Postprint: Relationship Between Surface Soil Pollen and Vegetation in the Xinjiang Xiaerxili Nature Reserve

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Abstract

The Xiaerxiri Nature Reserve in Xinjiang preserves a relatively pristine ecological environment, serving as an ideal region for investigating vegetation and environmental changes. Based on 33 surface soil pollen samples collected from the mountain steppe-desert zone, mountain dry steppe zone, and mountain forest zone at elevations ranging from 1,042 to 2,426 m within the reserve, combined with vegetation quadrat surveys conducted at each sampling site, ordered cluster analysis and redundancy analysis were performed on the pollen data to explore the correspondence between surface soil pollen assemblage characteristics and vegetation. The results indicate that: the characteristics of the three pollen assemblage zones generally correspond well with the vegetation of each vertical zone; pollen contents of Chenopodiaceae and Ephedra show no significant correlation with plant coverage in the quadrats, and these two pollen types exhibit over-representative distribution characteristics, likely representing extraregional pollen transported by airflow from low-altitude areas to high-altitude mountainous regions; Betula pollen and Fabaceae pollen correspond well with the respective Betula forest and Caragana shrubland vegetation communities; the [WTBX]A/C[WTBZ] ratio and total pollen concentration demonstrate significant indicative value in distinguishing forest zones from steppe-desert vegetation zones; fern spores are positively correlated with precipitation and altitude, while Fabaceae pollen is positively correlated with temperature. Due to differences in soil, moisture, and light intensity caused by mountainous terrain factors, transitional vegetation characterized by the alternation of forest vegetation and mid-mountain meadow vegetation forms on sunny and shady slopes at the same altitude, resulting in extensive pollen mixing in the assemblages and thereby reducing the correlation between Picea and Betula pollen and vegetation coverage; the quantitative relationship between such woody pollen and vegetation is relatively complex. This phenomenon is universal in plant ecological analysis but substantially impacts the application of surface soil pollen data in quantitative reconstruction of vegetation and climate. When utilizing mountainous surface soil pollen data for quantitative reconstruction of vegetation and climate, it is necessary to calibrate and screen the pollen data in conjunction with vegetation quadrat data and sedimentary environment characteristics.

Full Text

Abstract

Xarxili Nature Reserve maintains an original intact ecosystem and serves as an ideal area for studying vegetation-environment relationships in Xinjiang, China. In this study, we collected 33 surface pollen samples from the mountain steppe-desert zone, mountain steppe zone, and mountain forest zone across an elevation gradient from 1042 m to 2426 m, with each sampling site surveyed for vegetation. Cluster analysis (CA) and redundancy analysis (RDA) based on palynological data were carried out to examine relationships between surface pollen assemblages and modern vegetation. The results show good correspondence between three surface pollen assemblage zones identified by CA and RDA and the modern vegetation zones. Pollen contents of Chenopodiaceae and Ephedra were not significantly associated with vegetation coverage, presenting a super-representative distribution characteristic that indicates these pollen types were transported from lower to higher elevation regions via airflow; thus, Chenopodiaceae and Ephedra pollen are of exogenous origin. Betula and Leguminosae pollen showed good correspondence with birch grove and Caragana bush vegetation. The A/C ratio and pollen total concentration were important for distinguishing forest zone from steppe-desert zone. RDA results showed that fern spores were positively correlated with precipitation and elevation, while Leguminosae pollen was positively correlated with temperature. Due to differences in soil, moisture, and illumination caused by topographic variation, different vegetation zones formed on sunny and shady slopes at the same elevation, with forest and meadow zones occurring alternately. Influenced by mountain airflow and water flow, pollen composition mixed between these vegetation zones, decreasing the correlation between Picea and Betula pollen and vegetation coverage. Consequently, the quantitative relationship between pollen and vegetation became more complex, a phenomenon universal in phytoecology that significantly impacts quantitative vegetation and climate reconstruction when using surface pollen data. Therefore, when using surface pollen data from mountain regions for quantitative reconstruction, it is necessary to investigate vegetation status of sampling sites in detail, analyze sedimentary environment characteristics, and correct and filter surface pollen data accordingly.

Keywords: Xarxili; surface sporopollen; cluster analysis; redundancy analysis; Xinjiang

1. Introduction

Surface pollen analysis is a fundamental method for establishing relationships between modern vegetation and pollen assemblages, providing essential modern analogs for paleovegetation and paleoclimate reconstruction. Previous studies have demonstrated that pollen assemblages from surface samples generally reflect characteristics of modern vegetation, though representation varies significantly among taxa. In arid and semi-arid regions, factors such as wind transport, pollen productivity, and preservation conditions complicate the quantitative relationship between pollen percentages and vegetation coverage.

Mountain ecosystems exhibit strong vertical zonation, with vegetation types changing dramatically over short elevation gradients. This vertical heterogeneity creates complex pollen source patterns, as upslope transport of pollen from lower vegetation zones can significantly alter assemblages at higher elevations. Understanding these processes is crucial for accurate interpretation of fossil pollen records from mountainous regions.

Xarxili Nature Reserve in Xinjiang represents a pristine mountain ecosystem spanning from steppe-desert to forest zones, making it an ideal location to investigate pollen-vegetation relationships along elevation gradients. This study aims to: (1) characterize surface pollen assemblages across different vegetation zones; (2) evaluate the correspondence between pollen and vegetation using multivariate analysis; and (3) assess the influence of environmental factors on pollen distribution.

2. Materials and Methods

2.1 Study Area and Sampling

The study area is located in Xarxili Nature Reserve, Xinjiang, covering elevations from 1042 m to 2426 m. A total of 33 surface pollen samples were collected across three vegetation zones: mountain steppe-desert zone, mountain steppe zone, and mountain forest zone. Geographic coordinates of sampling sites ranged from 81°47 24 to 81°59 48 E and 45°06 08 to 45°13 54 N. At each sampling site, vegetation surveys were conducted to document community composition and coverage.

2.2 Pollen Analysis

Surface samples were processed using standard laboratory procedures. Pollen concentrations were calculated using the exotic marker method, with results expressed as grains per gram of dry sediment. A minimum of 300 terrestrial pollen grains were counted per sample. Pollen percentages were calculated based on the total sum of terrestrial pollen, while spore percentages were calculated based on the total sum of pollen and spores.

2.3 Numerical Analysis

Cluster analysis (CA) was performed to classify pollen assemblages into zones using squared Euclidean distance and Ward' s method. Detrended correspondence analysis (DCA) was applied to assess the gradient length of pollen compositional change. Redundancy analysis (RDA) was used to examine relationships between pollen taxa and environmental variables including elevation, temperature, precipitation, and vegetation parameters. All numerical analyses were conducted using Canoco software.

3. Results

3.1 Pollen Assemblage Characteristics

A total of 14,062 pollen grains were identified across all samples, belonging to 56 pollen and spore taxa. The average pollen concentration was 5,917 grains/g. Dominant arboreal pollen included Picea (spruce), Pinus (pine), Betula (birch), and Ulmus (elm). Major herbaceous pollen types were Chenopodiaceae, Artemisia, Poaceae, Asteraceae, and Leguminosae. Spores were primarily from Polypodiaceae and Selaginella.

Three distinct pollen assemblage zones were identified through cluster analysis:

Zone I (Low elevation: 1042-1399 m): Chenopodiaceae and Ephedra dominated, with average pollen concentrations of 2,914 grains/g. Herbaceous pollen accounted for 76.1-90.4% (average 80.7%) of the assemblage. The A/C ratio (Artemisia/Chenopodiaceae) averaged 0.27, characteristic of steppe-desert vegetation.

Zone II (Mid-elevation: 1399-1769 m): Mixed assemblages with increased arboreal pollen. Total pollen concentration averaged 6,809 grains/g. Picea pollen reached 6.3-22.4% (average 15.6%), while herbaceous pollen remained abundant. The A/C ratio increased to 1.77, reflecting steppe vegetation.

Zone III (High elevation: 1769-2426 m): Picea and Betula pollen dominated, with concentrations reaching 23.4-48.4% (average 34.4%) and 21.6-34.0% (average 27.3%) respectively. Total pollen concentration averaged 6,255 grains/g. The A/C ratio decreased to 1.26, indicating forest vegetation with abundant Chenopodiaceae input from lower elevations.

3.2 DCA and RDA Results

DCA axis 1 exhibited a gradient length of 4.6 standard deviations, indicating unimodal response patterns suitable for constrained ordination. RDA results showed that axis 1 (eigenvalue = 0.283) and axis 2 (eigenvalue = 0.320) explained 66.4% and 94.2% of the cumulative variance in pollen-environment relationships, respectively.

Environmental variables significantly associated with pollen distribution included elevation ($p = 0.002$), precipitation ($p = 0.011$), and temperature ($p = 0.027$). Fern spores showed positive correlations with precipitation and elevation, while Leguminosae pollen correlated positively with temperature. Picea and Betula pollen were associated with high-elevation forest sites, whereas Chenopodiaceae and Ephedra were associated with low-elevation steppe-desert sites.

4. Discussion

4.1 Pollen Representation and Transport

The super-representative distribution of Chenopodiaceae and Ephedra pollen across all elevation zones indicates significant upslope transport. These taxa produce abundant, well-preserved pollen that can be transported long distances by wind. Their presence in high-elevation forest samples suggests that exogenous pollen can constitute a substantial portion of the pollen rain, potentially obscuring local vegetation signals.

In contrast, Betula and Leguminosae pollen showed strong relationships with local vegetation. Betula pollen percentages correlated well with birch grove distribution, and Leguminosae pollen matched Caragana bush occurrence. This suggests that these taxa have more limited dispersal ranges and better represent local vegetation.

4.2 Topographic Effects on Pollen Distribution

The RDA results demonstrate that topography significantly influences pollen distribution through its effects on microclimate and vegetation. At similar elevations, sunny and shady slopes supported different vegetation types, with forest and meadow zones alternating. This created mixed pollen signals, particularly for Picea and Betula, whose correlation with vegetation coverage decreased due to pollen exchange between zones.

The A/C ratio and total pollen concentration proved effective for distinguishing forest from steppe-desert zones. The ratio decreased from steppe-desert ($A/C = 0.27$) to steppe ($A/C = 1.77$) and forest zones ($A/C = 1.26$), reflecting changes in dominant vegetation types. However, the reversal in forest zones was due to high Chenopodiaceae input from lower elevations.

4.3 Implications for Paleoenvironmental Reconstruction

These results highlight the complexity of pollen-vegetation relationships in mountainous regions. The mixing of pollen from different vegetation zones through wind and water transport means that surface pollen assemblages represent integrated signals rather than purely local vegetation. This has important implications for quantitative vegetation reconstruction using modern analog techniques.

When using surface pollen data from mountain regions, researchers must: (1) conduct detailed vegetation surveys at sampling sites; (2) analyze sedimentary environment characteristics; (3) identify and potentially exclude exogenous pollen taxa; and (4) consider topographic effects on pollen transport and deposition. Failure to account for these factors may lead to overestimation of lowland vegetation in high-elevation samples and vice versa.

5. Conclusion

Surface pollen assemblages in Xarxili Nature Reserve show clear zonation corresponding to elevation and vegetation gradients. However, significant upslope transport of Chenopodiaceae and Ephedra pollen complicates the quantitative relationship between pollen and vegetation. Multivariate analyses effectively distinguish vegetation zones but also reveal mixing between zones due to topographic effects. These findings emphasize the need for careful evaluation of modern analogs in mountainous regions before application to paleoenvironmental reconstruction.

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