower Haihaer River, and middle and lower Huolin River; (3) route surveys along major transportation lines (national highways, provincial roads, and desert-crossing roads); and (4) detailed surveys and observations of key sites based on LSR distribution patterns. Geographic coordinates of LSR locations were recorded with detailed descriptions, photographs, measurements, and samples collected.

2.1.2 Morphological Measurement Field measurements primarily used small tape measures, geological compasses, and electronic inclinometers. Measurements were taken at the central typical sections of LSRs, including individual width, height (wave amplitude), length (lateral extension distance), spacing (wavelength), strike, and slopes of windward and leeward sides. Height was measured using two graduated rods and a meter ruler. The rods were vertically aligned using the long bubble level of a compass, with the meter ruler perpendicular to the rods. Measurements were read by moving the ruler vertically, with the baseline set at the lowest point of the shallow trough or small depression corresponding to the LSR crest. If located on a distinctly sloping dune windward slope or riverbank, the rods were positioned perpendicular to the slope before measurement. A total of 86 observation data sets were obtained, including 32 combined measurements.

2.1.3 Sample Collection A random five-point sampling method was used to collect: (1) coarse sand from LSR crests with a sampling thickness of 1.0-1.5 cm; (2) mixed-layer sand samples from LSR troughs; and (3) surface sand from dunes with common ripples. A total of 46 samples were obtained.

2.2 Remote Sensing Analysis

2.2.1 Distribution Range First, LSR locations identified during field investigations were located on Google Earth imagery and centered on the computer screen to minimize geometric distortion. The image was then zoomed until LSRs were clearly discernible. The search area was expanded bilaterally along the central meridian or parallel until the entire region was covered, ensuring overlap between adjacent scan lines to guarantee at least some LSR imagery was captured. LSR distribution locations were then plotted on maps or remote sensing images to determine their spatial distribution range.

2.2.2 Morphological Measurement High-spatial-resolution satellite images from previous springs were selected and centered on the computer screen. Measurements were then taken directly using Google Earth' s measurement tools. Due to traffic conditions and typicality, field observations were mainly conducted in three areas: the southern bank of the middle Xilamulun River (Area A), the eastern bank of the Xiangshui River (Area B), and the Songshu Mountain area (Area C). Data on wavelength, length, height, and foreslope and backslope angles were obtained for statistical analysis. For descriptive convenience, this paper defines a continuous distribution of multiple LSRs with clear boundaries as a large-scale ripple spatial unit (LSRSU).

2.3 Grain Size Analysis

Grain size analysis was primarily performed using a Microtrac S3500 particle size analyzer (USA). Since the instrument can detect maximum particle sizes of only 1.4 mm, samples were first sieved using a 2.0 mm mesh metal sieve to manually calculate the mass percentage of particles >1.2 mm. The remaining material (<1.2 mm) was then analyzed using the laser particle size analyzer. Results from both sieving and laser analysis were weighted to obtain the actual grain size composition.

Grain size parameters including mean grain size (M), standard deviation (σ, sorting), skewness (SK), and kurtosis (KG) were calculated using the moment method:

$$M = \sum X_i f_i$$

$$\sigma = \sqrt{\sum (X_i - M)^2 f_i}$$

$$SK = \frac{\sum (X_i - M)^3 f_i}{\sigma^3}$$

$$KG = \frac{\sum (X_i - M)^4 f_i}{\sigma^4}$$

where f_i is the frequency percentage of each grain size class, and X_i is the median value of each class. The Folk and Ward classification standard was adopted for grain size description and parameter grading.

---

3 Results

3.1 Spatial Distribution Characteristics

Field investigations revealed that LSRs are absent in well-vegetated areas. They are primarily distributed in the western part of the Korqin Sandy Land, mainly in Ongniud Banner and the lower reaches of the Chaganmulun River, with particularly concentrated and typical development limited to these regions.

3.1.1 Area A: Southern Bank of the Middle Xilamulun River This area extends from Balinqiao in the west to Bolongke Grassland in the east, covering a vast spatial range with a maximum width of 12 km. The downwind longitudinal distance can reach 45 km. LSRs develop regularly in broad interdune areas, flat open dune windward slopes, and trough-like lowlands between dunes. In narrower sections near Shahu Lake, LSRSUs are often limited in scale, with longitudinal distances much shorter than lateral widths, and individual LSRs arranged irregularly with frequent lateral connections.

3.1.2 Area B: Eastern Bank of the Xiangshui River Extending from the Xiangshui Reservoir dam, this stripe-shaped area runs approximately 23 km in length with a width of 1.6 km. LSRSUs are primarily distributed on valley slopes and dunes along the river' s eastern bank. The geometric morphology is similar to Area A, with longitudinal distances up to 134 m and shorter distances of 28 m typically on dune middle and upper slopes. Due to more intense sand flow, LSRs on riverbank slopes and dune windward slopes are smaller and more scattered, often appearing as patches. Because of topographic forcing and acceleration in the valley, stripe-shaped LSRSUs often develop at the junction between floodplains and bank slopes, sometimes extending up the slopes. During winter, frozen river surfaces and floodplains allow sand flow to transport directly, forming LSRSUs of varying scales on riverbeds and floodplains.

3.1.3 Area C: Songshu Mountain Area Due to complex mountainous terrain causing high spatial variability in wind dynamics and irregular source material distribution, LSRs are mainly confined to narrow intermontane areas and bare ground between shrubs at mountain fronts. They appear as elongated stripes reaching 130 m in length, with regular downwind arrangement and greater width in the middle, resembling slender irregular fusiform shapes. In the northern part of this area where mountains are sparse and transverse dune groups are well-developed, patch-shaped LSRSUs on dune middle and upper slopes and large sheet-shaped LSRSUs in interdune areas are also common, with lengths of 45–85 m and widths up to 12 m.

3.2 Morphological Characteristics

3.2.1 Field Measurements Overall, LSR length varies significantly, ranging from 2.68 m to 11.97 m, with an average of 6.32 m. Extension direction is basically perpendicular to the local prevailing wind direction, with dunes and large interdune areas showing NE-SW orientation. On flat, uniform surfaces with abundant source material, adjacent LSRs often join laterally to extend farther. Under specific wind conditions, larger wavelengths occur on relatively firm, flat surfaces or in trough-shaped lowlands.

The average wavelength is 1.68 m (maximum 3.18 m, minimum 0.69 m), showing considerable spatial variability. Wave height (amplitude) is 12.13$\pm$2.75 cm, with relatively stable spatial variation. The ripple index (wavelength to height ratio) is 12.17$\pm$2.47 significantly smaller than common ripples (>10.00) and approaching critical values, and also smaller than those in the Kumtagh Desert of northwestern China and the Mojave Desert.

Cross-sections show distinct asymmetry. The lower windward slope is steeper (26.22°$\pm$2.47°) due to erosion, while the upper slope is gentler (12.17°$\pm$0.99°) due to deposition. The lee slope shows th
These results are consistent with measurements by Hoyle and Werner.

3.2.2 Google Earth Measurements Statistical analysis of 65 LSRSUs revealed an average length of 6.32 m (maximum 11.97 m, minimum 2.68 m), average strike of 43.87° (maximum 85.25°, nearly E-W orientation due to topographic forcing), and average wavelength of 1.68 m (maximum 3.18 m, minimum 0.69 m). Spatial variation is substantial, reflecting local influences of source material, topography, surface properties, and wind regimes.

3.3 Grain Size Characteristics The average grain size of coarse particles on LSR crests is 0.72 mm (medium sand), finer than those in northwestern China, West Asia, and North Africa. The mean standard deviation is 0.17 mm (extremely well sorted), indicating stable depositional environments or dynamic conditions. Mean skewness is 0.20 mm (near-symmetric to positive skew), showing a slight predominance of coarse particles. Mean kurtosis is 1.22 (very platykurtic), indicating gradual rather than abrupt wind strength fluctuations and non-uniform grain composition.

Mixed-layer sand has a mean grain size of 0.60 mm (medium sand) with a standard deviation of 0.20 mm (extremely well sorted). Skewness averages -0.17 (very negative to negative skew), indicating significantly higher fine sand content than medium sand. Kurtosis averages 1.40 (platykurtic to very platykurtic), showing gradual wind velocity changes above the threshold.

---

4 Discussion

4.1 Sources of Coarse Particles

As Bagnold noted, LSR formation and maintenance require a basically constant and sufficient supply of both coarse and fine sand, with winds strong enough to transport coarse grains but not so strong as to destroy the ripple structure. In western Korqin Sandy Land, wind conditions during winter and spring (especially during cold air outbreaks) are sufficiently strong to meet the threshold for coarse grain entrainment and transport. The widespread underlying gray-white loose sand layers, primarily fine sand, provide ample fine material.

Field observations show that coarse particles on LSR crests, interiors, and ridge flanks are predominantly dark-colored minerals (garnet, epidote, amphibole, hematite/limonite) and intermediate-acid volcanic rock fragments. Except for amphibole, these are stable minerals that have undergone some transport, but the substantial amphibole content indicates limited transport distance.

Specific source materials include: (1) fluvial sediments on old river channels, where coarse sand, fine gravel, and even pebbles are abundant; (2) underlying Quaternary fluvial-lacustrine strata exposed by river incision and lateral erosion, providing abundant medium to coarse sand; and (3) weathering crusts on denuded residual mountains and piedmont alluvial fans from seasonal water flow, supplying abundant coarse particles over extensive areas.

4.2 Differences from Common Wind-Blown Sand

First, LSR surfaces consist of coarse grains, primarily dark minerals and rock fragments, which strongly absorb light, making them easily distinguishable on remote sensing imagery at relatively far distances and moderate resolutions. This contrasts sharply with common wind-blown sand composed of gray-white or light yellow fine sand, which is difficult to identify on standard commercial imagery.

Second, grain size distribution curves show that LSRs exhibit bimodal distribution, while common wind-blown sand shows unimodal distribution, consistent with findings from other regions. In Area A, for example, medium sand content is highest (49.62%), followed by fine sand (28.42%) and coarse sand (19.65%). Fine sand plays a dual role: its saltating particles provide momentum to impact and move coarse grains, while also capturing and stabilizing coarse grains when they settle, allowing ridge accumulation.

Third, internal sedimentary structures differ markedly. LSR crests and ridge surfaces consist of black and gray-black medium-coarse sand (1.8 cm thick). The windward slope surface has recently deposited gray-white fine sand laminae, with indistinct foreset beds. Below lies a 5–8 cm thick interval of nearly horizontal alternating light and dark layers (2–3 mm each), underlain by alternating laminae (1–2 cm thick) extending to at least 1.5 m depth. This sequence closely resembles structures observed by Fryberger in the Namib Desert and differs substantially from common ripples.

4.3 Differences from Common Ripples

First, spatial scales differ dramatically. Common ripples in the Korqin Sandy Land have wavelengths of 10–15 cm and heights of 1–2 cm, while LSR wavelengths are typically 1.2 m—at least an order of magnitude larger. LSRs also have much larger ripple indices, with less pronounced differences between stoss and lee slopes.

Second, distribution ranges differ substantially. Common ripples occur throughout the Korqin Sandy Land, even in stabilized dune areas with small bare patches between shrubs. LSR development is much more restricted, requiring stronger winds and an appropriate proportion of coarse grains, thus occurring mainly in western Korqin near rocky hills.

Third, under suitable wind and topographic conditions, common ripples can develop on dune surfaces and even slip faces. LSRs, however, are generally limited to dune middle sections, appearing on dune tops only on arc-shaped dunes lacking slip faces or where the dune crest precedes the slip face ridge line. During the latter stages of strong wind events, as wind speeds gradually decrease, common ripple grids may cover entire dunes if moderate wind conditions persist, creating spectacular patterns.

Fourth, superposition patterns differ. Under weak sand-driving winds, common ripple grids often cover pre-existing LSRs, with LSRs only visible beneath shrub canopies. Under stronger winds, LSRs may bury or modify common ripples.

---

5 Conclusions

Using a combination of field investigation, observation, grain size analysis, and remote sensing imagery, this study systematically analyzed the spatial distribution, morphology, sedimentary structure, and material sources of large-scale ripples (LSRs) in the Korqin Sandy Land. The main conclusions are:

(1) LSRs are primarily distributed in four areas of western Korqin: the southern bank of the middle Xilamulun River, eastern bank of the Xiangshui River, Songshu Mountain, and lower Chaganmulun River, all adjacent to rocky mountains and hills. The Xilamulun River area has the largest spatial extent, while the Chaganmulun River area is the smallest.

(2) LSRSUs exhibit three spatial morphologies—sheet, patch, and stripe shapes—developing on broad interdune areas, dune middle and upper slopes, and trough-like lowlands, respectively.

(3) The average LSR length is 6.32 m with obvious regional variation. The average strike is NE-SW, generally perpendicular to the prevailing wind direction with minor regional differences. The average wavelength is 1.68 m, showing clear spatial variation. Individual LSRs have asymmetric cross-sections, with lee slope upper angles approaching the natural angle of repose.

(4) LSR grains are relatively coarse (medium to coarse sand), though finer than those in northwestern China and West/North Africa. Coarse particles mainly originate from fluvial deposits of old channels, underlying Quaternary fluvial-lacustrine strata, weathering crusts of denuded mountains, and piedmont alluvium.

(5) LSRs differ significantly from common ripples in appearance, composition, geometry, and internal structure, yet both represent small-scale transverse bedforms in the aeolian depositional landform hierarchy that can superimpose on various dune surfaces.

References

[1] Bagnold R A. The physics of blown sand and desert dunes[M]. London: Methuen, 1941: 153-157.

[2] Sharp R P. Wind ripples[J]. Journal of Geology, 1963, 71(5): 617-636.

[3] Zimbelman J R, Irwin III R P, Williams S H, et al. The rate of granule ripples movement on Earth and Mars[J]. Icarus, 2009, 203(1): 71-76.

[4] Wilson I G. Aeolian bedforms: Their development and origins[J]. Sedimentology, 1972, 19(3-4): 173-210.

[5] Ellwood J M, Evans P D, Wilson I G. Small scale aeolian bedforms[J]. Journal of Sedimentary Petrology, 1975, 45: 554-561.

[6] Foroutan M, Steinmetz G, Zimbelman J R, et al. Mega ripples at Namus Libya: A new analog for similar features on Mars[J]. Icarus, 2019, 319: 840-851.

[7] Fryberger S G, Hesp P, Hastings K. Aeolian granule deposits, Namibia[J]. Sedimentology, 1992, 39(2): 319-331.

[8] Tsoar H. Grain size characteristics of wind ripples on a desert seif dune[J]. Geography Research Forum, 1990, 10: 37-50.

[9] Yizhaq H, Isenberg O, Wenkart R, et al. Morphology and dynamics of aeolian mega ripples in Nahal Kasuy, southern Israel[J]. Israel Journal of Earth Sciences, 2009, 57: 149-165.

[10] Foroutan M, Zimbelman J R. Mega ripples in Iran: A new analog for transverse aeolian ridges on Mars[J]. Icarus, 2016, 274: 99-105.

[11] Hugenholtz C H, Barchyn T E. A terrestrial analog for transverse aeolian ridges (TARs): Environment, morphometry, and recent dynamics[J]. Icarus, 2017, 289: 239-253.

[12] Qian G, Dong Z, Zhang Z. Granule ripples in the Kumtagh Desert, China: Morphology, grain size and influencing factors[J]. Sedimentology, 2012, 59(6): 1888-1901.

[13] Li He, Ding Zhanliang, You Li, et al. A preliminary study of large scale ripples in the northwest margin of Ulanbuh Desert[J]. Journal of Arid Land Resources and Environment, 2020, 34(9): 129-136.

[14] McManus J. Grain size determination and interpretation[J]. Techniques in Sedimentology, 1988, 408: 112-116.

[15] 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.

[16] Pye K, Tsoar H. Aeolian sand and sand deposition[M]. London: Unwin Hyman, 1990: 176-183.

[17] Hoyle R B, Woods A W. Analytical model of propagating sand ripples[J]. Physical Review E, 1997, 56(6): 6861-6868.

[18] Werner B T, Haff P K, Livi R P, et al. The measurement of eolian ripple cross-sectional shapes[J]. Geology, 1986, 14: 743-745.

[19] Wang Yong, Han Guang, Yang Lin, et al. Grain size characteristics of sand dunes on the right bank of the middle Xiangshui River[J]. Journal of Desert Research, 2017, 37(1): 26-32.

[20] Wang Yong. Analysis of sand source of sand dunes on the right bank of the middle Xiangshui River in the west of the Horqin Sandy Land[D]. Changsha: Hunan Normal University, 2016.

[21] Warren A. Dunes: Dynamics, morphology, history[M]. New York: Wiley Blackwell, 2013: 109-111.