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Full Length Research Paper

Tree species diversity and related mechanism in an evergreen broad-leaved forest in Ailao Mountains, Yunnan, China

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There is no enough data or evidence to reach a firm conclusion for tree species diversity and related mechanism in an evergreen broad-leaved forest in Ailao Mountains, Yunnan, China. A 6-hm^2 plot was established in Ailao Mountains State Nature Reserve for the purpose of monitoring long-term dynamics of tree populations. All free-standing trees with diameter at breast height (*DBH*) ≥ 1 cm were tagged, mapped, measured (girth) and identified to species in the plot. The spatial distribution patterns of four dominant canopy tree species in the plot were analyzed using a point pattern analysis Ripley's L-function. A total of 12131 free-standing individuals with *DBH* ≥ 1 cm were recorded in the plot, including 68 species belonging to 49 genera and 25 families. *Lithocarpus hancei* had the largest basal area and the largest importance value. *Camellia forrestii*, an understory tree species was ranked the second in terms of importance value, although it showed the highest abundance (1712 individuals). The four canopy dominant species had a large number of seedlings and saplings and tend to be patchily distributed. And the spatial distributions of 26 tree species with ≥40 individuals was examined at each life history stage (diameter at breast height ≥1 cm), and 37 of 57 life history stages showed aggregated distribution pattern. It showed that it may be not density dependence but habitat heterogeneity as a prevalent mechanism for regulating the population spatial structure of most tree species in the subtropical forest studied here.

Key words: Evergreen broad-leaved forest, habitat heterogeneity, spatial distribution pattern, tree species diversity.

INTRODUCTION

Evergreen broad-leaved forest is a kind of climax vegetation that grows in the subtropical climate (Wu, 1980). In China, evergreen broad-leaved forests are just distributed in densely populated areas with a relatively fast speed of development in aspect of industrial and agricultural production and the distribution patterns are mostly fragmented and plaque-like, so it is extremely hard to protect the forests completely. Evergreen broad-leaved forests in Ailao Mountains Nature Reserve cover an area of 504 km^2 and it is one of nature reserves with the largest area of subtropical evergreen broad-leaved forests in China (Young and Wang, 1989). As the natural reserve lies in the transitional region between the southeast side of Qinghai-Tibet Plateau and from north rim of the tropical to subtropical zone of Yunnan Province, the compositions of species of Ailao Mountains are ancient and complicated. Tropical, subtropical and temperate species interlace and gather here and there are many endemic species, so a pattern with extremely,

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abundant biodiversity and complicated geographical compositions of the flora forms in the nature reserve (Qiu 1998). A lot of researches have been done on the diversity of tree species of Ailao Mountains evergreen broad-leaved forest and the characteristics of different levels of the forest (You, 1983; Qian, 1983; Young and Wang, 1989; Young et al., 1992; Young and Herwitz, 1995; Qiu, 1998; He et al,, 2000). These researches show that the diversity of tree species of evergreen broad-leaved forests is greatly variable at community level and the diversified distribution patterns of tree species at different levels have great uncertainty. Does this really reflect the natural distribution rules of tree species of these forest types? At present, there is no enough data or evidence to reach a firm conclusion. It is of significance to clearly explain the ecological characteristics of populations and the formation, stability and succession rules of communities of evergreen broad-leaved forest if further research is studied about the population structure and spatial distribution pattern of the forest (Da et al., 2004). Spatial patterns can be influenced by many factors, for example, limitation of seed dispersal, vegetative recruitment, nurse effects, site mosaics, disturbances, competition and life history strategies (Duncan, 1993; Camarero et al., 2000; Takahashi et al., 2001; Rozas, 2003). An analysis of spatial patterns within life stages can be helpful to understand processes of population development (Li et al., 2009).

Numerous studies of community-level evaluations have found evidence for negative density dependence (Harms et al., 2000; Peters, 2003), however other factors such as habitat heterogeneity may also be important on regulating the dynamics of tree populations (Wright, 2002; Getzin et al., 2008). But few studies in subtropical forests have found evidence for these mechanisms at the community level.

This paper utilized the data from tree species survey to analyze the diversity of tree species, spatial distribution pattern of dominant populations, and recruitment and death of seedlings of the evergreen broad-leaved forests in Ailao Mountains Nature Reserve, in order to fully recognize; (1) the characteristics of tree species diversity of Ailao Mountains mid-mountain humid evergreen broad-leaved forest; (2) the spatial distribution features of dominant species; (3)the mechanism of tree species diversity and then provide a theoretical basis for the protection, rehabilitation and reconstruction of evergreen broad-leaved forests in this area.

MATERIALS AND METHODS

Study area

This study area lies in Xujiaba of core area of Ailao Mountains Nature Reserve with a geographic coordinates of 24°32′ N and 102°01′ E and a height of 2400 to 2600 m above sea level. According to the data provided by Ailao Mountains Forest Ecosystem Research Station, in the research area, the mean annual precipitation is 1931 mm, there are clear rainy and dry seasons, the precipitation of rain season (May to October) accounts for 85% of mean annual precipitation, the annual average evaporation, temperature, temperature of the hottest month (July), temperature of the coldest month (January), and frost free period is 1485 mm, 11.3℃, 16.4℃, 5.4℃, and 200 days, respectively. The soil parent material consists of schist, gneiss, and diorite and is mostly developed as fertile yellow brown soil with slight acid (pH=4.4 to 4.9). The surface of the soil is covered by litter layer (with a thickness of 3 to 7 cm) and the contents of organic carbon, total nitrogen and total phosphorus in the soil are 12.91, 0.52 and 0.06%, respectively, the C/N ratio of the surface of the soil is 14.4, and the C/N ratio at the depth of 30 to 50cm is 15.3 (Liu et al., 2002). The trees of Ailao Mountains mid-mountain humid evergreen broad-leaved forest is mainly composed of Fagaceae, Theaceae, Lauraceae, and Magnoliaceae. Among them, *Lithocarpus xylocarpus* and *Castanopsis rufescens* of Fagaceae, *Schima noronhae*, *Hartia sinensis*, and *Camellia forrestii* of Theaceae, *Machilus bombycina* and *Litsea elongata* of Lauraceae, and *Manglietia insignis* and *Michelia floribunda* of Magnoliaceae are major dominant species. Besides, there are abundant and well developed vines and epiphytes in the forest, interlayer plants are mostly woody vines, and epiphytes are mostly mosses and ferns, forming a strange forest landscape (Qiu, 1998).

Survey methods

A 6 hm^2 permanent plot (200 m from east to west, 300 m from north to south) is set up in the mature forest in this study area according to the technical specifications of the 50 hm^2 plot set up by the Center for Tropical Forest Science of Smithsonian Tropical Research Institute in Barro Colorado Island, Panama in 1980 (Figure 1).

The geographical position of the plot is 101°01′34.7″ to 101°01′42.0″ E and 24°32′9.9″ to 24°32′20.3″ N. In the plot, the lowest and highest elevation is 2488.2 and 2537.8 m respectively. An Electronic Total Station (Topcon GTS-336) is adopted to divide the whole plot into 150 pieces of 20 × 20 quadrats. Then, divide the each quadrat into 4 pieces of 10 × 10 m sub-quadrats and then divide them into 16 pieces of 5 × 5 m small quadrats. In this way, the whole sample plot is divided into 2400 pieces of 5 × 5 m small quadrats for the convenience of positioning during the survey of trees. To hang aluminum boards on trees takes 20 × 20 m quadrat as the basic unit, aluminum boards are hung from the 5 × 5 m small quadrat at the bottom left of the quadrat in a clockwise direction, all trees with a diameter not below 1cm shall be hung with boards. Record and identify the number, specie name, height, diameters, and position of all trees in each 20 × 20 m quadrat, and paint the 1.3 m high places of the trees red, and then measure the diameter of the measuring tree with a steel diameter tape (205 Type), and the diameter of the tree will be measured to the accuracy of 0.1 cm. Trees 10 m high or below will be measured with a staff gauge while trees with a height above 10 m will be estimated to the accuracy of 0.1 m. Trees with a height ≥ 20 m are canopy trees, trees with a height of 10 to 20 m (including 10 m) are understory trees, and the dominant species of canopy trees are calculated by the abundance of each tree species of the level. The measurement of the plot was finished in November, 2007 and the field survey of tree species was finished in April to May, 2008.

Data analysis

Calculation of importance value

Importance value of tree equals to (relative density + relative

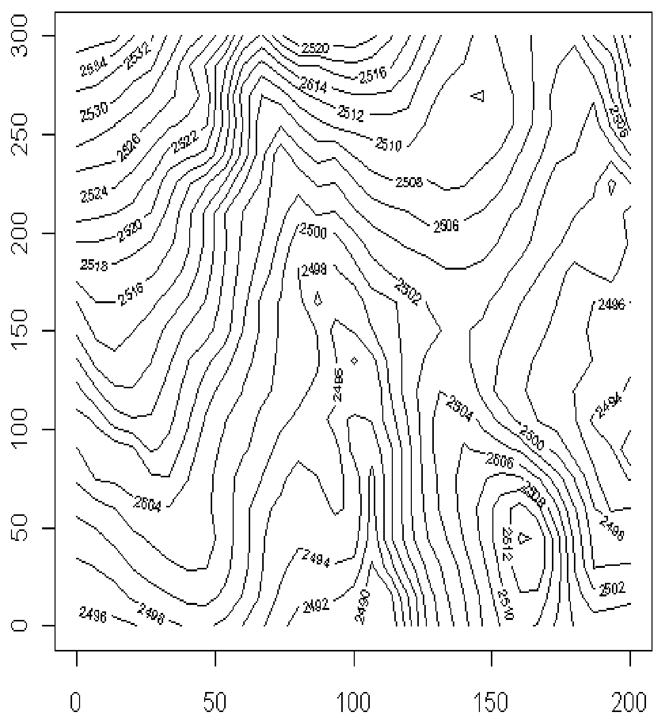

Figure 1. The topography map of evergreen broad-leaved forest dynamics plot of Ailao Mountains (with 20 m contour intervals).

frequency + relative dominance) / 3 (Sun et al., 2002) and there are 150 quadrats (20 × 20 m) for the calculation of relative frequency.

Measurement of species diversity

Diversity index adopts Shannon-Wiener index and Pielou evenness index (Magurran, 1988).

$$H = -\sum_{i=1}^{s} p_i \ln(p_i)$$

$$E = H / \ln(S)$$

H: Shannon-Wiener index; S: total species number; p_i: the percentage of individuals that belongs to species *i* in all individuals; E: Pielou evenness index.

Species-area curve

Beginning with original base point, We select the areas of 1200, 2400, 3600, 4800 and 6000 m^2 and so on, respectively, as the unit, gradually enlarge the sampling area, combine with the quantity of tree species in the processes, and draw species-area curve.

Division of growth period of tree species

We divide dominant species into three growth periods according to the location of dominant species in canopy layer of community: (1) saplings 1cm≤ DBH < 5 cm; (2) poles 5 cm ≤ DBH < 30 cm; (3) adults DBH ≥ 30 cm.

Analysis on spatial distribution patterns of tree species

The analysis on spatial distribution patterns of species has many methods (Lan and Lei, 2003), while the statistical theory of point pattern analysis was first proposed by Ripley (1977) and the distribution pattern at any distance scale can be analyzed, so it was the most common analysis method (Batista and Maguire, 1998), and later, the method was gradually developed into a new population pattern analysis method through the efforts of Diggle (1983). It takes the coordinate of plant species individual as basic data and every individual can be regarded as a point in two-dimensional space. In this way, all individuals compose a spatial distribution point diagram. The formula of measurement is as below:

$$\hat{H}_{(t)} = \sqrt{(\frac{A}{n})\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{1}{W_{ij}}It(u_{ij}) / \pi} - t$$

In the formula above, n refers to the number of points, *t* refers to study scale, u_{ij} refers to the distance between *i* and *j*, and when $u_{ij}<t$, It(u_{ij})=1; when u_{ij}>t, It (u_{ij})=0. W_{ij} refers to the observable probability of a point (tree). Here, it refers to weight and aims at eliminating boundary effect (Ward et al., 1996). $\hat{H}_{(t)}$ >0, referring to aggregated distribution; $\hat{H}_{(t)}$ <0, referring to uniform distribution; $\hat{H}_{(t)}$ =0, referring to random distribution.

Monte-Carlo fitting checking is used to calculate upper and lower envelopes, that is, confidence interval. Provided that populations are distributed at random, use random models to fit the coordinates of a group of points and calculate $\hat{H}_{(t)}$ for each *t* value; in the same way, use random models to fit the coordinates of another group of points and respectively calculate $\hat{H}_{(t)}$ for *t* of each scale; repeat the same process till the number of times reaches predetermined number; the maximum value and the minimum value of $\hat{H}_{(t)}$ are respectively the coordinates of upper and lower envelopes. The number of fitting times for 95% confidence level is 20 and the number of fitting times for 99% confidence level is 100 (Ripley, 1977). Thus, this method has a large amount of calculation. If $\hat{H}_{(t)}$ values under different scales obtained from the calculation with actual distribution data of populations are within envelopes, the distribution belongs to random distribution; if above envelopes, the distribution belongs to aggregated distribution; if below envelopes, the distribution belongs to uniform distribution (Lan and Lei, 2003). This paper applies single point pattern analysis method of Ripley'S L-Function to analyzing the spatial distribution pattern of dominant tree species in the plot, use Monte-Carlo fitting checking to calculate upper and lower envelopes (that is, confidence interval). If the number of fitting times is 99, the resulting confidence level is 99% (Lan et al., 2008). The data statistics software adopts R (2.7.2 version) language.

Test of mechanism of tree species diversity

One of method is to infer density dependence from the spatial distribution of trees (Getzin et al., 2006; Wiegand et al., 2007). On influence of strong density dependence, the distribution of live trees is expected to be more regular and clustering degree is expected to decline with increasing size classes (Sterner et al., 1986; Barot et al., 1999). Therefore, comparison of the spatial patterns of different size classes to test density dependence. Otherwise, it may be other factors such as habitat heterogeneity.

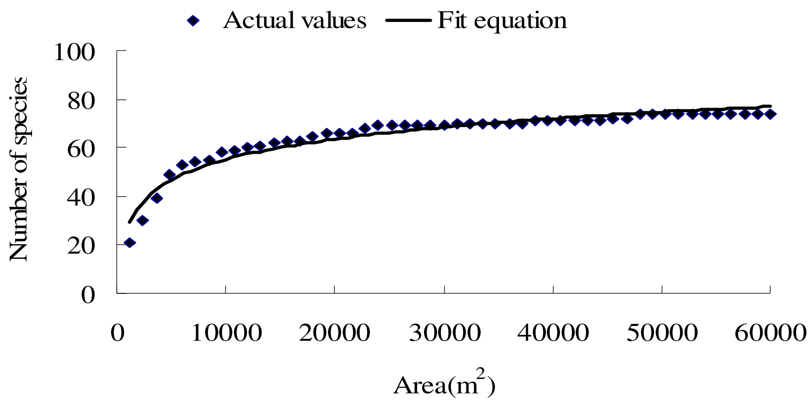

Figure 2. Species-area curve in Ailao Mountains plot.

RESULTS

Species-area curve and species diversity

There are totally 12131 trees with a diameter ≥ 1 cm recorded in the plot, 68 kinds of tree species, belonging to 25 families and 49 genus, which include 54, 13 and 1 species of evergreen broad-leaved, deciduous broad-leaved and evergreen coniferous species, respectively.

With the increase of area of the sample, the number of tree species increases rapidly, from 3600 to 4800 m^2, the number of tree species increases by 9, from 4800 to 6000 m^2, the number of tree species increases by 4, but from 6000 to 7200 m^2, the number of tree species increases by 1; to cover 80% tree species of the plot, 9600 m^2 sampling area is needed tree species to cover 80% of the plot needs a sampling area of 9600 m^2. Fit an equation according to Species-Area Curve (Yan and Hu, 2004), the equation: y = 10.614 ln(x) - 46.133, R^2=0.937, p<0.001, and the fitting effect is the best (Figure 2). If the basic area adopts 6000 m^2, the Shannon-Wiener index of the resulting community is 2.95 ± 0.11 and the Pielou evenness index of the community is 0.78 ± 0.02.

Tree species abundance and dominant species

In the plot, there are 6 tree species with more than 500 individuals, which account for 0.08% of total number of tree species, with 56.65% individuals. The species with the most individuals is *Camellia forrestii*, followed by *Vaccinium duclouxii*, *Symplocos ramosissima*, *Symplocos sumuntia*, *Lithocarpus hancei*, and *Castanopsis rufescens*. In the plot, there are also 6 tree species with only one individual, also accounting for 0.08% of total number of tree species. According to the definition of Hubbell and Foster on rare species (Hubbell and Foster, 1986), the tree species with less than 1 individual in each hectare on average is rare species; according to the definition, there are 19 rare species in the plot, accounting for 25.33% of total number of tree species in the sample plot. The importance value of *Lithocarpus hancei* in the plot is the largest, with 953 individuals, and its basal area is 46.45 m^2, followed by *Castanopsis rufescens*, and then *Camellia forrestii*. *Camellia forrestii* has 1712 individuals, and its basal area is 2.94 m^2 (Table 1).

Areal-types of genus and diameter class distribution of tree species

According to the study of The Areal-types of the World Families of Seed Plants (Wu, 2003; Wu et al., 2003), the areal-types of 47 genera in the 6 hm^2 plot in Ailao Mountains evergreen broad-leaved forest are analyzed (Table 2). In the plot, there are 23 genera containing some tropical elements as pantropical, tropical Asia and tropical Africa, old World Tropics, tropical Asia to Tropical Australasi, tropical Asia to Tropical Africa, and tropical Asia, while there are 21 genera containing such temperate attributes as north temperate, East Asia and North America disjuncted, old World Temperate, and temperate Asia.

In the plot, the total basal area of a tree with a *DBH* ≥1 cm is 48.23 $m^2 \cdot hm^{-2}$, from diameter structure, it can be seen that, the tree species with a DBH≤10 cm has more individuals, accounting for 69.46% of total number of individuals, the individuals of tree species with a DBH＞10 cm account for 30.54% of total number of individuals, and in the plot, the maximum tree diameter was 213.4 cm (*Lithocarpus xylocarpus*). Among dominant tree species of canopy layer, the top four tree species are *Lithocarpus hancei*, *Castanopsis rufescens*, *Lithocarpus xylocarpus*, and *Schima noronhae* in order.

Spatial distribution patterns of tree species in different growth periods

In the growth development of population, the distribution pattern is not constant and it represents a dynamic

Table 1. Top ten tree species with the highest important values in evergreen broad-leaved forest.

Rank	Species	Family	Relative density	Relative frequency	Relative dominance	Important value
1	*Lithocarpus hancei*	Fagaceae	7.86	5.01	27.48	13.45
2	*Castanopsis rufescens*	Fagaceae	4.46	4.75	16.06	8.42
3	*Camellia forrestii*	Theaceae	14.11	5.19	1.02	6.77
4	*Vaccinium duclouxii*	Vacciniaceae	11.17	4.48	3.06	6.24
5	*Lithocarpus xylocarpus*	Fagaceae	1.99	3.70	12.10	5.93
6	*Symplocos ramosissima*	Symplocaceae	9.88	4.52	1.84	5.41
7	*Symplocos sumuntia*	Symplocaceae	9.17	4.97	1.46	5.20
8	*Schima noronhae*	Theaceae	1.48	3.29	7.31	4.03
9	*Machilus yunnanensis*	Lauraceae	3.21	4.97	3.38	3.86
10	*Ilex corallina*	Aquifoliaceae	3.21	3.62	3.62	3.48

Table 2. Areal types of seed plants in the evergreen broad-leaved forest dynamics plot in the Ailao mountains.

Areal-types	Number of genera	Percentage
Cosmopolitan		
Pantropic	6	12.76
Tropical Asia and Tropical America disjuncted	5	10.64
Old World Tropics		
Tropical Asia to Tropical Australasia	1	2.13
Tropical Asia to Tropical Africa	1	2.13
Tropical Asia	10	21.28
Tropical elements (2-6)	23	48.94
North temperature	13	27.66
East Asia and North America disjuncted	7	14.89
Old World Temperate	1	45.84
Temperate Asia		2.13
Temperate elements(7-9)	21	44.68
Mediaterranea, West Asia to Central Asia		
Central Asia		
East Asia	3	6.38
Endemic to China		
Total	47	100

variation course as the time goes (Cao et al., 2003). L-Function of point pattern is used to analyze the variation of distribution patterns of tree species in different growth periods. 26 species (≥40 individuals at each life history stage) have been analysed, and the result shows that, for saplings, 13 of 23 species assume aggregated distribution, for poles, 18 of 21 species assume aggregated distribution, for adults, 6 of 9 species assume aggregated distribution. Clustering degree of 2 species is expected to decline with increasing size classes.

Spatial distribution features of dominant tree species of canopy layer

Lithocarpus hancei is mainly distributed in the west and south of the plot, *Castanopsis rufescens* is mainly distributed in the east and north of the plot, the two tree species assume complementary distribution, and *Lithocarpus xylocarpus* represents certain habitat preference and is collectively distributed in the area with a relatively higher elevation in the plot (Figure 4). The spatial distribution of the same tree species in different growth periods does not present obvious laws.

DISCUSSION

Tree species abundance and dominant species

Camellia forrestii is the species with the most individuals in the plot, but since the tree species lies in the understory

Table 3. The comparison of evergreen broad-leaved forest dynamics plot of Ailao mountains and other plot.

Plot	Ailao mountains, Yunnan, China	Santa Cruz mountains, California, USA
Location	24°32′ N, 102°01′	37°0.745′N,122°4.490′W
Forest type	Evergreen broad-leaved forest	Mixed evergreen coastal forest
Area (ha)	6	6
Altitude (m)	2500	314
Measured minimum DBH (cm)	1	1
Number of tree species	68	31

layer of community and mainly consists of small tress with a small diameter class. And *Lithocarpus hancei* lies in the canopy layer of community and has a large diameter class, the impact of *Lithocarpus hancei* on communities is greatly larger than *Camellia forrestii*. The communities in Ailao Mountains evergreen broad-leaved forest are of multiple co-dominant type. The previous research results show that: tree species of Ailao Mountains evergreen broad-leaved forest is mainly composed of Fagaceae, Theaceae, Lauraceae, and Magnoliaceae (Laboratory of Ecology of Kunming Branch of Chinese Academy of Sciences, 1983; Qiu, 1998), but from tree species with an importance value ranking top ten, the tree species are mostly plants of Fagaceae, Theaceae, Lauraceae, Vaccinioideae, and Symplocaceae, but without the plants of Magnoliaceae. The research results are inconsistent with the previous research results, perhaps because the previous study area is small. The tree species diversity reduces along with the rise of latitude (Barnes et al., 1998), thus tree species diversity of subtropical forest is higher than temperate forest (Ohsawa, 1991) (Table 3)

Areal-types of genus and diameter class distribution of tree species

Ailao Mountains evergreen broad-leaved forest is closely related to tropical and temperate flora (Table 2). Diameter structure is an important factor for the stability and growth and development of plant community (Ye et al., 2008). In the plot, the gross basal area of trees with a DBH ≥ 1 cm is 48.22 $m^2 \cdot hm^{-2}$, significantly larger than 30.17 $m^2 \cdot hm^{-2}$ in 20 ha plot in Dinghushan South Asia subtropical evergreen broad-leaved forest (Ye et al., 2008) and 36.9 $m^2 \cdot hm^{-2}$ in 24 ha plot in Gutianshan Middle Asia subtropical evergreen broad-leaved forest (Zhu et al., 2008), which reflects the primitiveness of the forest in this study plot. Individuals with a DBH above 10 cm account for 31.16%, greatly larger than 16.42% of Dinghushan South Asia tropical evergreen broad-leaved forest (Ye et al., 2008). Four dominant tree species in canopy layer are *Lithocarpus hancei*, *Castanopsis rufescens*, *Lithocarpus xylocarpus*, and *Schima noronhae*, which is consistent with the research results of Zhang and Xie (2000). The four dominant tree species of canopy layer have many individuals with a medium or small diameter, but few individuals with a large diameter, which shows that the four tree species have enough seedlings and saplings and the forest community lies in a relatively stable status (Figure 3).

Spatial distribution patterns of tree species in different growth periods

The spatial distribution patterns of tree species in different growth periods have no law, which is caused by the impact of growth, survival and competition of various tree species in different microenvironment conditions (Frelich et al., 1993) and various microenvironment conditions of each tree species in different growth periods (Manabe et al., 2000); the spatial distribution patterns vary little at different scales, which indicates that scale is not the key factor to restrict the spatial distribution patterns of tree species in the plot. However, from the whole population, the four dominant tree species of canopy layer show very distinct aggregated distribution features, which indicates the high relativity between dominant population and aggregated distribution (Tang et al., 2006). And aggregated distribution is also the major spatial distribution pattern of dominant tree species in the plot, which is consistent with the research result of Dinghushan South Asia tropical evergreen broad-leaved forest (Li et al., 2009).

26 species (≥40 individuals at each life history stage) have been analysed, and clustering degree of only 2 species is expected to decline with increasing size classes (from aggregated distribution to random distribution), and no tree species shows regular distribution. It shows that it may be not density dependence but habitat heterogeneity as a prevalent mechanism for regulating the population spatial structure of most tree species in the subtropical forest. But most species exhibit density dependence predominantly at close distances among neighbors in Gutianshan Middle Asia subtropical evergreen broad-leaved forest (Zhu et al., 2008). 37 of 53 life history stages (26 species) show aggregated distribution, therefore most species show aggregated distribution, it is consistent with the research result of subtropical forest (Manabe et al., 2000; Tsutomu, 2003).

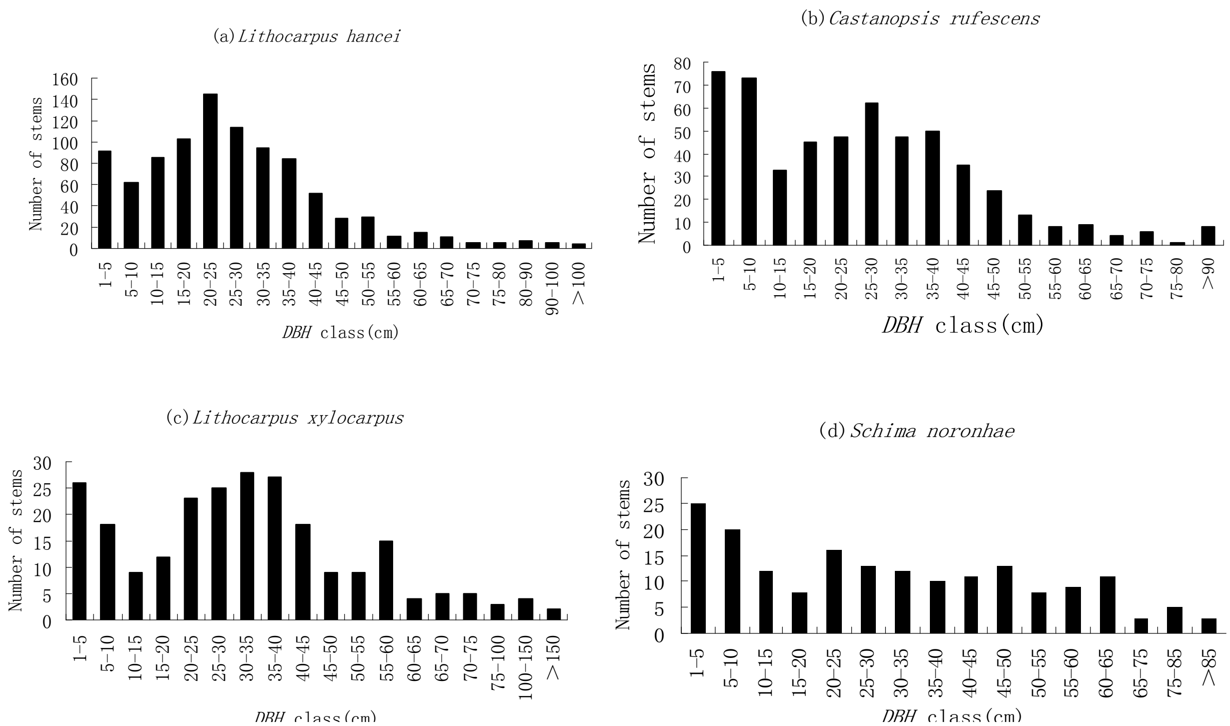

Figure 3. DBH distribution of 4 dominant canopy species in evergreen broad-leaved forest dynamics plot of Ailao mountains.

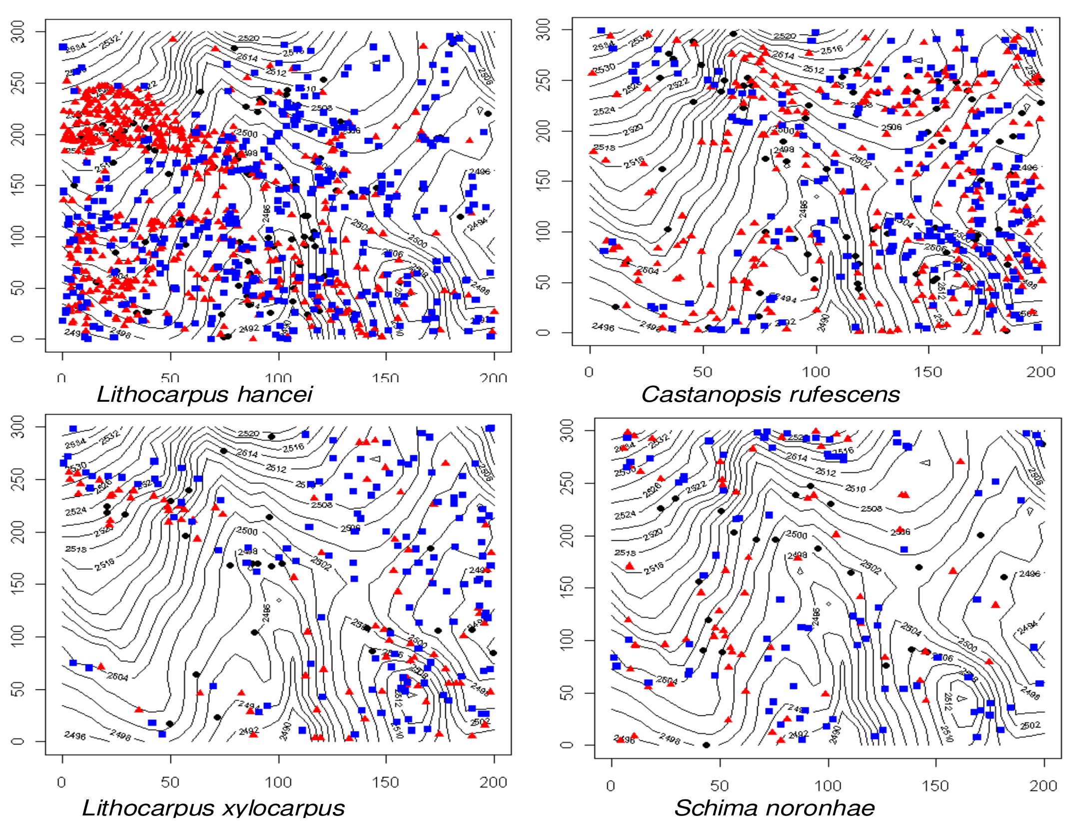

Figure 4. Spatial distribution maps of 4 dominant canopy species in evergreen broad-leaved forest dynamics plot of Ailao Mountains. ●: 1 cm ≤ *DBH* < 5 cm; ▲: 5 cm ≤ *DBH* < 30 cm; ■: *DBH* ≥ 30 cm.

Spatial distribution features of dominant tree species of canopy layer

The dominant tree species of canopy layer of Ailao Mountains evergreen broad-leaved forest assume complementary distribution features in space, which is consistent with the result of Ye et al. (2008) and may be due to the competition among the tree species; however, the spatial distribution of the same tree species in different growth period does not assume distinct complementary distribution features, which is inconsistent with the research result of Ye et al. (2008). Meanwhile, some dominant tree species show distinct habitat preferences, which shows that ecological niche differentiation mechanism plays a crucial role in maintaining the biodiversity of forest communities in the plot (Zhu et al., 2008).

Conclusion

1. In the 6 hm^2 plot of Ailao Mountains mid-mountain humid evergreen broad-leaved forest, there were 12131 trees with a DBH ≥ 1 cm recorded, belong to 25 families, 49 genus, and 68 species. Shannon-Wiener index of tree species was 2.95 ± 0.11 and Pielou evenness index of community was 0.78 ± 0.02. And Ailao Mountains evergreen broad-leaved forest is closely related to both tropical and temperate flora, therfore reflects the transition feature of plant flora in the plot.
2. In respect of community structure, *Lithocarpus hancei* and *Camellia forrestii* are the dominant tree species of canopy and understory layer respectively, and there are some tree species with a large amount of individuals (such as *Camellia forrestii*) and many rare species in the plot.
3. In the community, the dominant tree species of canopy layer have many individuals with a small and medium diameter and very few individuals with a large diameter.
4. In the plot, most species show aggregated distribution pattern. Our findings suggest that it may not be density dependence but habitat heterogeneity as a prevalent mechanism for regulating the population spatial structure of most tree species in the subtropical forest studied here. The dominant tree species of canopy layer assume complementary distribution features in space.

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APPENDIX

Appendix 1. The catalog of tree species in the evergreen broad-leaved forest dynamics plot of the Ailao Mountains.

Species	Number	Relative density	Relative frequency	Relative dominance	Importance value
Castanopsis rufescens	541	4.46	4.75	16.06	8.42
Rhododendron leptothrium	22	0.18	0.30	0.04	0.17
Symplocos anomala	222	1.83	3.55	0.19	1.86
Stewartia pteropetiolata	91	0.75	1.12	0.67	0.85
Symplocos poilanei	424	3.50	3.81	0.17	2.49
Padus napaulensis	1	0.01	0.04	0.06	0.04
Manglietia forrestii	1	0.01	0.04	0.00	0.02
Populus rotundifolia	181	1.49	0.56	1.36	1.14
Machilus yunnanensis	390	3.21	4.97	3.38	3.86
Neolitsea polycarpa	102	0.84	2.02	0.35	1.07
Michelia floribunda	25	0.21	0.82	0.37	0.47
Symplocos ramosissima	1198	9.88	4.52	1.84	5.41
Ilex polyneura	4	0.03	0.11	0.00	0.05
Cyclobalanopsis stewardiana	18	0.15	0.45	0.29	0.29
Stranvaesia davidiana	33	0.27	0.64	0.29	0.40
Ilex manneiensis	86	0.71	1.76	0.32	0.93
Manglietia insignis	298	2.46	2.69	1.46	2.20
Ternstroemia gymnanthera	32	0.26	0.93	0.02	0.41
*Pinus armandi*i	5	0.04	0.15	0.32	0.17
Juglans mandshurica	1	0.01	0.04	0.04	0.03
Litsea elongata	121	1.00	2.13	0.13	1.08
Machilus gamblei	324	2.67	3.48	2.70	2.95
Laurocerasus undulata	59	0.49	1.27	1.45	1.07
Symplocos dryophila	13	0.11	0.45	0.01	0.19
Daphniphyllum macropodum	3	0.02	0.11	0.00	0.05
Ilex gingtungensis	234	1.93	3.21	0.84	1.99
Eurya jintungensis	29	0.24	0.78	0.08	0.37
Malus rockii	20	0.16	0.49	0.11	0.25
Eriobotrya prinoides	273	2.25	3.03	0.87	2.05
Machilus salicina	7	0.06	0.22	0.04	0.11
Rhododendron irroratum	17	0.14	0.49	0.05	0.22
Acer campbellii	88	0.73	1.72	1.03	1.16
Clethra brammeriana	4	0.03	0.11	0.05	0.06
Lithocarpus xylocarpus	242	1.99	3.70	12.10	5.93
Osmanthus fragrans	5	0.04	0.07	0.00	0.04
Schima noronhae	179	1.48	3.29	7.31	4.03
Skimmia arborescens	7	0.06	0.22	0.00	0.09
Schefflera shweliensis	56	0.46	1.23	1.27	0.99
Lindera thomsonii	30	0.25	0.86	0.03	0.38
Symplocos sumuntia	1113	9.17	4.97	1.46	5.20
Litsea cubeba	2	0.02	0.07	0.00	0.03
Meliosma kirkii	30	0.25	0.97	1.45	0.89
Prunus conradinae	2	0.02	0.07	0.10	0.06
Ilex corallina	389	3.21	3.62	3.62	3.48
Ilex szechwanensis	8	0.07	0.22	0.00	0.10
Sorbus rhamnoides	6	0.05	0.22	0.19	0.16
Viburnum cylindricum	17	0.14	0.30	0.13	0.19
Tetracentron sinense	4	0.03	0.11	0.29	0.15
Lithocarpus pachyphyllus	23	0.19	0.49	0.40	0.36

Appendix 1**. Contd.**

Padus perulata	12	0.10	0.45	0.49	0.35
Styrax perkinsiae	185	1.53	2.35	0.63	1.50
Schefflera fengii	4	0.03	0.15	0.03	0.07
Gamblea ciliata	58	0.48	1.27	0.99	0.91
Rhamnus xizangensis	21	0.17	0.64	0.00	0.27
Betula alnoides	1	0.01	0.04	0.06	0.03
Ilex micrococca	32	0.26	0.67	0.08	0.34
Eurya obliquifolia	341	2.81	2.62	0.23	1.89
Neolitsea chuii	49	0.40	1.23	1.24	0.96
Lithocarpus hancei	953	7.86	5.01	27.48	13.45
Camellia forrestii	1712	14.11	5.19	1.02	6.77
Pygeum henryi	1	0.01	0.04	0.00	0.02
Docynia delavayi	3	0.02	0.11	0.03	0.06
Prunus yunnanensis	3	0.02	0.07	0.03	0.04
Vaccinium duclouxii	1355	11.17	4.48	3.06	6.24
Myrsine semiserrata	1	0.01	0.04	0.00	0.02
Lyonia ovalifolia	54	0.45	0.97	0.81	0.74
Illicium burmanicum	314	2.59	2.43	0.76	1.93
Ligustrum delavayanum	52	0.43	1.05	0.12	0.53
Total	1,2131	100	100	100	100