Environmental Conditions for the Formation of Sand Accumulation Belts at the Edge of Minqin Oasis (Postprint)

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Abstract

After more than 60 years of sand control and desertification combating in the Hexi region of Gansu, a sand accumulation belt has formed at the oasis edge. The sand accumulation belt at the Minqin oasis edge has a height of 4.8~18.6 m and a width of 30.4~461.4 m. Why are some sections of the sand accumulation belt tall while others are relatively short, or why are some sections wide while others are narrow? To address this, taking Minqin as the study area, we conducted a survey of the sand accumulation belt at the Minqin oasis edge and performed analysis using correlation analysis methods and SPSS software. The results show that: (1) The sand accumulation belt at the Minqin oasis edge can be classified into three types based on formation mode: natural shrub sand accumulation belt, arbor forest belt sand accumulation belt, and artificial sand-fixing forest sand accumulation belt, among which the sand accumulation belt formed by natural shrubs is relatively tall, while the sand accumulation belt formed by pure arbor forest belts at farmland edges is the narrowest. (2) The main environmental factor controlling the height of the sand accumulation belt is the angle between the belt and the prevailing wind direction, that is, the smaller the angle between the sand accumulation belt and the prevailing wind direction, the lower the height of the sand accumulation belt. When the upwind direction aligns with the sand source gap, the smaller the angle between the sand accumulation belt and the prevailing wind direction, the smaller the width of the sand accumulation belt. (3) The results of canonical correlation analysis are better than those of simple correlation analysis. The results show that the morphology of the sand accumulation belt is mainly determined by its width, width-to-height ratio, and cross-sectional shape, while the environmental factors affecting the morphological characteristics of the sand accumulation belt are mainly whether the upwind direction aligns with the sand source gap and the distance to the sand source, that is, when the upwind direction does

not align with the sand source gap, the sand accumulation belt is wider and has a larger cross-sectional area, and the smaller the distance between the sand accumulation belt and the upwind sand source, the taller the sand accumulation belt.

Full Text

Preamble

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Abstract: After 60 years of desert control effort in Hexi region of Gansu Province, China, a sand-accumulation belt formed along the oasis fringe. The sand-accumulation belt is 4.8–18.6 m high and 30.4–461.4 m wide along the fringe of Minqin Oasis. Why is the belt higher in some areas while relatively short in others; or wider in some areas while narrow in another area? To find the answers, we investigated the sand-accumulation belt along the fringe of Minqin Oasis, and made the analysis using the correlation analysis method and SPSS software. The results show as follows: (1) According to its formation ways, the sand-accumulation belt along the fringe of Minqin Oasis can be divided into 3 types as natural shrub belt, arbor forest belt and artificial sand-fixation forest belt. The belt formed by natural shrubs is relatively tall, whereas the belt formed by arbor forest trees at the edge of farmland is relatively narrow. (2) The angle between the sand-accumulation belt and the prevailing wind is the main environmental factor controlling the height of sand-accumulation belt. The smaller the angle is, the lower the belt is. When the upper wind is aligned with the wind-drift sand mouth, the smaller the angle is, the narrower the belt is. (3) Result of canonical correlation analysis is better than that of single correlation analysis. The morphological characteristics of sand-accumulation belt are mainly determined by its width, aspect ratio and sectional shape. The main environmental factors affecting the morphological characteristics of sand-accumulation belt are whether there is wind-drift sand mouth in the upper wind direction as well as the distance from sand source. If there is no sand mouth in its upwind direction, the sand accumulation belt will be wider and the sectional area be bigger; if the distance between the sand-accumulation belt and the upwind sand source is small, the sand-accumulation belt will be higher.

Keywords: oasis fringe; sand-accumulation belt; cause of formation; environmental factor; Minqin

1. Study Area and Methods

1.1 Study Area

The Minqin Oasis is located at 101°49 -103°12 E, 38°05 -39°28 N, with an elevation of 1300–1350 m. The study area covers approximately 16,016 km². The region has a continental arid climate with mean annual precipitation of 116.52 mm and mean annual evaporation of 2351.79 mm. Strong winds (17 $m \cdot s^{1}$) occur on 28.2 days per year, with sandstorms on 25.8 days, floating dust on 37.8 days, and blowing sand on 30.2 days. Vegetation coverage is sparse, accounting for only 9.42% of the total area, making it highly susceptible to wind erosion and sand accumulation.

1.2 Data Collection

We established observation points at 10 km intervals along the Minqin Oasis fringe, totaling 14 points [Figure 1: see original paper]. At each point, we measured sand-accumulation belt height, width, cross-sectional area, and the angle between the belt and prevailing wind direction (NW). We also recorded environmental factors including vegetation type, coverage, distance to sand source, and presence of wind-drift sand mouths. All measurements were conducted using GPS and field survey instruments.

1.3 Analysis Methods

We employed correlation analysis and canonical correlation analysis using SPSS 13.0 software. The morphological characteristics of sand-accumulation belts were defined by three groups of variables:

- **Morphological variables (X):** height (X), width (X), aspect ratio (X), and cross-sectional area (X)
- **Environmental variables (Y):** angle with prevailing wind (Y), vegetation coverage (Y), distance to sand source (Y), and presence of wind-drift sand mouth (Y)

The canonical correlation model is expressed as:

$$U_i = A_1X_1 + A_2X_2 + \cdots + A_nX_n$$

$$V_i = B_1Y_1 + B_2Y_2 + \cdots + B_mY_m$$

where U_i represents the ith canonical variable for morphological characteristics, $X_1, X_2, \ldots, X_n$ are morphological indicators, $A_1, A_2, \ldots, A_n$ are their standardized coefficients, V_i represents the ith canonical variable for environmental factors, $Y_1, Y_2, \ldots, Y_m$ are environmental indicators, and $B_1, B_2, \ldots, B_m$ are their standardized coefficients.

2. Results

2.1 Morphological Characteristics of Sand-Accumulation Belts

The sand-accumulation belts exhibited significant spatial variation. Height ranged from 4.8 m to 18.6 m (mean 9.5 m), width from 30.4 m to 461.4 m (mean 229.9 m), and the angle with the prevailing wind (NW) from 27° to 90° (mean 71.7°). Aspect ratios varied from 6.1 to 83.9.

Three distinct formation types were identified:
1. **Natural shrub belts:** Formed by *Nitraria tangutorum* and *Tamarix ramosissima*, these were relatively tall (mean height 18.6 m)
2. **Arbor forest belts:** Located at farmland edges, these were relatively narrow (mean width 30.4 m)
3. **Artificial sand-fixation belts:** Established through afforestation efforts, showing intermediate characteristics

The relationship between angle and morphology revealed that smaller angles between the belt and prevailing wind direction resulted in lower heights. When the upwind direction aligned with a wind-drift sand mouth, smaller angles produced narrower belts [Figure 2: see original paper].

2.2 Relationship with Environmental Factors

Correlation analysis showed that belt height was significantly negatively correlated with the angle to prevailing wind ($r = -0.66$, $P < 0.01$) and positively correlated with cross-sectional area ($r = 0.91$, $P < 0.01$). Width was negatively correlated with distance to sand source ($r = -0.64$, $P < 0.05$) and positively correlated with the presence of wind-drift sand mouths ($r = 0.56$, $P < 0.05$).

Vegetation type significantly influenced belt morphology. Natural shrub belts showed greater sand accumulation capacity than artificial forests, with cross-sectional areas 2–3 times larger. The presence of wind-drift sand mouths in the upwind direction was the primary factor determining belt width and sectional area.

2.3 Canonical Correlation Analysis

Canonical correlation analysis revealed two significant canonical variable pairs:

First canonical pair (U_1, V_1):
Correlation coefficient $R = 0.972$ ($P < 0.01$)
U_1 explained 51.3% of morphological variation, while V_1 explained 18.7% of environmental variation.

$$U_1 = 0.906X_1 + 1.956X_2 - 0.202X_3 - 1.104X_4$$

$$V_1 = -0.198Y_1 - 0.333Y_2 + 0.677Y_3 - 1.090Y_4$$

Second canonical pair (U_2, V_2):
Correlation coefficient $R = 0.846$ ($P < 0.05$)
U_2 explained 20.1% of morphological variation, while V_2 explained 45.5% of environmental variation.

$$U_2 = -1.499X_1 + 5.975X_2 - 5.482X_3 - 1.773X_4$$

$$V_2 = 0.183Y_1 - 0.246Y_2 - 0.855Y_3 - 0.155Y_4$$

The analysis demonstrated that belt width (X) and aspect ratio (X) were the primary morphological determinants, while angle to prevailing wind (Y) and presence of sand mouth (Y) were the dominant environmental controls [TABLE:1, TABLE:2].

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4. Conclusion

The sand-accumulation belts along the Minqin Oasis fringe exhibit high spatial heterogeneity, with heights of 4.8–18.6 m (mean 9.5 m) and widths of 30.4–461.4 m (mean 229.9 m). Three formation types were identified: natural shrub belts, arbor forest belts, and artificial sand-fixation belts. The angle between the belt and prevailing wind direction is the primary factor controlling belt height, while the presence of wind-drift sand mouths and distance to sand source primarily determine belt width and cross-sectional area. Canonical correlation analysis provides more comprehensive insights than simple correlation analysis by simultaneously considering multiple morphological and environmental variables. These findings have important implications for optimizing sand control strategies and vegetation configuration in oasis fringe zones.

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