Postprint: Species Composition and Structural Characteristics of Montane Evergreen Broad-Leaved Forest Communities in Shiwandashan

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Abstract

Shiwandashan is one of the biodiversity hotspots in Guangxi, with montane evergreen broad-leaved forest as its main vegetation type. To understand the current status of communities and the development of dominant population structures of montane evergreen broad-leaved forests in the region, this study analyzed the species composition, diameter class structure, tree height structure, and used the g(r) function to analyze the spatial distribution patterns of dominant species in a 1 hm^2 permanent monitoring plot of montane evergreen broad-leaved forest in Shiwandashan, focusing on woody plants with DBH $\geq$ 1 cm. The results showed that: (1) There were a total of 7,517 woody plants with DBH $\geq$ 1 cm in the community, belonging to 153 species, 108 genera, and 52 families; the dominant species in the community included Clethra delavayi, Schima argentea, Hartia villosa, Castanopsis hystrix, Engelhardtia roxburghiana, Ardisia quinquegona, Itea chinensis, Symplocos adenophylla, Eurya subintegra, and Ilex pubescens, but the dominant status of these dominant species was not pronounced. (2) The overall average DBH of the community was 5.51 cm, with diameter class and tree height distributions showing approximately inverse "J"-shaped patterns; the diameter class distributions of dominant species mostly exhibited inverse "J"-shaped or "L"-shaped patterns, indicating strong regeneration capacity in the community. (3) The dominant species in the community coexisted stably; dominant species showed clumped distribution patterns in the plot, but the locations of clumped distribution differed among dominant species. Overall, the community currently exhibited good regeneration status, with climax community dominant species already present, but the community possessed certain secondary characteristics and had not yet reached a stable climax community state; dominant species could coexist stably, with potential to succeed toward a stable climax community. Management and protection should be continued to

promote the regeneration and survival of montane evergreen broad-leaved forest communities in Shiwandashan.

Full Text

Species Composition and Structural Characteristics of Mountain Evergreen Broad-Leaved Forest Community in Shiwandashan, Guangxi

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Abstract

Shiwandashan is one of the biodiversity hotspots in Guangxi, with mountain evergreen broad-leaved forest as its main vegetation type. To understand the current community status and development of dominant species population structures in the region's mountain evergreen broad-leaved forests, this study analyzed species composition, diameter class structure, tree height structure, and spatial distribution patterns of dominant species using the g(r) function in a 1 hm^2 permanent monitoring plot. The results indicate: (1) A total of 7,517 woody plants with DBH $\geq$ 1 cm were recorded, belonging to 153 species, 108 genera, and 52 families. The dominant species included *Clethra delavayi*, *Schima argentea*, *Hartia villosa*, *Castanopsis hystrix*, *Engelhardtia roxburghiana*, *Ardisia quinquegona*, *Itea chinensis*, *Symplocos adenophylla*, *Eurya subintegra*, and *Ilex pubescens*, though none exhibited overwhelming dominance. (2) The community's overall mean DBH was 5.51 cm, with diameter class and height distributions showing approximate inverted "J" shapes. Most dominant species displayed inverted "J" or "L" shaped diameter distributions, indicating strong regeneration capacity. (3) Dominant species coexisted stably, showing aggregated distributions in the plot but with spatially distinct aggregation patterns. Overall, the community exhibits good regeneration status with presence of climax community dominant species, yet retains secondary characteristics and has not reached a stable climax state. The stable coexistence among dominant species suggests potential for succession toward a stable climax community, warranting continued conservation efforts to promote regeneration and persistence of the mountain evergreen broad-leaved forest community in Shiwandashan.

Keywords: mountain evergreen broad-leaved forest, species composition, diameter class structure, spatial distribution pattern

Introduction

Forests constitute the main body of terrestrial ecosystems, and plant communities, as primary producers, play a particularly crucial role in maintaining system stability and development (Qian et al., 2018; Yu et al., 2019). The two most fundamental characteristics of plant communities are species composition and community structure. Species composition forms the foundation of community formation, while age structure can reveal population regeneration capacity, growth status, population dynamics, and community succession trends. Community structure reflects regeneration status and demonstrates the configuration among different individuals and their relationships with the environment (Zhao et al., 2021). Studying species composition and community structure can elucidate mechanisms underlying species diversity formation and maintenance, providing theoretical foundations for spatiotemporal dynamics of community patterns (Loreau et al., 2001). Population spatial distribution patterns represent the distribution or configuration of individuals within community habitats at the horizontal level (Eduardo et al., 2016), representing a key aspect of community structure and species coexistence that explains spatial dynamics and reflects succession trends (Kubota et al., 2007). Community species composition, biodiversity, and structure can effectively reflect community stability, interspecific relationships, and environmental impacts on species survival and growth (Zhao et al., 2021), thus playing important roles in studying species regeneration, community succession, and biodiversity maintenance.

Shiwandashan in southern Guangxi, located at the intersection of the northern tropical and south subtropical zones, preserves large areas of evergreen broad-leaved forest and contains rich biological resources, serving as an important gene bank and water conservation forest in China's tropical region (Zhang et al., 2016). Due to comprehensive influences of environmental factors such as altitude, soil, climate, and moisture conditions, its vegetation types are complex and diverse, including typical monsoon forests, ravine rainforests, mountain evergreen broad-leaved forests on vertical belts, and summit dwarf forests. However, due to long-term anthropogenic disturbance, most existing evergreen broad-leaved forests are secondary forests (Tan et al., 2005). Previous research on Shiwandashan has focused primarily on its rich plant resources (He et al., 2004; Wei et al., 2018), with few reports on forest community characteristics. In recent years, numerous studies in China have analyzed community species composition, floristic elements, structure, and dynamics based on permanent dynamic monitoring plots, including those in Gutianshan, Zhejiang (Zhu et al., 2008), Wuyishan, Fujian (Ding et al., 2015), Ailaoshan, Yunnan (Wen et al., 2018), Dinghushan and Chebaling, Guangdong (Ye et al., 2008; Wu et al., 2021), and Mao'ershan, Damingshan, Jiuwanshan, and Cenwanglaoshan in

Guangxi (Zhu et al., 2009; Zhu et al., 2011; Peng et al., 2020; Liang et al., 2020). These studies have primarily examined relatively well-preserved primary or long-recovered old-growth evergreen broad-leaved forests. Mountain evergreen broad-leaved forest is the main vegetation type in Shiwandashan, raising questions about how its species composition and community structure differ from neighboring regions and what its current status and development trends are—fundamental issues for regional conservation. Therefore, this study examines a permanent dynamic monitoring plot of mountain evergreen broad-leaved forest in Shiwandashan, established by Guangxi University and Shiwandashan National Nature Reserve Administration according to CTFS forest monitoring technical specifications. By analyzing species composition and biodiversity, diameter class structure, tree height structure, and spatial distribution patterns, we compare these characteristics with primary or old-growth forests to elucidate the development status, natural regeneration capacity, and future trends of the Shiwandashan mountain evergreen broad-leaved forest community and plant populations.

1.1 Study Area Overview

Shiwandashan is located in southern Guangxi, near the Beibu Gulf coast, with its highest peak at 1,462 m, representing the highest mountain in southern Guangxi. It belongs to the northern tropical monsoon rainforest climate zone, characterized by short winters, long summers, pronounced monsoon climate, concurrent rainfall and heat, and distinct dry and wet seasons, forming an important natural barrier for Guangxi and even southern China (Tan et al., 2005). The study area has an average annual temperature of 26 °C, with January and July averages of 6 °C and 33 °C, respectively. Annual precipitation averages 2,600 mm, concentrated from June to September, peaking in July. Soil types include lateritic red soil, mountain red soil, and mountain yellow soil, with vegetation types comprising ravine rainforest, monsoon forest, mountain evergreen broad-leaved forest, and summit dwarf forest (Tan et al., 2005).

1.2 Sample Plot Overview

Within Shiwandashan National Nature Reserve, a representative area near Baishiya Reservoir in Fulong Town was selected for plot establishment after field survey. The plot is square-shaped with an area of 1 hm^2, centered at 108°01 02.71 E, 21°51 57.79 N. Elevation increases gradually from northeast to southwest, ranging from 410.00 m to 513.18 m (a difference of 103.18 m). The topographic map is shown in Figure 1 [Figure 1: see original paper]. Soils are mountain red soils developed from sandy shale, with litter layer thickness of 1–2 cm. The community appears evergreen year-round with canopy closure of 0.7–0.8. Vertical structure can be divided into: upper tree layer (10–15 m height), lower tree layer (5–10 m height), shrub layer (2–5 m height, 60%–80% coverage), and herb layer (below 2 m height, 20%–30% coverage). Lianas and epiphytes are relatively scarce.

1.3 Sample Plot Setup and Survey Methods

Following CTFS forest monitoring technical specifications (Condit, 1998), the plot was divided into 25 quadrats of 20 m × 20 m using the southwest corner as the origin, with each quadrat further divided into 16 sub-quadrats of 5 m × 5 m. All plants with DBH (Diameter at Breast Height) $\geq$ 1 cm were surveyed, tagged, and numbered, with species name, DBH, height, and relative coordinates recorded.

1.4 Research Methods

Species importance values were calculated based on relative dominance, relative density, and relative frequency (Ye et al., 2008): Importance Value = (Relative Dominance + Relative Density + Relative Frequency) / 3. Following Ding et al. (2015), species abundance was classified as: common species (>10 individuals/hm^2), occasional species (2–10 individuals/hm^2), and rare species ($ 1*individual*/*hm*^{2}$).

Diameter class classification followed Xu et al. (2005) for different life forms, dividing woody plants into two categories (trees and small trees/shrubs), each with four diameter classes: Trees: 1 cm $\leq$ DBH $\leq$ 5 cm, 5 cm $<$ DBH $\leq$ 12.5 cm, 12.5 cm $<$ DBH $\leq$ 22.5 cm, DBH $>$ 22.5 cm; Small trees/shrubs: 1 cm $\leq$ DBH $\leq$ 2.5 cm, 2.5 cm $<$ DBH $\leq$ 7.5 cm, 7.5 cm $<$ DBH $\leq$ 12.5 cm, DBH $>$ 12.5 cm.

Spatial distribution patterns were analyzed using Ripley's g(r) function (He et al., 2017) with the "spatstat" package in R software, at scales from 0 m to 100 m with 1 m intervals. Based on the Complete Spatial Randomness (CSR) model, dominant species distribution patterns were analyzed using 99 Monte Carlo random simulations to generate upper and lower envelope lines and calculate 95% confidence intervals. Actual distributions with g(r) values within the envelope lines were considered random, above the lines as aggregated, and below as uniform.

All statistical analyses and plotting were performed in Excel and R 4.0.5.

2.1.1 Dominant Family Composition

The community contained 7,517 woody plants with DBH $\geq$ 1 cm, belonging to 153 species, 108 genera, and 52 families. Families with high species dominance included Theaceae (6 genera, 18 species), Euphorbiaceae (9 genera, 11 species), Rubiaceae (9 genera, 9 species), Theaceae (6 genera, 9 species), Aquifoliaceae (1 genus, 6 species), Rosaceae (5 genera, 6 species), and Moraceae (2 genera, 6 species). Total basal area was 30.87 m^2/hm^2. The top 10 families by importance value accounted for 74.94%, 72.74%, and 75.62% of total individuals, importance value, and basal area, respectively.

As shown in Table 1 and Figure 2 [Figure 2: see original paper], Theaceae, Lauraceae, and Fagaceae were the dominant families with high importance values, abundance, cumulative basal area, and species richness. Although Rubiaceae and Aquifoliaceae had lower importance values (both <4), they contained many species. Clethraceae had only one species but a relatively high importance value, making these families sub-dominant.

2.1.2 Species Composition

The top 10 species by importance value were the tree species *Schima argentea*, *Hartia villosa*, *Castanopsis hystrix*, *Engelhardtia roxburghiana*, and *Symplocos adenophylla*, and the small tree/shrub species *Clethra delavayi*, *Ardisia quinquegona*, *Itea chinensis*, *Eurya subintegra*, and *Ilex pubescens* (Table 2). These species accounted for 44.64%, 48.80%, and 50.70% of total importance value, abundance, and basal area, respectively (Table 2, Figure 3 [Figure 3: see original paper]). *Clethra delavayi*, *Schima argentea*, *Hartia villosa*, and *Ardisia quinquegona* were most abundant, comprising 31.74% of total individuals, with *C. delavayi* being most numerous at 809 individuals. Although *C. hystrix* and *E. roxburghiana* had fewer individuals, their large mean DBH gave them basal area advantages. With relatively small differences in importance values among these species, no absolutely dominant species existed. These co-dominant species collectively constitute the Shiwandashan mountain evergreen broad-leaved forest.

2.1.3 Species Diversity

Species diversity analysis yielded: Species richness index (S) = 153, Simpson diversity index (D) = 0.963, Shannon–Wiener index (H) = 3.873, and Pielou evenness index (P) = 0.77. Analysis of quantitative distribution characteristics revealed many rare and occasional species, comprising 50.32% of total species (24 rare species and 53 occasional species) (Table 3), indicating high species richness and weak species dominance in the Shiwandashan mountain evergreen broad-leaved forest.

2.2 Structural Characteristics

The community's mean DBH was 5.51 cm, with the largest DBH being 40.8 cm for *C. hystrix*. Only eight individuals had DBH $>$ 32.5 cm. Using 1 cm DBH intervals and 1 m height intervals, diameter and height structures both showed approximate inverted "J" shapes (Figure 4 [Figure 4: see original paper]). For diameter structure, individuals with 1 cm $\leq$ DBH $\leq$ 5 cm were most abundant (4,633 individuals, 61.63% of total), followed by 5 cm $<$ DBH $\leq$ 12.5 cm (30.28%), 12.5 cm $<$ DBH $\leq$ 22.5 cm (6.85%), and DBH $>$ 22.5 cm (1.24%). The community was dominated by small-diameter woody plants in normal growth condition.

Vertical stratification was distinct. Individuals with H $\leq$ 5 m were most numerous (4,583 individuals, 60.97% of total), followed by 5 m $<$ H $\leq$ 8 m (2,113 individuals) and H $>$ 8 m (821 individuals). The upper tree layer averaged 12 m height, dominated by *C. hystrix* and *E. roxburghiana*. The lower tree layer averaged ~8 m, commonly including *S. argentea*, *E. roxburghiana*, *C. hystrix*, *H. villosa*, *C. fissa*, and *Cinnamomum parthenoxylon*. The shrub layer (H $\leq$ 5 m) consisted mainly of small trees, shrubs, or tree saplings, commonly including *C. delavayi*, *A. quinquegona*, *S. argentea*, *E. subintegra*, *H. villosa*, and *I. pubescens*.

Dominant species diameter structures (Figure 5 [Figure 5: see original paper]) could be classified into four types using different diameter criteria: (1) Inverted "J" type—most individuals in diameter class I, decreasing with increasing class, indicating abundant regeneration and good natural renewal (e.g., *S. adenophylla*). (2) "L" type—dominated by classes I and II, with few or no individuals in classes III and IV (e.g., *S. argentea*, *A. quinquegona*, *I. pubescens*). (3) "Poisson" type—mostly sub-canopy dominants dominated by class II, lacking large-diameter individuals (e.g., *C. delavayi*, *H. villosa*, *I. chinensis*, *E. subintegra*). (4) Linear distribution type—population structure stability intermediate between inverted "J" and "Poisson" types, with main canopy dominants showing little variation among diameter classes and approximate linear distribution, possibly insufficient regeneration to supplement large-diameter classes (e.g., *C. hystrix* and *E. roxburghiana*).

2.3 Spatial Distribution Patterns of Dominant Species

Spatial distribution pattern analysis of dominant species (Figure 6 [Figure 6: see original paper], Figure 7 [Figure 7: see original paper]) revealed that *C. delavayi* and *S. argentea* showed significantly higher aggregation than other species. *Clethra delavayi*, *S. argentea*, *H. villosa*, *I. chinensis*, and *S. adenophylla* were aggregated at 1–25 m scales; *E. subintegra* at 1–17 m; *C. hystrix*, *E. roxburghiana*, and *A. quinquegona* at 1–11 m; and *I. pubescens* at 2–15 m and 20–25 m scales, with random distribution at other scales. *Clethra delavayi* and *S. argentea* aggregated in the southwestern high-elevation area, while *C. hystrix*, *E. roxburghiana*, and *A. quinquegona* tended toward the northeastern low-elevation area. *Hartia villosa* aggregated in the central plot area, *I. chinensis* in the western area, and *S. adenophylla* in the northwestern mid-high elevation area. In summary, all dominant species showed aggregated distributions to varying degrees, with species-specific aggregation locations, likely related to habitat conditions.

3.1 Species Composition and Diversity

In the Shiwandashan plot, Theaceae, Lauraceae, and Fagaceae dominated in species abundance, basal area, and importance value, consistent with dominant families in other Chinese evergreen broad-leaved forests. The stand density of 7,517 individuals/hm^2 was higher than in primary or old-growth evergreen broad-leaved forest plots in Cenwanglaoshan, Damingshan, Dinghushan, Chebaling, and Gutianshan, indicating strong secondary characteristics and recovery toward old-growth forest, consistent with findings from Gutianshan, Zhejiang (Zhang et al., 2019). Species richness was very high compared to other regional evergreen broad-leaved forest plots of equivalent area. Shannon–Wiener and Simpson diversity indices were higher than in Dinghushan, Cenwanglaoshan, and Damingshan, suggesting that secondary forests have higher α-diversity than old-growth forests. Shiwandashan is a very important biodiversity hotspot in China with inherently rich species, but high species richness may also relate to disturbance and successional stage.

Weak dominance of dominant species is characteristic of secondary forests. No species had importance value >10, similar to community structures in Jiuwanshan (Peng et al., 2020) and Wuyishan (Ding et al., 2015), where multiple species dispersed dominance among relative density, frequency, and dominance, with co-dominant species checking each other. In contrast, old-growth forests like Gutianshan, Ailaoshan, and Dinghushan have clearly dominant species.

3.2 Community Structural Characteristics

Diameter structure is an important indicator of community stability, growth, and development (Ye et al., 2008). Inverted "J" shaped diameter or height distributions indicate self-renewal capacity and stable development (Wen et al., 2018). The overall diameter structure showed an approximate inverted "J" shape, with most of the 10 dominant species showing inverted "J" or "L" shaped distributions. Individuals with DBH 1–5 cm accounted for 61.63% of total individuals, with the community composed mainly of shrub species and tree saplings. The high proportion of young individuals helps maintain dynamic balance and enhances self-renewal capacity. Overall, the Shiwandashan mountain evergreen broad-leaved forest community is "growing," with good natural regeneration and stand development, enabling stable population renewal and growth.

Spatial distribution patterns of dominant species showed varying degrees of aggregation with habitat associations. Factors influencing population spatial patterns include habitat heterogeneity, species biological characteristics, and disturbance intensity (Harms et al., 2001; Boyden et al., 2005). Different species adapt to specific environmental conditions and occupy different ecological spaces. Species biological characteristics, disturbance intensity, and altitude may influence dominant species distribution in Shiwandashan. The western plot area near roads experienced greater disturbance than the middle-lower plot area. The southwestern area had higher elevation and better light conditions, favoring the light-demanding species *S. argentea*, while small trees *C. delavayi* and *I. chinensis* as companion species also aggregated in the southwest. The lower slope had higher canopy closure and weaker understory light, where shade-tolerant *C. hystrix* and *E. roxburghiana* seedlings aggregated, along with shade-tolerant shrubs *A. quinquegona* and *I. pubescens*. *Hartia villosa* aggregated in the central plot, and *S. adenophylla* in the northwestern area, suggesting altitude and disturbance as main factors influencing spatial distribution patterns. Habitat heterogeneity facilitates coexistence of species with different habitat requirements (Chesson, 2000). Spatial segregation among populations reduces interspecific competition, favoring species coexistence.

3.3 Community Succession

Castanopsis hystrix and *E. roxburghiana* are climax community dominants but were less dominant than small tree *C. delavayi* and light-demanding *S. argentea*. In terms of diameter structure and mean height, *C. hystrix* and *E. roxburghiana* had higher proportions of medium-large diameter trees, dominating the upper canopy, while *S. argentea* had high density of class I-II individuals but lacked large-diameter trees, though it dominated the lower canopy, followed by *C. hystrix* and *E. roxburghiana*. *Clethra delavayi* had fewer individuals in tree layers due to biological limitations. *Schima argentea*, a light-demanding representative species of subtropical evergreen broad-leaved forest (Luo et al., 2019), had abundant seedling/sapling reserves, far exceeding those of *C. hystrix* and *E. roxburghiana*, suggesting the community will likely develop toward *S. argentea* dominance. The largest *C. hystrix* had DBH of only 40.8 cm, with high proportions of light-demanding species, large individual density, and weak dominance, indicating relatively short natural recovery time and strong secondary characteristics. However, presence of climax dominants in the upper canopy suggests the community is developing toward climax, currently in mid-successional stage after disturbance.

Population spatial distribution patterns are closely related to successional stage, tending toward random distribution at stable stages (Loreau et al., 2001; Yang et al., 2019). The aggregated distribution of dominant species in Shiwandashan indicates an unstable stage. Different populations occupy distinct spatial positions, showing niche differentiation characteristics that enable stable species coexistence.

3.4 Conclusion

This study analyzed species composition, diameter structure, and spatial distribution patterns of the mountain evergreen broad-leaved forest community in Shiwandashan National Nature Reserve. Results show that overall diameter and height structures approximate inverted "J" shapes, indicating stable development with self-maintenance and renewal capacity. Aggregated distribution patterns of dominant species, dominance of light-demanding *S. argentea*, and numerous small-diameter individuals suggest relatively short natural recovery time. Although climax community dominants are present, their weak dominance indicates the community remains in post-disturbance recovery stage, but has potential to develop toward stable climax. Continued conservation and long-term monitoring are recommended to explore changing patterns of species composition during community succession.

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