DIVERSITY CHANGES AND PHYLOGENETIC STRUCTURE OF WOODY PLANTS IN DIFFERENT VERTICAL ZONES OF THE SYGERA MOUNTAINS

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Abstract. This study examines the woody plant community in the Sygera Mountains to reveal the diversity changes and phylogenetic structure of woody plants in different vertical zones. Three plots of 400 m^2 and two plots of 900 m^2 are set up in each zone. The line transect method is used to supplement the woody plant species list. Meteorological data are adopted to analyze the composition of woody plant flora, the characteristics of the phylogenetic structure, and their relationship with annual average temperature. Results showed that (1) temperate woody plants account for a large proportion (65.6%) in the woody plant community of the Sygera Mountains, and widespread woody genera account for a small proportion (12.6%). The composition of families and genera is rich in the mountainous warm temperate zone, and the species composition is rich in the mountainous temperate zone. (2) The Gleason index and phylogenetic diversity of the woody plant communities in the five vertical zones are significantly positively correlated with the annual average temperature ($P < 0.01$), whereas the net relatedness and nearest taxon indices are not correlated with the annual average temperature. (3) The woody plant communities in the alpine frigid and alpine desert zones of the Sygera Mountains exhibit phylogenetic clustering, which suggests that habitat filtering plays an important role in the construction of woody plant communities in these vertical zones. However, the other vertical zones show either phylogenetic clustering or phylogenetic overdispersion, indicating that the results might be the combined effects of habitat filtering and competitive exclusion. This study provides new insights into the diversity composition and construction mechanisms of woody plant communities in the Sygera Mountains.
Keywords: *woody plant diversity, flora, phylogenetic structure, vertical zones, Sygera Mountains*

Introduction

Mountains serve as cradles and sanctuaries for species and provide an ideal natural laboratory to study the response of biotic and abiotic factors to varying altitudinal gradients (Devadoss et al., 2020; Tito et al., 2020). They nurture an exceptionally diverse plant life and play a crucial role in shaping global and regional climates (Yu et al., 2021; Perrigo et al., 2020). The mechanisms responsible for the formation and maintenance of biodiversity in mountainous areas and the factors that affect species diversity are currently receiving considerable attention (Vellend, 2016; Leibold et al., 2018; Zhang et al., 2003, 2022; Wang et al., 2022; Janzen et al., 1967; Mi et al., 2021). Mountainous regions, with their relatively intact altitudinal gradients, encompass a comprehensive range of environmental factors that collectively reflect the variations in temperature, precipitation, soil, and light intensity in response to elevation changes (Austin et al., 1996; Stegen et al., 2009). These factors influence the composition and phylogenetic structure of woody plant communities (Zeng et al., 2018). Luo et al. (2023) conducted a research on the phylogenetic community structure and composition of woody plants in the southern Taihang Mountains and revealed that the assembly of woody plant communities is primarily influenced by neutral processes and habitat filtering. Du et al. (2022) studied the plant diversity and phylogenetic structure in the eastern region of the Kunlun Mountains and reported that this area should be a focal point for biodiversity conservation. Habitat filtering plays a crucial role in this ecological process. The study conducted by Lu et al. (2014) on the subtropical forests of Ailaoshan Mountain in Yunnan showed that the phylogenetic structure of forest communities in Ailaoshan Mountain becomes increasingly divergent or decreasingly clustered as the elevation increases along the altitudinal gradient. Although the findings of studies in different regions differ, these studies provide reliable evidence on the influence of environmental factors on species formation and the phylogenetic structure of communities (Webb et al., 2002; Jetz et al., 2012).

The Sygera Mountains, located in the southeastern part of the Qinghai–Tibet Plateau, is an integral component of the eastern Himalayas. It is recognized as one of the 25 biodiversity hotspots worldwide and serves as a typical representative area of forest and alpine ecosystems in the northern slopes of the eastern Himalayas (Myers et al., 2000). The mountainous terrain of the Sygera Mountains is characterized by a unique, complex topography that involves a network of intersecting mountain ranges. The convergence of the Indian Ocean monsoon warm and humid airflow with the cold airflow from the northern plateau creates a relatively unique humid to semihumid climate in this region (You et al., 2013). The Sygera Mountains exhibit a vertical zonation of vegetation from low to high altitudes due to the uplift of the plateau and changes in elevation. This zonation includes the warm temperate to moist coniferous and broad-leaved mixed forest zone; the temperate to cool and moist coniferous forest zone; the subalpine cold temperate zone characterized by cold, moist, and dark coniferous forests; the alpine subarctic zone with sparse forests, shrubs, and meadows; and the high mountain desert zone. This vertical zonation forms a spectrum of seed plant assemblages known as the floristic belt of the Sygera Mountains (*Fig. 1*; Chai et al., 2004). The development of a relatively intact native mountainous vertical ecosystem that is based primarily on the subtropical zone has fostered an exceptionally high abundance of plant resources (Luo et al., 2006; Zhou et al., 2013; Lan et al., 2018; Wang et al., 2018; Zhang et al., 2018). The mountainous ecosystems in the Qinghai–Tibet Plateau, with the Sygera Mountains as a representative example, serve as ideal laboratories for studying the response of biotic and abiotic factors to changes in altitudinal gradients (Gao et al., 2020). These ecosystems integrate multiple environmental and topographic factors within a limited spatial range, resulting in a highly heterogeneous habitat (Devadoss et al., 2020; Tito et al., 2020). Temperature is the most influential among these factors, and it affects

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mountainous plant species (Körner et al., 2012). By studying the diversity of woody plant species and their phylogenetic diversity in relation to temperature factors, we can obtain insights into the composition and characteristics of woody plants in this mountainous ecosystem and understand the distribution patterns of the vertical zonation of woody plants. This research can help uncover the relationship between the evolution and development of woody plants in this region and temperature. Through field surveys and analyses of relevant literature, this study aims to address two scientific issues: (1) the variation characteristics of woody plant diversity and the distribution patterns of the vertical zonation of woody plant assemblages along the altitudinal gradient in the Sygera Mountains and (2) the differences in woody plant richness and phylogenetic diversity in different vertical zones and their relationship with the mean annual temperature of each zone. This study aims to examine the main mechanisms and ecological processes involved in the formation of woody plant communities in the Sygera Mountains.

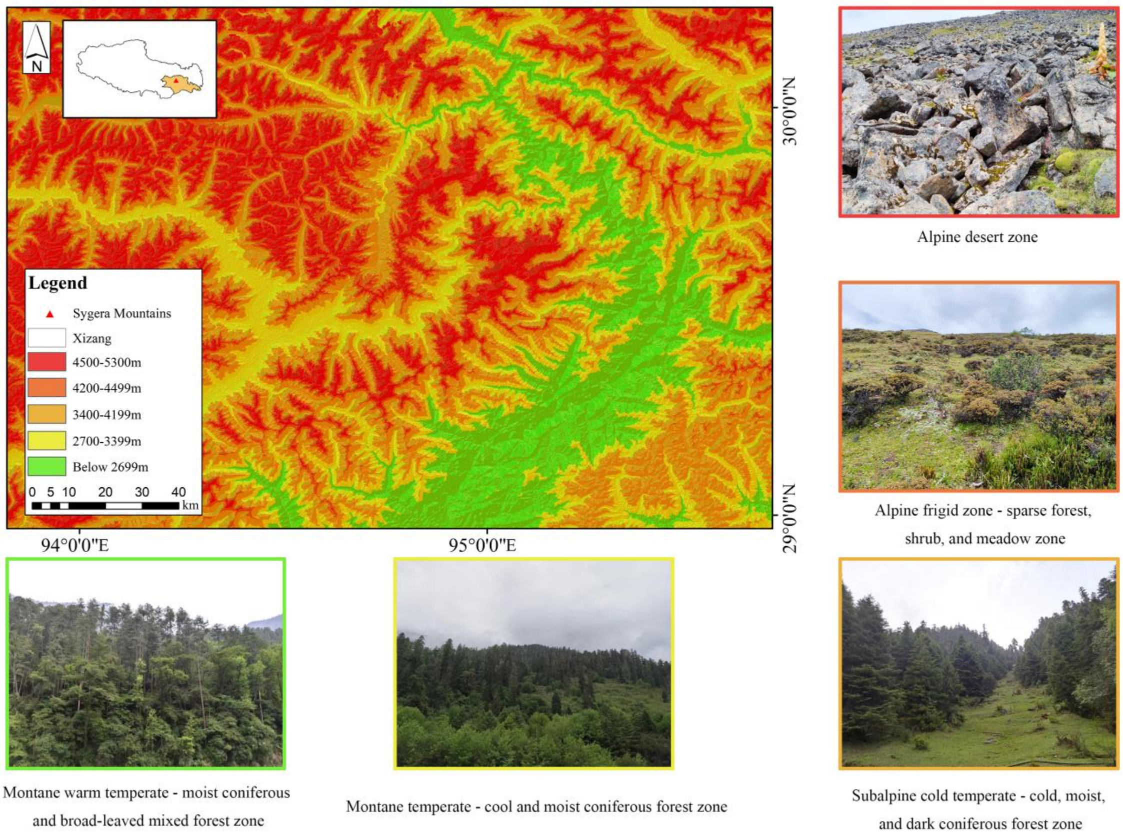

Figure 1. *Geographical location of the Sygera Mountains and vertical zonation of its different seed plant flora and natural landscape*

Materials and methods

Data sources and compilation

In August 2021, a systematic sampling method was employed to establish five plots (three plots of 400 m^2 and two plots of 900 m^2) in each vertical zone, resulting in a total of 25 plots. Information on each plot, such as the names of woody plant species, tree height, and diameter at breast height, was recorded. Additionally, supplementary

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surveys were conducted multiple times between September 2021 and June 2023 by using a transect method to further investigate the woody plants in the Sygera Mountains. Data were compiled by cross-referencing information from various sources, including Flora of Tibet (Wu, 1983–1987), Flora of China (Hong et al., 2015), the online database of Flora of China (http://www.eflora.cn/), and newly published literature on woody plants in the research area, to ensure the completeness of woody plant species in the study area. Latin names were verified and corrected, and the compiled woody plant species were classified in accordance with their families and genera.

The geographical composition of woody plants and the distribution area types of their families and genera were determined based on the System of Area Types for the Distribution of Seed Plant Families (Wu et al., 2003a), Distribution Area Types of Seed Plant Genera in China (Wu et al., 1991), and Comprehensive Treatise on Families and Genera of Chinese Angiosperms (Wu et al., 2003b). The woody plant checklist was then divided based on the altitudinal zonation of seed plants in the Sygera Mountains (*Fig. 1; Table 1*), and a statistical analysis was conducted based on this classification (Chai et al., 2004).

The meteorological data were primarily from the long-term monitoring of different vertical zones. The observational data used in this study spanned the period January–December 2021 (Chen et al., 2023).

Analytical methods

The Gleason index (1926) was used to measure species diversity (Hurlbert et al., 1971). The formula for the index is as follows (*Eq. 1*):

$$R = \frac{S}{\ln A} \qquad \text{(Eq.1)}$$

where A represents the area of the study region (m^2) and S represents the number of woody plant species in A.

A phylogenetic tree was constructed by processing the species' taxonomic information by using the U. Taxonstand package in R language (Zhang et al., 2023). The topology of the phylogenetic tree was built using R language (Jin et al., 2022; Swenson et al., 2007; Wickham et al., 2023) on the basis of the Angiosperm Phylogeny Group III classification system for flowering plants (Angiosperm et al., 2009). The resulting phylogenetic tree was imported into MEGA 11.0 for visualization (*Fig. 2*). The branch structure was fitted in R software to obtain the phylogenetic tree. The phylogenetic diversity index (PD) was calculated for each sample to analyze the position of species in the evolutionary tree and compute the phylogenetic distance between species. Assuming a random species distribution, we standardized the phylogenetic distance by using a random model to obtain the community phylogenetic structure indices, namely, net relatedness index (NRI, *Eq. 2*) (Webb et al., 2002) and nearest taxon index (NTI, *Eq. 3*) (Swenson et al., 2006). The formulas for calculating the community phylogenetic structure indices are as follows:

$$NRI_{sample} = -1 \times \frac{MPD_{sample} - MPD_{randsample}}{SD(MPD_{randsample})} \qquad \text{(Eq.2)}$$

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$$NTI_{sample} = -1 \times \frac{MNTD_{sample} - MNTD_{randsample}}{SD(MNTD_{randsample})} \quad \text{(Eq.3)}$$

where NRI_{sample} and NTI_{sample} represent the community phylogenetic structure indices for the sample plot; MPD_{sample} and $MNTD_{sample}$ denote the observed values of mean phylogenetic distance and mean nearest taxon distance, respectively; and $MPD_{rndsample}$ and $MNTD_{rndsample}$ are the average values of mean phylogenetic distance and mean nearest taxon distance obtained through software random simulations, respectively. A t-test was performed to determine if statistically significant differences in phylogenetic structure existed among the five vertical zones. The statistical analysis was conducted using Excel 2021, SPSS 27, Origin 2022, MEGA 11.0, and R language 4.2.3.

Results

Composition of woody plant flora in the Sygera Mountains

A total of 326 species of woody plants were recorded in the survey of the Sygera Mountains (*Fig. 2*). According to the classification system of Flora of China, these species belong to 55 families and 114 genera. Among them, 21 species are from 2 families of gymnosperms, and 307 species are from 53 families of angiosperms.

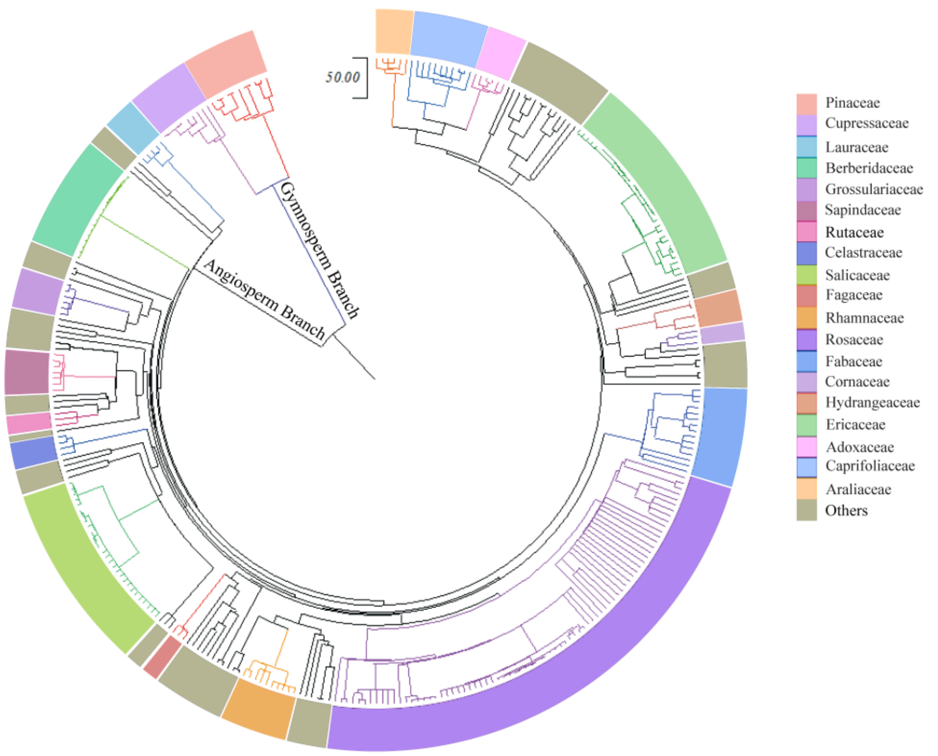

Figure 2. *Phylogenetic tree of woody plants in the Szechuan–Tibet Plateau*

Among the families, Rosaceae has the largest proportion and accounts for 23.6% (77 species) of the total number of woody plants in the region. Following Rosaceae, Ericaceae, Salicaceae, Berberidaceae, and Fabaceae account for 10.1% (33 species),

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8.5% (28 species), 5.2% (17 species), and 4.6% (15 species) of the total woody plant species, respectively. These five families together make up 52% of the total woody plant species in the Sygera Mountains, and they are an important component of the woody plant flora in the region. Forty-two woody species are from families, such as Caprifoliaceae, Pinaceae, Cupressaceae, and Rhamnaceae, each having not fewer than 10 species; they account for 13.0% of the total woody plant species in the area. Eight families, including Sapindaceae, Grossulariaceae, and Adoxaceae, each having not fewer than 5 species, account for 14.1% (46 species) of the total woody plant species. The remaining 38 families account for 20.9% (68 species) of the total woody plant species. Among them, 20 families, such as Smilacaceae, Primulaceae, and Cannabaceae, have only one species.

Plant genera provide an accurate reflection of the evolutionary process and diversity characteristics of plants (Ci et al., 2017). The 114 genera of woody plants in the area were classified into five types based on the number of species they contain (Shang et al., 2024): single-species genera (1 species), small genera (2-5 species), medium-sized genera (6-9 species), large genera (10-14 species), and very large genera (≥15 species) (*Table 1*). Among the woody plants in the area, four genera are very large and have a total of 79 species, namely, *Salix* (23 species), *Rhododendron* (21 species), and *Rubus* (19 species). These genera account for 3.5% of the total number of genera and 24.2% of the total number of species. Furthermore, two genera are classified as large and have 24 species, namely, *Cotoneaster* (14 species) and *Sorbus* (10 species); these genera account for 1.8% of the total number of genera and 7.4% of the total number of species. Seven genera are medium sized and have 52 species, namely, *Lonicera* (9 species), *Spiraea* (9 species), *Prunus* (8 species), *Acer* (8 species), *Ribes* (6 species), *Rosa* (6 species), and *Viburnum* (6 species). These genera account for 6.1% of the total number of genera and 16% of the total number of species. The small genera, which consist of 40 genera and 110 species, have the largest proportion among the different categories. They account for 35.1% of the total number of genera and 33.7% of the total number of species. They are second only to the monotypic genera in terms of the proportion of genera. Sixty-one genera are monotypic and account for 53.5% of the total number of genera and 18.7% of the total number of species.

Table 1. *Composition of woody plant genera in the Sygera Mountains*

Number of species within a genus	Number of genera	Percentage of the total number of genera	Number of species	Percentage of the total number of species
≥15	4	3.51%	79	24.23%
10–14	2	1.75%	24	7.36%
6–9	7	6.14%	52	15.95%
2–5	40	35.09%	110	33.74%
1	61	53.51%	61	18.71%
Total	114	100.00%	326	100.00%

The statistical analysis of genera showed that 88.6% of the plant species in the study area are concentrated in small and monotypic genera, making them the dominant components of the woody plant composition in the area. Monotypic genera form the backbone of the woody plant genera in the area, and the plant species encompassed by small genera constitute the majority of the woody plant species in the area.

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Dominant woody families in different altitudinal zones

The Sygera Mountains, a warm–temperate zone, has a total of 53 families, 99 genera, and 236 species of woody plants. The dominant families with no fewer than 10 species are Rosaceae, Ericaceae, Berberidaceae, Fabaceae, and Rhamnaceae. The mountain temperate zone has a total of 46 families, 89 genera, and 249 species of woody plants. The dominant families with no fewer than 10 species are Rosaceae, Ericaceae, Salicaceae, Berberidaceae, Pinaceae, Fabaceae, and Rhamnaceae. The subalpine cold–temperate zone has a total of 33 families, 59 genera, and 166 species of woody plants. The dominant families with no fewer than 10 species are Rosaceae, Ericaceae, and Salicaceae. The alpine cold zone has a total of 16 families, 24 genera, and 47 species of woody plants. Only two families, namely, Salicaceae and Ericaceae, have no fewer than 10 species. The high alpine cold zone has 10 families, 12 genera, and 22 species of woody plants, but none of them has more than 10 species (*Fig. 3*).

The warm–temperate zone of the Sygera Mountains has several woody plant families that are exclusively present, and these include Juglandaceae, Cannabaceae, Iteaceae, Simaroubaceae, Phyllanthaceae, Aquifoliaceae, and Actinidiaceae. The mountain temperate zone has one woody plant family that is exclusively present, namely, Meliaceae.

At the family level, the warm–temperate zone of the Sygera Mountains has 12 families with a worldwide distribution, 18 families with a tropical distribution, 19 families with a temperate distribution, and 4 families with an Asian distribution. The mountain temperate zone has 12 families with a worldwide distribution, 15 families with a tropical distribution, 17 families with a temperate distribution, and 2 families with an Asian distribution. The subalpine cold–temperate zone has 8 families with a worldwide distribution, 8 families with a tropical distribution, and 17 families with a temperate distribution. The alpine cold zone has 3 families with a worldwide distribution, 2 families with a tropical distribution, and 11 families with a temperate distribution. The high mountain desert zone has 2 families with a worldwide distribution, 2 families with a tropical distribution, and 6 families with a temperate distribution.

Dominant woody genera in different altitudinal zones

According to *Figure 4*, as the altitude increases, the number of woody genera in each altitudinal zone decreases. Among the zones, the warm–temperate zone has the largest number of genera (99), and the high mountain desert zone has the smallest number of genera (12). In the warm–temperate zone, 23 genera, such as *Ilex*, *Meliosma*, and *Parthenocissus*, are exclusively distributed. In the mountain temperate zone, only one genus, namely, *Morus*, is exclusively distributed. In the subalpine cold–temperate zone, two genera, *Diplarche* and *Chelonopsis*, are exclusively distributed.

At the genus level, the temperate component (T8) of woody plants in the Sygera Mountains has a much larger proportion in each altitudinal zone compared with other floristic types. The proportion of the temperate component gradually increases as the vegetation belt altitude increases, and only a slight decrease is observed in the high mountain desert zone. Meanwhile, the proportion of the tropical component shows a gradual decrease, and a slight increase is observed only in the high mountain desert zone.

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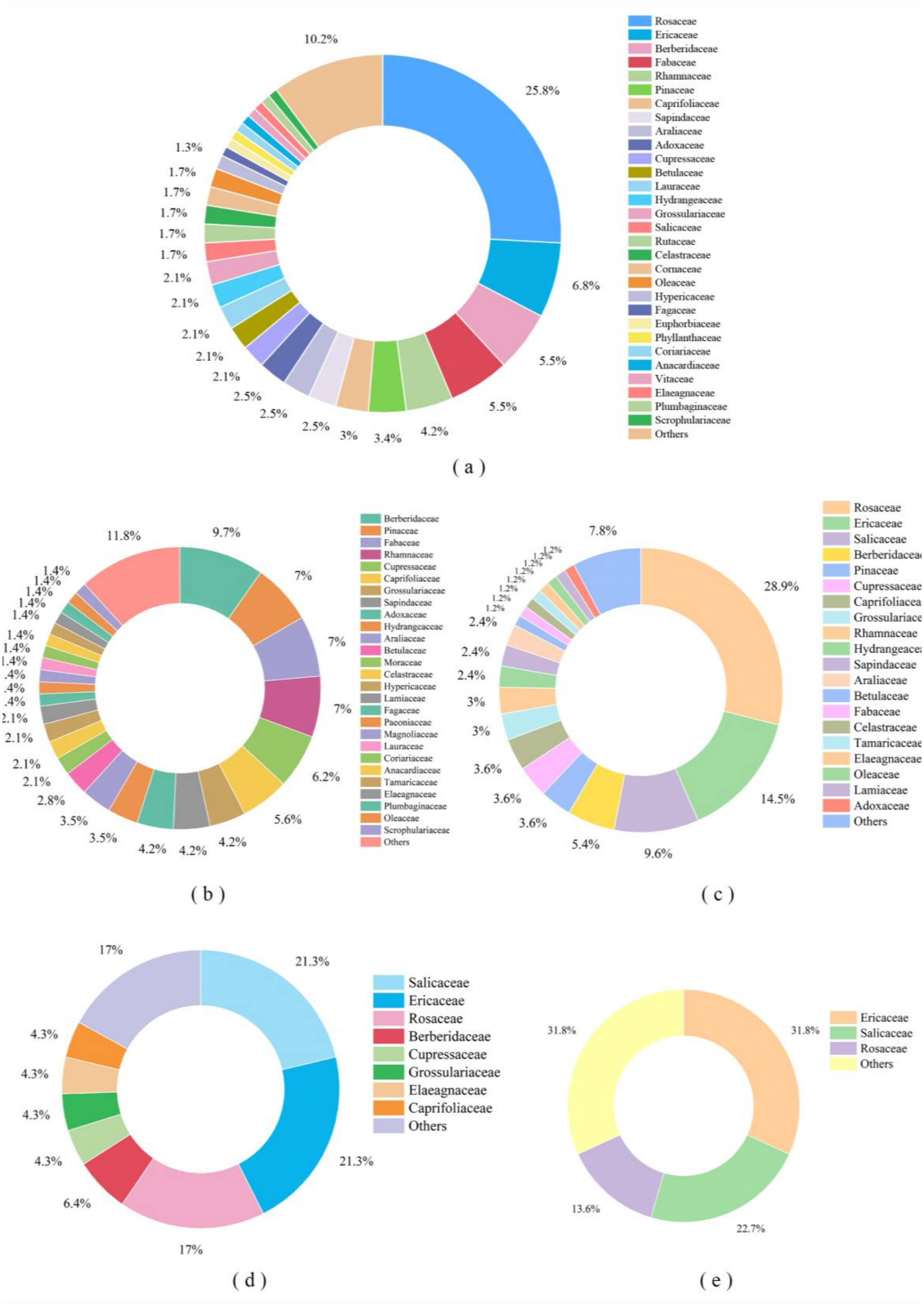

Figure 3. *Composition of woody plant families across different vertical zones. (a) Montane warm temperate – moist coniferous and broad – leaved mixed forest zone; (b) Montane temperate – cool and moist coniferous forest zone; (c) Subalpine cold temperate – cold, moist, and dark coniferous forest zone; (d) Alpine frigid zone – sparse forest, shrub, and meadow zone; (e) Alpine desert zone*

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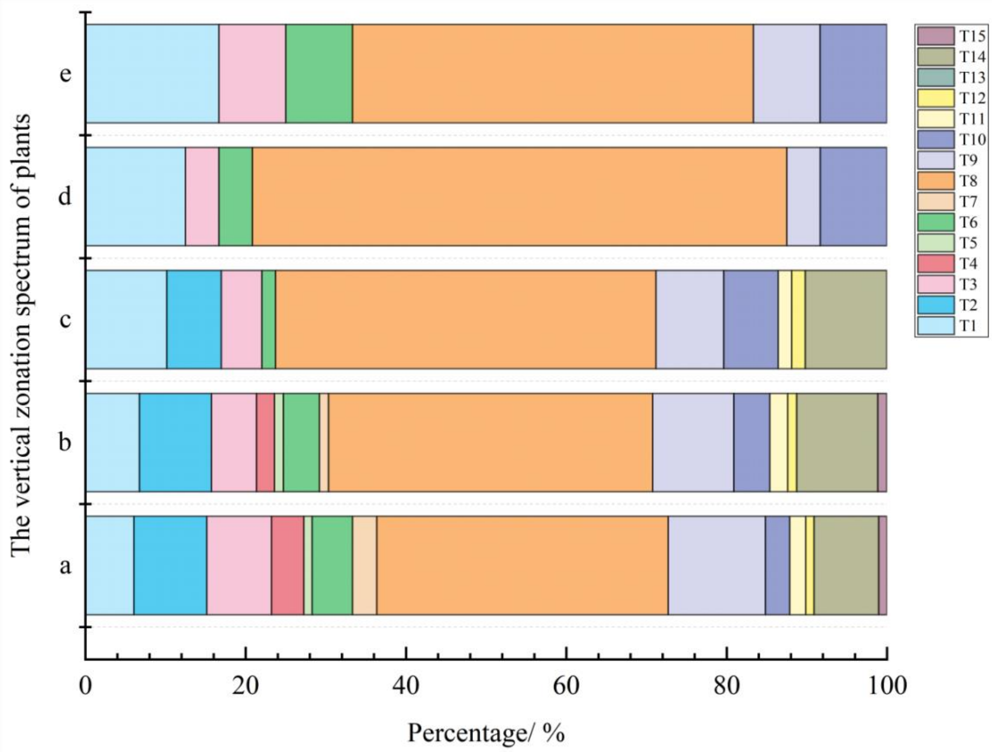

Figure 4. *Comparison of the distribution types and proportions of woody plant genera in different vertical zones. (1) T1: Widespread; T2: Pantropic; T3: Trop. & Subtr. E. Asia & (S.) Trop. Amer. Disjuncted; T4: Old World Tropics; T5: Trop. Asia to Trop. Australasia Oceania; T6: Trop. Asia to Trop. Africa; T7: Trop. Asia = Trop. SE. Asia + Indo-Malaya + Trop. S. & SW. Pacific Isl; T8: N. Temp; T9: E. Asia & N. Amer. Disjuncted; T10: Old World Temp; T11: Temp. Asia; T12: Medit., W. to C. Asia; T13: C. Asia; T14: E. Asia; T15: Endemic to China. (2) (a) Montane warm temperate – moist coniferous and broad-leaved mixed forest zone; (b) Montane temperate – cool and moist coniferous forest zone; (c) Subalpine cold temperate – cold, moist, and dark coniferous forest zone; (d) Alpine frigid zone – sparse forest, shrub, and meadow zone; (e) Alpine desert zone*

The proportion of the worldwide distributed component (T1) presents a unimodal increasing trend with increasing altitude and reaches its peak of 16.67% in the high mountain desert zone. The China-specific component (T15) has the smallest proportion among all the components, and its proportion fluctuates within the range of 1.00%–1.50%.

Differences in species richness and phylogenetic diversity of woody plants exist across different altitudinal zones

A highly significant positive correlation ($P < 0.01$) exists between the species richness and phylogenetic diversity (PD) of the woody plants in the different altitudinal zones of the Sygera Mountains. The Gleason index and PD of the woody plant communities in the five altitudinal zones also show a highly significant positive correlation ($P < 0.01$) with the mean annual temperature. However, NTI and NRI are not correlated with the mean annual temperature.

According to NRI, the montane temperate and subalpine cold–temperate zones exhibit phylogenetic divergence (NRI < 0), and the montane warm–temperate, alpine

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cold, and alpine desert zones of the woody plants show phylogenetic clustering (NRI > 0). With regard to NTI, the montane warm–temperate zone demonstrates phylogenetic divergence, whereas the four other vertical zones exhibit clustering. However, the NRI and NTI of the woody plants in the alpine cold and alpine desert zones are consistent, indicating phylogenetic clustering.

Discussion

Analysis of woody plant composition in different vertical zones

The main characteristics of the woody plant community in the Sygera Mountains are the dominance of temperate woody plants, which account for 65.6% (*Fig. 4*), and the small proportion (12.6%) of widely distributed woody genera. The taxonomic composition of woody plants is highly diverse in the montane warm–temperate zone, and the species composition is highly diverse in the montane temperate zone. This result differs from the findings of Chai Yong's study in 2004, which showed that the montane temperate zone has the largest number of genera in the Sajila seed plant flora (Chai et al., 2004). The study area is located in an area where the warm and humid Indian Ocean monsoon and the cold air mass from the northern plateau converge (You et al., 2013), resulting in abundant moisture. However, a remarkable temperature variation exists along the elevation gradient, leading to the formation of distinct vertical zones of woody plants as the elevation increases and the temperature decreases.

In terms of woody genera that are exclusively found in a single vertical zone, among all the zones, the montane warm–temperate zone has the largest number of genera, namely, 23, which account for 88.5% of the woody genera that appear exclusively in one zone. Compared with other vertical zones, this zone experiences less environmental stress and provides more favorable growth conditions, leading to higher levels of species diversity (Liang et al., 2010; Gu et al., 2022). As a result, certain tropical woody genera that cannot adapt to low temperatures, intense ultraviolet radiation, and harsh soil conditions can thrive only in this particular habitat (Amin et al., 2023; Hollósy et al., 2002; Fu et al., 2023).

In the alpine cold and alpine desert zones of the Sygera Mountains, the average annual temperature remains below 0 C and exhibits a highly pronounced temperature decrease. The composition of woody plants in these zones is uniform, characterized by stunted growth, and dominated by shrubs. The region is covered with ice and snow throughout the year, resulting in reduced efficiency of photosynthesis. The transportation of water in tall woody plants is hindered, thus inhibiting horizontal and vertical growth and the diversity of woody plant distribution in this habitat (Ding et al., 2023). As a result, the number of woody genera and species considerably decreases in the alpine cold and alpine desert zones.

Process of community assembly and variations in driving factors across different vertical zones of woody plant communities

As the elevation increases along the gradient of the Sygera Mountains, the phylogenetic structure of the woody plant communities shows a decreasing trend in the degree of phylogenetic clustering or dispersion, indicating a nonrandom pattern. This finding suggests that neutral theory, which predicts a random phylogenetic structure in communities, is inapplicable to the region of the Sygera Mountains. Instead, the

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ecological processes related to niche play an important role in shaping and maintaining the composition of woody plant communities in this area. In ecological niche theory, habitat filtering and competitive exclusion are opposing processes. Habitat filtering leads to a clustered phylogenetic structure among species, whereas competitive exclusion prevents closely related species from coexisting, resulting in a dispersed phylogenetic structure (Niu et al., 2011). The woody plant communities in the alpine cold and alpine desert zones of the Sygera Mountains exhibit a phylogenetic clustering pattern, indicating that habitat filtering plays a dominant role in these vertical zones. This phylogenetic clustering pattern may be attributed to the low temperatures and year-round ice and snow cover in the alpine cold and alpine desert zones that make the growth of woody plants challenging. Consequently, these zones are predominantly occupied by small-statured plants. The reduced heterogeneity in the terrain and habitat promotes the coexistence of taxonomic groups with similar evolutionary histories (Chen et al., 2023; Mo et al., 2013; Dinnage et al., 2009). The low- and mid-altitude regions exhibit a mixed pattern of phylogenetic clustering and dispersion. These areas are generally characterized by mature forests at the late stages of succession (Ding et al., 2023). Intense competition among populations leads to the segregation of ecologically similar species. Additionally, the habitat heterogeneity in the mid- and low-altitude regions is complex (Liu et al., 2016), resulting in a shift in resource utilization strategies from diversification (Chen et al., 2023). This shift leads to the alternating occurrence and interaction of habitat filtering and competitive exclusion, which contribute to the diversification of the phylogenetic structure.

The community phylogenetic indices, NRI and NTI, reveal contrasting phylogenetic structures of woody plants in the low-altitude regions (temperate–warm, mountain temperate, and subalpine cold zones). In the mountain warm–temperate zone, NRI indicates a phylogenetic clustering pattern, whereas in the mountain temperate and subalpine cold zones, it shows a phylogenetic dispersion pattern. NTI reveals a phylogenetic dispersion pattern in the mountain warm–temperate zone, whereas in the mountain temperate and subalpine cold zones, it exhibits a phylogenetic clustering pattern. NRI reflects the overall phylogenetic pattern across the entire phylogenetic tree, whereas NTI is based only on the nearest phylogenetic relationships, focusing on the terminal branches of the phylogenetic tree. Both indices are interrelated but provide different measures of the phylogenetic structure (Kraft et al., 2007). Inconsistencies between NRI and NTI have also been observed in other studies. For example, Kress et al. (2009) studied the phylogenetic structure of forest systems in different habitats on Barro Colorado Island and found that within the same habitat, NRI is greater than zero, whereas NTI is less than zero. Li et al. (2017) investigated the phylogenetic pattern structure of the Hengduan Mountains and found that latitude is closely related to NRI, and longitude is closely related to NTI.

Conclusion

Research has found that due to temperature constraints, the middle to low vertical zones of the Sygera Mountains exhibit high woody plant diversity, with temperate components accounting for a considerable proportion. The construction of the woody plant community phylogenetic structure shows a pattern of decreasing phylogenetic clustering or dispersion with increasing elevation in the Sygera Mountains. This result suggests that ecological niche processes play an important role in community assembly

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in the mountain ecosystems of the Sygera Mountains. Habitat filtering has a dominant role in the assembly of high-altitude communities, but both habitat filtering and competitive exclusion contribute to the assembly of woody plant communities in the mid- and low-altitude regions. This study provides new insights into the diversity composition and assembly mechanisms of woody plants in the typical mountain vertical zones of the southeastern Tibetan Plateau.

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Conflict of interests. The authors declare that they have no conflict of interests.

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