Relationship Between Soil Factors and Ephemeral Plant Species Diversity on Typical Sand Dunes in the Mosuowan Region (Postprint)

Authors: Li Yaping, Jiang Jin, Chunwu Song, Li Zhehua, Jiang Jin

Date: 2018-06-28T00:00:00+00:00

Abstract

Taking the Mosuowan area on the southern margin of the Gurbantunggut Desert as the study region, typical sample plots were selected from fixed and semi-fixed dunes with vegetation coverage of 10% and 15%, respectively, and from fixed dunes with 30% vegetation coverage. Canonical Correspondence Analysis (CCA) was applied to analyze the relationships among quadrats, environmental factors, and species abundance in this region, while canonical correlation analysis was employed to examine the correlations between species diversity and topographic factors as well as soil physicochemical factors across the sample plots. The results demonstrate a significant correlation between species and environmental factors, with the first four axes explaining 84.4% of the total species variation. Soil sand content serves as a relatively sensitive indicator factor influencing species distribution, with species heavily distributed along the ordination axis representing soil sand content. Species significantly affected by topography include Arnebia decumbens, Centaurea chrysocephala, Echinops gmelinii, and Salsola ruthenica; species markedly influenced by soil organic matter, soil moisture, and soil pH include Schismus arabicus, Ceratocarpus arenarius, Astragalus membranaceus, and Erodium oxyrhinchum. Canonical correlation analysis results for different indicator systems reveal that the first canonical correlation coefficient between topographic factors and species diversity factors is 0.54. The first pair of canonical coefficients between soil physicochemical factors and species diversity are 0.93 and 0.96, respectively, while the second pair are 0.79 and 0.80, respectively, indicating significant correlations. Among topographic factors, slope aspect primarily influences the Simpson species richness index; among soil physicochemical factors, sand content and soil organic matter mainly affect the Shannon dominance index, whereas soil water content and pH primarily influence the Pielou evenness index. The species distribution pattern in this region is jointly determined by topographic and soil factors.

Full Text

Preamble

ChinaXiv Collaborative Journal
DOI: 10.13866/j.azr.2018.04.20

Authors: Liyaping[1],[2], Jiang Jin[1],[2], Song Chunwu[1],[2], Li Zehua[1],[2]
[1]. Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830000, China
[2]. University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Taking Mosuowan on the southern margin of the Gurbantunggut Desert as the study area, fixed dunes with 10% and 15% vegetation cover and fixed dunes with 30% vegetation cover were selected as typical plots. Using Canonical Correlation Analysis (CCA) to analyze quadrats, environmental factors, and species abundance in this area, the relationship between species diversity and terrain factors and soil physicochemical factors was examined through canonical correlation analysis. The results showed a significant correlation between species and environmental factors, with the first four axes explaining 84.4% of total species variation. Grit was a sensitive indicator of species distribution. Species were distributed across a large number of axes. Species significantly affected by terrain included *Arnabia decumbens*, *Echinops gmelinii*, *Amberboa turanica*, and *Agriophyllum aquarrosum*. Species significantly affected by soil organic matter, soil moisture, and soil pH were *Schismus arabicus*, *Ceratocarpus arenarius*, *Astragalus membranaceus*, and *Erodium oxyrrhynchum*. Typical correlation analysis results of different indicator groups showed that the first model correlation coefficient between topography and species diversity was 0.54. The first pair of model coefficients between soil physicochemical factors and species diversity were 0.93 and 0.96, and the second pair were 0.79 and 0.80, indicating significant correlation. Among topographical factors, the slope index mainly affected the Simpson species richness index. Soil physical and chemical factors, sand, and soil organic matter mainly affected the Shannon dominance index, while soil moisture and pH mainly affected the Pielou evenness index. Species distribution in this area is influenced by both topography and soil factors.

Keywords: Soil factor; Ephemeral plant; Species diversity; Canonical Correlation; Canonical correlation analysis; Mosuowan; Xinjiang

---

1 Study Area and Methods

1.1 Study Area Overview

The study area is located at Mosuowan on the southern edge of the Gurbantunggut Desert, with geographic coordinates of 86°06 ~86°50 E, 44°40 ~45°N, at an elevation of 346.8 m. The terrain is relatively flat with slopes of 5-20 m.

The area has a temperate continental arid climate with an annual average temperature of 4-6°C, annual precipitation of 114.89 mm, and annual evaporation of 1942.1 mm. The annual average wind speed is 16.9 m/s, with 3000-3500 hours of sunshine at temperatures $ $10°C, and 3100-3200 hours of annual sunshine duration. The prevailing wind direction is WNW and ESE. The average sand grain size is 13 cm, with a maximum of 27 cm.

1.2 Sample Plot Selection and Survey Methods

Three typical fixed dunes (A, B, C) with vegetation coverage of 10%, 15%, and 30% were selected as sample plots. Fixed dunes with 200 m length and 7 m width were established. For each dune, three aspects (sunny slope, shady slope, and top) were surveyed. Dune A had a height of 27.6 m with a 21° slope for the sunny aspect, and 13.4 m height with 16° slope for the shady aspect. Dune B had a height of 8 m with 12° slope for the sunny aspect, and 24.3 m height with 16° slope for the shady aspect. Dune C had a height of 12.7 m with 19° slope for the sunny aspect, and 4 m height with 20° slope for the shady aspect.

Five parallel transects were established along the slope direction for each dune aspect. Sample quadrats of 1.0 m × 1.0 m were set up at 2 m intervals along each transect. Three parallel quadrats were established for each aspect to survey herbaceous plants, shrubs, and environmental factors. A DU800 spectrophotometer was used to measure soil nutrients, and a BT-2001V analyzer was used for soil particle size analysis.

1.3 Diversity Index Calculation

The Shannon-Wiener diversity index was calculated as:
H = - (P_i ln P_i) where **P_i = n_i/N**

The Simpson diversity index was calculated as:
D = 1 - P_i

The Pielou evenness index was calculated as:
E = H/ln S

Where:
- S = total number of species
- P_i = relative importance value of species i
- n_i = importance value of species i
- N = sum of importance values of all species
- n_i = (n^{JK} + n^{JK} + n^(cid:176)K + n^{1K}) × 100/4

1.4 Data Analysis Methods

Canoco 4.5 software was used for detrended correspondence analysis (DCA) and redundancy analysis (CCA). When the gradient length exceeded 4.253, CCA was selected for direct gradient analysis. Shannon diversity index, Simpson

diversity index, and Pielou evenness index were calculated using Spaa software in R. PCA analysis was performed using R' s labdsv package, and CCA analysis was conducted using the vegan package in R.

2 Results

2.1 Species Distribution Characteristics

The survey recorded 20 ephemeral plant species belonging to 8 families and 17 genera. The distribution varied significantly among different dune types and aspects. Dune A (10% vegetation cover) showed the highest species richness, while Dune C (30% cover) had the lowest. The sunny slopes generally harbored more species than shady slopes across all dune types.

2.2 Principal Component Analysis

PCA analysis revealed that the first three principal components explained 75% of the total variance. The first axis (53.9% variance) was strongly correlated with soil organic matter, soil moisture, and pH. The second axis (31.7% variance) was associated with topographic factors including slope and aspect. The third axis explained 13.5% of variance and was related to soil texture components.

2.3 Canonical Correspondence Analysis

CCA results showed significant correlations between species distribution and environmental factors. The first two CCA axes explained 52.8% and 21.1% of species-environment variance respectively, totaling 73.9%. Soil moisture, organic matter, and pH were the primary factors influencing species distribution. Topographic factors (slope, aspect) explained an additional 19% of variance.

The CCA ordination diagram [Figure 1: see original paper] shows that species such as *Schismus arabicus*, *Ceratocarpus arenarius*, and *Astragalus membranaceus* were positively correlated with soil moisture and organic matter, while *Erodium oxyrrhynchum* and *Amberboa turanica* were associated with higher pH and sand content.

2.4 Canonical Correlation Analysis

Canonical correlation analysis between species diversity indices and environmental factors yielded significant results. The first canonical correlation coefficient between topographic factors and diversity indices was 0.54 ($p < 0.05$). The first pair of canonical variables for soil physicochemical factors showed correlation coefficients of 0.93 and 0.96 for species diversity indices, while the second pair showed coefficients of 0.79 and 0.80, both statistically significant.

Topographic factors primarily influenced the Simpson diversity index (species richness), while soil organic matter and sand content mainly affected the Shan-

non dominance index. Soil moisture and pH were the key factors influencing the Pielou evenness index.

Tables

Features of various dune morphology

Distribution of short-lived plants in early spring

The basic statistics of the average of each factor different dune

Factor loading, Eigenvalue and cumulative percentage of principle analysis

Eigenvalues and species-environment correlations coefficient of CCA axis

Canonical Coefficients and Correlation Coefficients of Environmental variables and the axis of CCA

Results of canonical analysis

References

[1] Zhang Rong, Liu Tong. Plant species diversity and community classification in the southern Gurbantunggut Desert[J]. Acta Ecologica Sinica, 2012, 32(19): 6056-6066.

[2] Liu Zhongquan, Liu Tong, Zhang Rong, et al. Species diversity and spatial differentiation of ephemeral plant community in southern Gurbantunggut Desert[J]. Chinese Journal of Ecology, 2013, 30(1): 45-52.

[3] Qian Yibing, Wu Zhaoning, Zhang Liyun, et al. The spatial distribution of ephemeral plants in Gurbantunggut desert[J]. Chinese Science Bulletin, 2007, 52(19): 2299-2306.

[4] Yan Dongfeng, Yang Xitian. Quantitative ordination and environmental analysis of woody plant communities in Baotianman, Henan Province[J]. Ecology And Environment, 2010, 19(12): 2826-2831.

[5] Shi Zuoming, Cheng Ruimei, Liu Shirong, et al. Community Structure and Species Diversity of Platycarya Strobilacea Forest in Baotianman, Henan Province[J]. Journal of Mountain Science, 2005, 23(3): 374-380.

[6] Tang Da, Zhang Huimin, Zhang Ximing, et al. Relationships between Sap Flow Velocity of Hippophae rhamnoides Linn. and Meteorological Factors in the Qaidam Basin[J]. Arid Zone Research, 2017, 34(3): 630-637.

[7] Liu Guojun, Li Yaping, Jiang Jin, Song Chunwu. Relationship between soil factors and ephemeral plant species diversity in the typical sand dunes in the Mosuowan[J]. Arid Zone Research, 2018, 35(1): 910.

[8] Ye Qing, Zhou Huarong, Yuan Lei, et al. Effect of soil moisture on longitudinal dune surface in Gurbantonggut desert[J]. Arid Zone Research, 2016, 33(5): 1119-1124.

[9] Zhang Liyun. A preliminary study on the ephemerals in the mosowan district, Xinjiang[J]. Chinese Journal of Plant Ecology, 1985, 9(3): 213-222.

[10] Zang Runguo, Jing Xuehui, Ding Yi, et al. Quantitative classification, ordination and environmental analysis of woody plant communities in Xiaodonggou forest area of the Altai mountain, Xinjiang[J]. scientia silvae sinicae, 2010, 46(2): 24-31.

[11] Wang Xueqin, Jiang Jin, Lei Jiaqiang, et al. Relationship between ephemeral plants distribution and soil factors[J]. Chinese Journal of Applied Ecology, 2004, 15(4): 556-560.

[12] Liu Shiliang, Makeming, Fu Bojie, et al. The relationship between landform, soil characteristics and plant community structure in the DongLinShan mountain region, Beijing[J]. Acta Phytoecologica Sinica, 2003, 27(4): 496-502.

[13] Ding Gaigai, Jiang Jin, Song Chunwu, et al. Ecological characteristics of cultivated Haloxylon ammodendron communities in Gurbantunggut desert[J]. Chinese Journal of Eco-Agriculture, 2017, 25(10): 1423-1432.

[14] Li Shilang, Ma Keming, Fu Bojie, et al. The relationship between topography, soil characteristics and plant community structure in Beijing mountain region[J]. Acta Phytoecologica Sinica, 2001, 25(1): 11-16.

[15] Wang Yanwu, Chai Qiang, Ouyang Xuezhi, et al. Evolution of Soil Nutrition and Biological Properties Under Sand-fixing Plants in Fringe Area of Minqin Oasis[J]. Journal of Soil and Water Conservation, 2013, 30(1): 141-146.

[16] Liu Guojun, Li Yaping, Jiang Jin, et al. Relationship between soil factors and ephemeral plant species diversity in the typical sand dunes in the Mosuowan[J]. Arid Zone Research, 2016, 33(5): 1119-1124.

[17] Liu Shirong, Ma Keming, Fu Bojie, et al. Relationship between topography, soil characteristics and plant community structure[J]. Acta Ecologica Sinica, 2001, 21(1): 171-176.

[18] Wang Yanwu, Chai Qiang, Ouyang Xuezhi, et al. Evolution of Soil Nutrition and Biological Properties Under Sand-fixing Plants in Fringe Area of Minqin Oasis[J]. Journal of Soil and Water Conservation, 2013, 30(1): 141-146.

[19] Zhang Liyun. A preliminary study on the ephemerals in the mosowan district, Xinjiang[J]. Chinese Journal of Plant Ecology, 1985, 9(3): 213-222.

[20] Liu Guojun, Li Yaping, Jiang Jin, Song Chunwu. Relationship between soil factors and ephemeral plant species diversity in the typical sand dunes in the Mosuowan[J]. Arid Zone Research, 2018, 35(1): 910.

[21] Ding Gaigai, Jiang Jin, Song Chunwu, et al. Ecological characteristics of cultivated Haloxylon ammodendron communities in Gurbantunggut desert[J]. Chinese Journal of Eco-Agriculture, 2017, 25(10): 1423-1432.

[22] Liu Shiliang, Makeming, Fu Bojie, et al. The relationship between landform, soil characteristics and plant community structure in the DongLinShan mountain region, Beijing[J]. Acta Phytoecologica Sinica, 2003, 27(4): 496-502.

[23] Wang Yanwu, Chai Qiang, Ouyang Xuezhi, et al. Evolution of Soil Nutrition and Biological Properties Under Sand-fixing Plants in Fringe Area of Minqin Oasis[J]. Journal of Soil and Water Conservation, 2013, 30(1): 141-146.

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