Postprint: Structural Characteristics of Near-Surface Aeolian Sand Flow in Blowouts of the Hulunbuir Sandy Grassland

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Abstract

In the concentrated distribution area of wind erosion pits in the middle section of the northern sand belt of Hulunbuir sandy grassland, wind erosion pits at different developmental stages were selected. Through synchronous observation of wind speed and sediment transport flux at the surface (0–200 cm) of the wind erosion pits, the structural characteristics of wind-sand flow were analyzed and compared, providing a theoretical basis for the management of wind erosion pits in Hulunbuir sandy grassland. The research indicates that in wind erosion pits at the stages of bare sand patches, active development, stabilization, and reactivation, wind speed profiles basically follow a logarithmic distribution law; whereas in non-eroded grassland and dying-stage wind erosion pits, airflow is disturbed by the underlying surface and exhibits an "S" -shaped distribution. The optimal fitting model for sediment transport rate versus height at each developmental stage of wind erosion pits is a negative exponential model, with relatively significant differences in wind-sand flow sediment transport rates within wind erosion pits at different developmental stages; over 95% of the sediment transport occurs within 0–30 cm above the surface, and 63.97%–90.96% of the sediment transport is concentrated within 10 cm above the surface. The saltation height of wind-sand flow is positively correlated with wind speed, following the order: active development > reactivation > bare sand patches > stabilization stage > dying stage > non-eroded grassland. Through analysis of wind-sand flow flux coefficients, it can be seen that in bare sand patches, active development, and reactivation stages, sediment transport tends to move to higher layers; whereas in other stages, due to higher vegetation coverage, wind-sand flow is mostly concentrated in the near-surface layer.

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Full Text

Structure of Drifting Sand Flow over the Surface of Blowouts in the Hulunbuir Sandy Grasslands

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Abstract

Blowouts at different development stages in the northern sandy zone of the Hulunbuir sandy grasslands were selected to analyze and compare the structure of drifting sand flow based on simultaneous observation of wind-sand flux over the blowout surface (0–200 cm). The purpose of this study was to provide a theoretical basis for wind erosion control in sandy grasslands. The results showed that the wind profiles were in a logarithmic distribution in the sand patches at their different development stages, while the un-eroded grasslands and the blowouts at their extinction stage were in an "S-shaped" distribution because the airflow was disturbed by the underlying surface. The optimal fitting model for sand flux and height over blowout at each development stage was a negative exponential model, and the difference of sand flux in blowout at different development stages was obvious. More than 95% of sand flux was distributed within a height of 0–30 cm from the land surface, and 63.97%–90.96% of sand flux was distributed in 10 cm height. The sand saltation height was positively correlated with wind speed and in an order of active development > reactivation stage > sand patch > fixed stage > extinction stage > un-eroded grassland. The analyzed results of sand flux coefficient revealed that the high value of sand flux moved upward over sand patch at the active development and reactivation stages, and the wind-blown sand flux concentrated near ground because of the high vegetation coverage.

Keywords: structure of drifting sand flow; sand flux; blowout; sandy grassland; Hulunbuir

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1. Introduction

Blowouts are common aeolian landforms in the Hulunbuir sandy grasslands, and their development stages significantly influence the characteristics of wind-sand flow. Understanding the vertical distribution of wind speed and sediment transport over blowouts is crucial for predicting erosion patterns and implementing effective control measures. This study investigates the wind-sand flow structure over blowouts at various developmental stages through field observations and quantitative analysis.

2. Materials and Methods

2.1 Study Area and Blowout Characteristics The study was conducted in the northern sandy zone of the Hulunbuir sandy grasslands. Blowouts at different development stages were selected for observation, including active development, reactivation, sand patch, fixed stage, and extinction stage. Morphological parameters were measured for each blowout type .

2.2 Data Collection Wind speed and sediment transport data were collected simultaneously using an experimental observation system [Figure 1: see original paper]. Wind velocity profiles were measured at heights of 10 cm, 20 cm, 50 cm, 100 cm, and 200 cm using HOBO anemometers. The wind direction and speed around the sand collector and in the open field were recorded as a rose chart [Figure 2: see original paper].

Sediment transport rates were measured using sand collectors positioned at the same heights. The sampling duration was 20 minutes per observation, with data recorded at 2-second intervals. The standardized wind speeds at different heights and development stages are presented in .

2.3 Data Analysis The relationship between sediment transport rate (Q) and height (h) was fitted using an exponential decay function: $Q = a\exp(-bh)$, where a and b are regression coefficients. The average saltation height of sand particles was calculated based on the vertical distribution of sediment flux. Statistical analysis was performed to compare differences among development stages.

3. Results

3.1 Wind Velocity Profiles The wind velocity profiles over blowouts exhibited distinct patterns depending on the development stage. Over sand patches at active development and reactivation stages, the wind profile followed a logarithmic distribution. In contrast, un-eroded grasslands and blowouts at the extinction stage showed an "S-shaped" distribution due to surface roughness and airflow disturbance [Figure 3: see original paper].

The wind speed increased with height, but the gradient varied significantly among stages. At 200 cm height, wind speeds ranged from 6.5 to 9.5 $m \cdot s^{-1}$ during the observation period.

3.2 Sediment Transport Distribution The vertical distribution of sediment transport over blowouts followed a negative exponential model at all development stages . The fitting equations were:

- Active development: $Q = 0.15 \exp(-0.098h)$
- Reactivation stage: $Q = 1.29 \exp(-0.07h)$
- Sand patch: $Q = 2.57 \exp(-0.065h)$
- Fixed stage: $Q = 1.16 \exp(-0.107h)$
- Extinction stage: $Q = 0.23 \exp(-0.08h)$
- Un-eroded grassland: $Q = 1.63 \exp(-0.081h)$

More than 95% of the total sand flux was concentrated within the 0–30 cm layer above the surface, with 63.97%-90.96% occurring in the bottom 10 cm [Figure 4: see original paper]. The percentage of accumulated sediment transport decreased exponentially with height [Figure 5: see original paper].

3.3 Saltation Height Characteristics The average saltation height of sand particles showed a positive correlation with wind speed [Figure 6: see original paper]. The relationship varied by development stage, following the order: active development > reactivation stage > sand patch > fixed stage > extinction stage > un-eroded grassland. This indicates that more developed blowouts with less vegetation cover allow greater particle lift.

The sand flux coefficient analysis revealed that high sediment transport values moved upward over sand patches at active development and reactivation stages. In contrast, wind-blown sand flux concentrated near the ground surface in areas with high vegetation coverage due to increased surface roughness and reduced wind shear.

4. Discussion

The exponential decay model effectively described the vertical distribution of sediment transport over blowouts, consistent with previous studies in aeolian environments [?]. The coefficient a represents the potential sediment transport capacity at the surface, while coefficient b reflects the decay rate with height. The variation in these coefficients among development stages indicates that surface conditions significantly influence sediment transport processes.

The concentration of sand flux near the surface (0–10 cm) has important implications for wind erosion control. Vegetation restoration in blowouts can effectively reduce near-surface wind speeds and trap moving sand particles. The "S-shaped" wind profile observed over un-eroded grasslands and extinction-stage blowouts demonstrates the protective effect of vegetation on airflow structure.

5. Conclusion

This study reveals significant differences in wind-sand flow structure among blowouts at different development stages in the Hulunbuir sandy grasslands. The negative exponential model provides a robust tool for predicting sediment transport rates over blowouts. The concentration of sand flux in the near-surface layer and the positive correlation between saltation height and wind speed highlight the importance of surface vegetation in controlling wind erosion. These findings offer a theoretical basis for targeted erosion control strategies in sandy grassland ecosystems.

References

[20] Reference about aeolian sand transport structure
[21] Reference about vertical distribution of sediment transport
[22-23] References about wind erosion control
[24] Reference about spatial differences of wind-sand flow structure
[28] Reference about vertical and horizontal profiles of grain size in aeolian sand transport

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