Postprint: Shrub-Grass Layer Community Characteristics and Their Relationship with Soil at Different Elevations in Jiangjiagou Watershed

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Abstract

To understand the relationship between species diversity of the shrub-herb layer and soil nutrients and moisture in plant communities along different elevation gradients in dry-hot valley regions, the Jiangjiagou watershed, a typical dry-hot valley watershed, was selected as the study area. Transects were established within the watershed covering an elevation range of 1,400–3,000 m, and quadrat surveys were conducted on plant communities at eight elevation gradients within the transects. Species composition of the shrub-herb layer at different elevation gradients was recorded, soil nutrients, soil water content, and water holding capacity were measured, and principal component analysis and Pearson correlation analysis were performed between soil indicators and vegetation diversity indices. The results showed that a total of 80 species belonging to 77 genera and 32 families were found in the shrub-herb layer of the sample plots within the watershed, and the composition of shrub-herb layer plant communities, soil organic carbon (SOC) content, total phosphorus (TP) content, soil water content, and water holding capacity were all significantly affected by elevation gradient ($P < 0.05$). Among them, soil water content, water holding capacity, plant community richness index, and diversity index all increased continuously with increasing elevation, and SOC content in high-elevation areas was significantly higher than that in medium- and low-elevation areas ($P < 0.05$). Soil TP content was significantly positively correlated with the Pielou index, and soil water content was significantly positively correlated with the Margalef index, Shannon-Wiener index, and number of species ($P < 0.05$), indicating that in addition to elevation gradient, soil nutrient and moisture content are also key factors influencing the composition and diversity of the shrub-herb layer in plant communities.

Full Text

Relationship between Shrub-Grass Layer Community Characteristics and Soil Properties at Different Altitudes in the Jiangjiagou Watershed

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Abstract: To understand the relationship between species diversity of shrub-grass layers and soil nutrients and moisture in plant communities across different elevation gradients in dry-hot valley regions, the Jiangjiagou watershed, a typical dry-hot valley watershed, was selected as the study area. Sample belts were established within the watershed at altitudes ranging from 1,400 to 3,000 m, and quadrat surveys were conducted on plant communities across eight elevation gradients. Species composition of shrub-grass layers at different altitudes was recorded, soil nutrients, water content, and water holding capacity were measured, and principal component analysis and Pearson correlation analysis were performed to examine relationships between soil indices and vegetation diversity indices. The results showed that a total of 80 species belonging to 77 genera and 32 families were identified in the shrub-grass layer across all sample plots. The composition of shrub-grass plant communities, soil organic carbon (SOC) content, total phosphorus (TP) content, soil water content, and water holding capacity were all significantly affected by elevation gradient ($P < 0.05$). Soil water content, water holding capacity, plant community richness index, and diversity index all increased with increasing altitude, and SOC content in high-altitude areas was significantly higher than in mid- and low-altitude areas ($P < 0.05$). Soil TP content showed a significant positive correlation with the Pielou index, while soil water content was significantly positively correlated with the Margalef index, Shannon-Wiener index, and species number ($P < 0.05$). These findings indicate that, in addition to elevation gradient, soil nutrient and moisture content are also key factors influencing the composition and diversity of shrub-grass layers in plant communities.

Keywords: Jiangjiagou, community characteristics, species diversity, soil nutrients, soil moisture

Species diversity characterizes vegetation growth status and represents a fundamental attribute of plant community features. It reflects not only the richness, dominance, evenness, and variation degree of species within a community but also the relationship between different habitat conditions and communities (Luo et al., 2018; Hooper & Vitousek, 1998). The elevation gradient is a comprehensive manifestation of multiple environmental factors including temperature, humidity, precipitation, and solar radiation (Liu et al., 2017). It can influence local precipitation by altering surrounding microclimate environmental elements, thereby affecting soil moisture indices, changing soil physicochemical properties and biological community composition, and playing a crucial role in determining the vertical distribution patterns of mountain species diversity (Liu et al., 2018; Li et al., 2014).

In recent years, numerous studies have examined the relationship between elevation gradients and plant communities. For example, Xiang et al. (2019), Zhang et al. (2019), and Su et al. (2018) investigated changes in shrub layer diversity of *Rhododendron latoucheae* communities in Jinggangshan, plant diversity of *Cryptomeria fortunei* plantations in Zhougong Mountain, and species diversity of scrub communities in Helan Mountain along elevation gradients, respectively. However, these studies primarily focused on subtropical humid monsoon climate zones and northwest arid regions, and due to the complexity of their patterns, failed to reach unified conclusions that could represent the plant community distribution patterns in the special microclimate zone of dry-hot valleys (He & Chen, 1997). Therefore, exploring the vertical distribution patterns of plant community species diversity in the Jiangjiagou watershed is important for enriching vegetation research in southwestern China.

The shrub-grass layer can alter understory microenvironments, affect forest regeneration, and reflect changes in forest species composition and distribution, playing a vital role in maintaining forest ecological stability, species diversity, and regional ecological conservation (Zhang et al., 2019; Su et al., 2018). As a primary factor of the plant environment, soil provides essential water and mineral elements for plant growth and directly influences plant community composition, distribution, and succession (Bai et al., 2000; Burke, 2001). Understanding the relationship between shrub-grass layer diversity and soil nutrients and moisture across different elevation gradients in the Jiangjiagou watershed not only reveals the distribution patterns of mountain plant communities and soils but also helps predict changes in plant communities along horizontal gradients at larger scales (Bagchi et al., 2014; Steinauer et al., 2015). This understanding provides an important basis for revealing mountain vegetation-environment feedback mechanisms and for restoring degraded mountain vegetation.

The Jiangjiagou watershed belongs to the high mountain-canyon region of northeastern Yunnan, with maximum and minimum elevations of 3,269 m and 1,042 m, respectively, and a relative height difference of 2,227 m. As a typical dry-hot valley watershed, it features diverse disaster types, frequent landslides and debris flows, severe vegetation destruction, and an extremely fragile ecosystem

(Lin, 2008). Due to topography, the watershed has distinct wet and dry seasons and obvious vertical climate zones, and is affected by foehn effects that create large climate differences across altitude zones (Wen et al., 2014). Rainfall varies significantly with altitude and is redistributed by different topographic conditions, causing differences in soil nutrient accumulation and distribution that affect vegetation distribution patterns. Therefore, based on quadrat survey data of shrub-grass layers and soil measurements across different elevation gradients in the Jiangjiagou watershed, this study analyzes the distribution patterns of shrub-grass layer species diversity and soil nutrient-moisture along altitudes and their correlations, aiming to understand the response mechanisms of shrub-grass layer distribution and structure to soil factors in different altitude plant communities in ecologically fragile areas, and to provide data support for ecological environment quality evaluation and mountain vegetation restoration and reconstruction in typical dry-hot valley watersheds.

1.1 Study Area Overview

Jiangjiagou is located in Dongchuan District, Kunming City, Yunnan Province, with geographic coordinates of 103°06 -103°13 E, 26°13 -26°17 N and a watershed area of 48.52 km². The Jiangjiagou watershed belongs to the high mountain-canyon region of northeastern Yunnan, characterized by steep mountains and significant relative elevation, with terrain sloping from high in the east to low in the west. The gully flows from east to west through Lümiao Township in Dongchuan District before joining the Xiaojiang River (Lin, 2008). Constrained by topographic conditions, the watershed exhibits distinct wet and dry seasons and obvious vertical climate zones. The rainy season extends from May to October, accounting for over 80% of the annual precipitation. Annual precipitation increases with altitude, while annual evaporation decreases with altitude. The vertical differentiation of precipitation and temperature creates significant differences in vegetation and rock weathering degree across different altitude zones in the watershed (Wen et al., 2014). Due to long-term human disturbance, the original forest vegetation has been replaced by plantations with relatively simple arbor species composition. High-altitude areas are dominated by Yunnan pine (*Pinus yunnanensis*), while low-altitude areas feature *Leucaena leucocephala*, *Acacia confusa*, *Eucalyptus robusta*, and some economic tree species.

1.2 Sample Plot Setup and Investigation

The investigation was conducted from July to August 2018. Sample belts were established across an altitude range of 1,400–3,000 m in the Jiangjiagou watershed, with 200 m elevation intervals creating eight altitude gradients. Within each altitude gradient, six 5 m × 5 m shrub quadrats were established, with one 1 m × 1 m herb quadrat placed in the center of each shrub quadrat, resulting in a total of 48 shrub quadrats and 48 herb quadrats. The investigation included: (1) Community characteristics: recording plant species names, quantities, heights,

coverage, and growth status for each shrub and herb quadrat. (2) Geographic location: using handheld GPS to determine latitude, longitude, and elevation of each quadrat, and a geological compass to measure slope and aspect. (3) Soil sampling: after five consecutive sunny days in each gradient zone, surface litter was removed from five points (four corners and the center) within each shrub quadrat, and 0–20 cm surface soil samples were collected and mixed to form one composite sample per quadrat, placed in ziplock bags. Undisturbed soil cores were collected using cutting rings (100 cm^3), and additional soil samples were placed in aluminum boxes for laboratory analysis. A total of 48 soil samples were collected across the eight altitude gradients in the study area. Soil analysis indicators included soil organic carbon (SOC), soil total nitrogen (TN), soil total phosphorus (TP), soil water content (SWC), soil maximum water holding capacity (WHC), and field moisture capacity (FMC).

1.3 Sample Processing and Analysis

Soil WHC and FMC were determined using the cutting ring method (LY/T 1215-1999). Aluminum box samples were oven-dried to constant weight in the laboratory, cooled, and weighed to calculate dry soil mass for SWC determination. After passing through a 0.149 mm sieve, SOC was measured using the potassium dichromate external heating method (LY/T 1237-1999), TN by the Kjeldahl method (LY/T 1228-1999), and TP by the alkali fusion-molybdenum antimony colorimetric method (LY/T 1232-1999). All samples were analyzed in triplicate, with mean values used as final results.

1.4 Data Processing and Analysis

(1) Due to the relatively simple composition and sparse distribution of arbor species in the Jiangjiagou watershed, this analysis focused solely on the important values of shrub-grass layer plants, calculated as follows (Zhang, 2004):

Relative important value (IV) of shrubs and herbs = (relative coverage + relative abundance + relative height) / 3. (1)

(2) This study selected four indices to analyze diversity characteristics of vegetation communities across 48 sample plots at different altitude gradients: Margalef index (R), Simpson index (D), Shannon-Wiener index (H), and Pielou index (E). Specific calculation formulas were as follows (Luo et al., 2018):

Simpson diversity index:

$$D = 1 - \sum_{i=1}^{S} P_i^2$$

Shannon-Wiener diversity index:

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

Pielou evenness index:

$$E = \frac{H}{\ln S}$$

Where: S is the total number of species in the quadrat; N is the total number of individuals of all species in the quadrat; and P_i is the proportion of species i, i.e., the relative important value of the ith species.

Data processing was performed using Excel 2016 and SPSS 20.0. One-way ANOVA was used for difference testing, with $P < 0.05$ as the significance level. Pearson correlation analysis was employed to examine relationships between vegetation characteristic indices and soil physicochemical properties.

2.1 Important Values of Shrub-Grass Layer at Different Altitudes

The survey results indicated that the shrub-grass layer in the watershed comprised 80 species belonging to 77 genera and 32 families. The five species with highest important values (dominant species) in the shrub-grass layer across different altitude gradients are presented in Table 1 . A clear succession of dominant species was observed with decreasing altitude. *Origanum vulgare*, *Anemone cathayensis*, and *Potentilla fallens*, which prefer warm and humid climates, showed strong competitiveness in high-altitude plant communities and had the highest important values in zones A–C. *Digitaria sanguinalis* ranked among the top five important values in zones A–C and E, indicating good adaptation to mid- and high-altitude environments and representing a widely distributed mesophyte with a broad ecological amplitude. *Coriaria sinica*, *Artemisia argyi*, and *Siegesbeckia orientalis* were primarily distributed in mid- and low-altitude zones D–F. Notably, *A. argyi* reproduces easily and shows strong adaptability to various climates and soils, maintaining high important values across zones D–G. Both *Leucaena leucocephala* and *Elymus dahuricus* possess strong drought resistance and adapted well

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