Combined community ecology and floristics, a synthetic study on the upper montane evergreen broad-leaved forests in Yunnan, southwestern China

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A B S T R A C T

The upper montane evergreen broad-leaved forest in Yunnan occurs mainly in the zone of persistent cloud and has a discontinuous, island-like, distribution. It is diverse, rich in endemic species, and likely to be sensitive to climate change. Six 1-ha sampling plots were established across the main distribution area of the upper montane evergreen broad-leaved forest in Yunnan. All trees with d.b.h. > 1 cm in each plot were identified. Patterns of seed plant distributions were quantified at the specific, generic and family levels. The forests are dominated by the families Fagaceae, Lauraceae, Theaceae and Magnoliaceae, but are very diverse with only a few species shared between sites. Floristic similarities at the family and generic level were high, but they were low at the specific level, with species complementarity between plots. Diversity varied greatly among sites, with greater species richness and more rare species in western Yunnan than central Yunnan. The flora is dominated by tropical biogeographical elements, mainly the pantropic and the tropical Asian distributions at the family and genus levels. In contrast, at the species level, the flora is dominated by the southwest or the southeast China distributions, including Yunnan endemics. This suggests that the flora of the upper montane forest in Yunnan could have a tropical floristic origin, and has adapted to cooler temperatures with the uplift of the Himalayas. Due to great sensitivity to climate, high endemism and species complementarity, as well as the discontinuous, island-like, distribution patterns of the upper montane forest in Yunnan, the regional conservation of the forest is especially needed.

1. Introduction

Yunnan Province of southwestern China lies between 21°09’ and 29°15’ N, 97°32’ and 106°12’ E, and occupies an area of 394,100 km². It has a mountainous topography with mountain ridges generally running in a north-south direction, decreasing in elevation southward. Its elevation ranges from 76.4 m at the lowest valley bottom in the southeast (Red River) to 6740 m at the highest mountain summit in the northwest. Yunnan is extremely diverse in habitats and topography. The general climatic pattern consists of tropical wet climates in the southern lowlands, tropical dry climates in deep valleys below 1000 m alt. due to the Foehn effect, subtropical climates on the central plateau, and temperate to cold temperate climates in the northern high mountains.

Several comprehensive vegetation studies in Yunnan (Wu, 1987; Shimizu, 1991; Jin, 1979, 1992) have also been published. Previously, the evergreen broad-leaved forest was treated as a vegetation type in the vegetation classification of Yunnan (Wu, 1980, 1987). The upper montane evergreen broad-leaved forest was classified into the type of mid-montane wet evergreen broad-leaved forest (Jin, 1979).

The upper montane evergreen broad-leaved forest in Yunnan is a species-rich vegetation type and of important significance in the ecosystem and conservation. Aside from several works on community characteristics (Meng et al., 2013) and species composition (Yang et al., 2010) based on one site plot survey, there have been fewer studies on the upper montane forests in Yunnan. Due to geographical isolation and habitat heterogeneity, the floristic
composition, species diversity and vegetation structure of this kind of forest has conspicuous variation across its distribution area. Studies on single plots can give limited information (Peng and Wu, 1998; Wang and Peng, 2004; Liu and Peng, 2007; Gong et al., 2011). To provide a better understanding of this kind of forest, we established six 1-ha plots across the main distribution area of the upper montane evergreen broad-leaved forest in Yunnan.

The upper montane evergreen broad-leaved forest in Yunnan has been likened to cloud forests or mossy forests of Asia (Shi and Zhu, 2009). Studies on cloud forests have mainly been done in tropical America, especially focusing on the Mexican montane forests (Alcántara et al., 2002; Cavelier et al., 1996; Hamilton et al., 1994; Kapos and Tanner, 1985; Kelly et al., 1994; Luna-Vega et al., 2001; Nadkarni et al., 1995; Sugden, 1982; Torre-Cuadros et al., 2007; Williams-Linera, 2002; Williams-Linera et al., 2005), while relatively few studies have been conducted in SE Asia (Aiba and Kitayama, 1999; Brujinzeel et al., 1993; Meijer, 1959; Ohsawa, 1991; Sakhan et al., 2002).

As a new attempt, community ecology and floristics were combined in vegetation studies by Wu Zhengyi in his huge works (Wu, 1980, 1987). Recently, this integrated approach has successfully been used in the tropical forest studies in southern Yunnan to clarify the nature of vegetation types (Zhu, 1997, 2004, 2008; Zhu et al., 1998, 2005, 2006a,b, 2015a,b). In this article, the combination of community ecology and floristics are used to explore the physiognomy, species composition, plant diversity and biogeography of the forest, and to provide suggestions for its conservation.

2. Methods

Six 1-ha sampling plots were established in well-conserved forest patches across the main distribution area of the upper montane evergreen broad-leaved forest in Yunnan (Fig. 1), among them three are located in western Yunnan and three in central Yunnan. Our plots were selected in currently well-conserved patches of the forest (it is impossible to design well-distributed sampling plots according to normative latitude and altitude in Yunnan due to the complicated topography and serious human disturbances). Each 1-ha sampling plot was divided into 100 10 m × 10 m subplots. All trees with d.b.h. > 1 cm in each plot were identified and their d.b.h. and height measured. Importance value indices (IVI) (Curtis and McIntosh, 1951) were calculated for each tree species in the six 1-ha plots (IVI = Relative abundance + Relative dominance + Relative frequency). In each 1-ha sampling plot, importance value indices at family level were calculated by the sum of all species in this family. Shannon–Wiener index \( H' = -\sum P_i \ln P_i \) and Simpson’s diversity index \( D = 1 - \sum P_i^2 \) for species diversity were calculated from the plot data. Species authorities follow Flora Reipublicae Popularis Sinicae (Flora of China). Patterns of seed plant distributions were quantified at the specific level from data in the Flora of China, at the generic level based on Wu’s documentation (1991) and at the family level following Wu et al. (2003). Comparisons of both floristic composition and geographical elements were made to assess floristic similarities and variation in these sites, as well as to determine biogeographical affinities of the upper montane forest.
| Table 1 | Dominant tree species (top 30) and their important values (IVI) in the sampling plots. |
|---------|-------------------------------------------------------------------------------------------------|
| Location: 22° 06’ 36” N, 99° 23’ 54” E |
| Total tree species: 36 |
| Total tree stems: 4930 |
| Shannon–Wiener’s diversity index: 3.61614 |
| Simpson index: 0.96259 |
| Location: 24° 30’ 11” N, 99° 23’ 54” E |
| Total tree species: 54 |
| Total tree stems: 5387 |
| Shannon–Wiener’s diversity index: 3.60832 |
| Simpson index: 0.96340 |

| Location: 24° 16’ 53” N, 101° 15’ 53” E |
| Total tree species: 57 |
| Total tree stems: 5387 |
| Shannon–Wiener’s diversity index: 2.73883 |
| Simpson index: 0.89651 |

| Location: 21° N, 101° 01’ 34” E |
| Total tree species: 38 |
| Total tree stems: 3480 |
| Shannon–Wiener’s diversity index: 2.99099 |
| Simpson index: 0.93245 |

| Location: 25° 05’ 54” N |
| Total tree species: 31 |
| Total tree stems: 3980 |
| Shannon–Wiener’s diversity index: 2.43101 |
| Simpson index: 0.86066 |

| Helicia shweliensis |
| 21.29 |
| Helicia shiawensis |
| 28.53 |
| Beilschmiedia yunnanensis |
| 13.77 |
| Lithocarpus xyloterus |
| 39.14 |
| Castanopsis virginiana |
| 35.88 |
| Schima noronhae |
| 33.57 |
| Rhododendron delavayanum |
| 25.24 |
| Rhododendron delavayanum |
| 25.06 |
| Vaccinium caffrum |
| 18.13 |
| Vaccinium duclouxii |
| 13.10 |
| Vaccinium duclouxii |
| 12.31 |
| Vaccinium duclouxii |
| 11.12 |
| Syzygium lineatum |
| 4.65 |
| Syzygium lineatum |
| 9.21 |
| Cerasus yunnanensis |
| 6.74 |
| Syzygium lineatum |
| 6.68 |
| Daphne tatarica |
| 3.16 |
| Daphne tatarica |
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| 3.16 |
3. Results

3.1. Species assemblage

The upper montane evergreen broad-leaved forest in Yunnan is very diverse in species composition, even in dominant species (Table 1), although most sites are dominated by the families Fagaceae, Lauraceae, Theaceae and Magnoliaceae or Ericaceae at higher altitudinal sites (Table 2). The families Fagaceae, Lauraceae and Theaceae have the highest importance values in most plots (Table 2), followed by Magnoliaceae and Rosaceae. However, the Proteaceae has high importance values in Daheishan I and Daheishan II, while the Symplocaceae and Ericaceae have a high importance value in Xujiaiba and Nanhua, respectively. Fagaceae, Lauraceae, Theaceae are the most species-rich families in all six plots, followed in most plots by Rosaceae and Araliaceae.

The two nearby plots Daheishan I and Daheishan II in western Yunnan share the dominant tree species Helicia shwéliensis, but differ in subdominant species. In the Gaoligong Mts. plot, Belischmiedia yunnanensis is the most dominant species. In the Qianjiazaig plot in central Yunnan, Lithocarpus xylocarpus is the most dominant species, while in the Xujiaiba plot at higher elevation, Castanopsis wuttii is the most dominant species. In the Nanhua plot at the highest elevation, Castanopsis orthacantha is the most dominant species, followed by Vaccinium duchouxi, Rhododendron delavoyi.

Among the top ten dominant species, none is shared by all six plots. However, among the all tree species recorded, five species, Laurocerasus undulata, Michelia floribunda, Lithocarpus hancei, Ternstroemia gymnanthera and Symposcos ramosissima, were found in five plots. L. xylocarpus and Machilus yunnanensis were found in four plots. The two nearby plots, Daheishan I and Daheishan II, share 59 species, but shared species are much less important in the other plots.

3.2. Physiognomy

The six plots covered an altitudinal range of 2190 m–2730 m, and of them three plots representing different altitudes were selected to illustrate the physiognomy of the forest.

Table 2
Dominant families ranked by the Importance Value Index (IVI) and by species richness in the six 1-ha plots.

| Location       | Family ranked by IVI | Family ranked by number of species |
|----------------|----------------------|-----------------------------------|
| Daheishan I    | Lauraceae 67.57      | Lauraceae 25                      |
| Daheishan II   | Lauraceae 77.11      | Lauraceae 16                      |
| Gaoligong Mts. | Fagaceae 35.07       | Fagaceae 10                       |
| Qianjiazi      | Proteaceae 21.29     | Theaceae 8                        |
| Xujiaiba       | Rosaceae 20.94       | Rosaceae 5                        |
| Nanhua         | Theaceae 19.09       | Araliaceae 4                      |

Table 3
Comparisons of plant life forms in three 1-ha forest plots.

| Location       | L | Megaph | Mesoph | Microph | Nanoph | HPH & Ch | H | G | Ep | Sa | Total |
|----------------|---|--------|--------|---------|--------|----------|---|---|----|----|-------|
| Nanhua (2730 m alt.) | 16 | 0      | 22     | 24      | 17     | 13       | 13| 6 | 6  | 0  | 116   |
| %              | 13.79 | 0.00  | 18.97  | 20.69   | 14.66  | 11.21    | 11.21| 5.17 | 5.17 | 0.00 | 100.00 |
| Xujiaiba (2450 m alt.) | 18 | 1     | 44     | 12      | 9      | 28       | 21 | 7  | 2  | 2  | 164   |
| %              | 10.98 | 0.61  | 26.83  | 7.32    | 5.49   | 17.07    | 12.80| 4.27 | 13.41 | 1.22 | 100.00 |
| Daheishan I (2250 m alt.) | 26 | 3     | 72     | 16      | 15     | 13       | 15 | 6  | 36 | 7  | 209   |
| %              | 12.44 | 1.44  | 34.45  | 7.66    | 7.18   | 6.22     | 6.22| 2.87 | 17.22 | 3.35 | 100.00 |

L: Liana; Megaph: Megaphanerophytes; Mesoph: Mesophanerophytes; Microph: Microphanerophytes; Nanoph: Nanophanerophytes; HPH & Ch: Chamaephytes & Herbaceous phanerophytes; G: Geophytes; H: Hemicyryptophytes; Ep: Epiphytes; Sa: Sarpophytes (Raunkiaer (1934) revised by Mueller-Dombois and Ellenberg, 1974).

3.3. Species diversity

The number of tree species >1 cm d.b.h. (diameter at breast height) in a 1-ha sampling plot was 39–88 in these upper montane forests (see Table 1). The number of species was more in the three plots in western Yunnan than in other three plots in central Yunnan. The Shannon–Weiner index showed a similar pattern to species richness. Species sequences ranked by Importance Value

Table 4
Comparisons of leaf features of tree species in three 1-ha plots.

| Location       | Leaf sizea | Leaf type | Leaf margin |
|----------------|------------|-----------|-------------|
|                | Ma % | Me % | Mi % | Single | Compound % | Entile | None | entile % |
| Nanhua         | 5.13 | 53.85 | 41.03 | 100 | 0 | 56.41 | 43.59 |
| Xujiaiba       | 4.88 | 65.85 | 29.27 | 90.24 | 9.76 | 48.78 | 51.22 |
| Daheishan I    | 4.65 | 72.09 | 23.26 | 93.02 | 6.89 | 76.74 | 23.26 |

Ma: Macrophyll; Me: Mesophyll; Mi: Microphyll.

R-values

*Webb (1959) split off the lower end of Raunkiaer's big mesophyll class (2025–18,225 mm²) as notophylls (2025–4500 mm²). Although it is better for detailing categories of leaf size spectrum, Chinese botanists are more familiar with Raunkiaer's big mesophyll class, and here we use Raunkiaer's big mesophyll class for the evergreen broad-leaved forest in Yunnan.
Index (IVI) of the six forest plots showed the presence of more rare species in the three plots in western Yunnan (Fig. 2). Species sequences ranked by stems of the six plots showed the same patterns as the species sequences ranked by IVI: the presence of more rare species in the three plots in western Yunnan (Fig. 3).

3.4. Floristic analysis

A total of 219 tree species in 91 genera and 41 families were recorded from the six 1-ha plots. Eight geographical elements at the family level were recognized, of which the pantropic distribution is the most dominant element, accounting for 36.59% of the total families, followed by the north temperate distribution (Table 5). All tropical families together made up 53.66%, while all temperate families together made up 31.71% of total families. At the generic level, 13 geographical elements were recognized, of which the tropical Asian genera contributed 27.47%, followed by the pantropic genera (13.19%), and the east Asia and north America disjunct genera (14.29%), as well as the north temperate genera (12.09%) (Table 5). All tropical elements together made up 59.34% of the total genera, and all temperate elements made up 38.46%. Clearly, at both the family and the genus levels, tropical elements were dominant. At the species level, however, elements from southwest or southeast China, including Yunnan, have the highest percentage, accounting for 44.29% of the total species, followed by the species with south Asia to mainland southeast Asia (SE Himalaya) distributions, which accounted for 26.94%.

3.5. Species complementarity

Floristic similarities between plots are high at the family and generic levels, but low at the species level (Table 6), with the exception of Daheishan I and Daheishan II. Species-level similarities decline with separation distance. Species complementarity between plots is conspicuous.

4. Discussion

The upper montane evergreen broad-leaved forest in Yunnan is dominated by the families Fagaceae, Lauraceae, Theaceae and Magnoliaceae. However, it is very diverse in species. Only five species were found in common in five of the six plots, and none of these are dominants. Floristic similarities at the family and generic levels were high, but low at the species level, demonstrating species complementarity across plots. One possible explanation could be that upper montane evergreen broad-leaved forest areas in Yunnan were quickly uplifted with the Himalayas during the Quaternary period, while the common Tertiary flora underwent conspicuously rapid speciation in response to the quick uplift of the mountains.

Fig. 2. Species sequences ranked by IVI of the six forest plots.
Species richness was higher in the three plots in western Yunnan than in the three plots in central Yunnan. Species sequence patterns show the presence of more rare species in the three plots in western Yunnan. Charcoal was frequently found in the soil during our field survey in central Yunnan, suggesting a possibly long history of anthropogenic fires, which would explain the lower richness. The large areas of pine forest dominated by the fire-tolerant *Pinus yunnanensis* in central Yunnan support this historical explanation (Tang et al., 2013).

Yunnan has a similar latitude and mountain topography to Mexico. The Mexican cloud forests have a wider distribution range, from 600 m to 3000 m a.s.l., but optimally between 1200 m and 2450 m (Alcántara et al., 2002). The montane forests in Yunnan occur in a relatively narrow range from 2100 m to 2900 m a.s.l., and have a generally higher altitudinal distribution. It could be related to the large uplift of the Himalayas and be affected by the ‘Massenerhebung’ effect (Grubb, 1971; Bruijnzeel et al., 1993). The Mexican cloud forests are characterized by species in the genera *Clethra, Magnolia, Meliosma, Styrax, Symplocos* and *Ternstroemia* (Alcántara et al., 2002). The upper montane forests in Yunnan have the same six genera as Mexico, although they are not dominant. In a 1-ha plot of tropical montane forest in Peru, trees with dbh >10 cm belonging to 135 species, 66 genera and 35 families were recorded (Torre-Cuadros et al., 2007). In our plots, tree species >1 cm dbh in a 1-ha sampling plot included 39–88 species, 28–55 genera and 15–31 families. Although the species richness varies conspicuously from place to place in tropical America, floristic richness of the montane forest in Yunnan looks lower than that in American montane forests.

Studies on tropical montane forests in tropical America suggested that similar elevation and environmental conditions do not dictate similar structure and floristics (Nadkarni et al., 1995). They have great heterogeneity in species composition and vegetation structure over short geographical distances (Williams-Linera, 2002). This is supported by our work in Yunnan, which shows conspicuous floristic variation occurs among the six plots. In the fragments of Mexican montane forests, species composition was different, but complementary. The similarity in species was low between fragments, and species turnover between sites was very high, with complementarities between pairs of sites higher than 50% in all cases (Williams-Linera, 2002; Williams-Linera et al., 2005). In the montane forest in Yunnan, as in the fragments of Mexican montane forests, the species similarity is low and species complementarity is conspicuous between plots in separate sites.

The flora of the tropical American montane forests was suggested to be a blend of Neotropical elements that have adapted to
floristic similarities at the family, generic and species levels.

Table 5
Composition of geographical elements at the family, genus and species levels.

| Geographical elements at family level | Number of families | % |
|--------------------------------------|--------------------|---|
| Cosmopolitan                         | 6                  | 14.63 |
| Pantropic                            | 15                 | 36.59 |
| Tropical Asia and tropical America disjunct | 5                  | 12.20 |
| Tropical Asia to tropical Australia  | 1                  | 2.44 |
| Tropical Asia                        | 1                  | 2.44 |
| (Tropical in total)                  | (22) (53.66)       | |
| North temperate                      | 8                  | 19.51 |
| East Asia and North America disjunct | 3                  | 7.32 |
| East Asia                            | 2                  | 4.88 |
| (Temperate in total)                 | (12) (31.71)       | |
| Total number of families             | 41                 | 100 |

| Geographical elements at genus level | Number of genera | % |
|-------------------------------------|------------------|---|
| Cosmopolitan                        | 2                | 2.20 |
| Pantropic                           | 12               | 13.19 |
| Tropical Asia and tropical America disjunct | 8      | 8.79 |
| Old world tropic                    | 3                | 3.30 |
| Tropical Asia to tropical Australia | 3                | 3.30 |
| Tropical Asia to tropical Africa    | 3                | 3.30 |
| Tropical Asia                        | 25               | 27.47 |
| (Tropical in total)                 | (54) (59.34)     | |
| North temperate                      | 11               | 12.09 |
| East Asia and North America disjunct | 13               | 14.29 |
| Old world temperate                 | 1                | 1.10 |
| Mediterranean, W Asia to C Asia     | 1                | 1.10 |
| East Asia                            | 7                | 7.69 |
| Endemic to China                    | 2                | 2.20 |
| (Temperate in total)                | (35) (38.46)     | |
| Total number of genera              | 91               | 100.00 |

| Geographical elements at species level | Number of species | % |
|---------------------------------------|-------------------|---|
| East Asia                             | 11                | 5.02 |
| SW or to SE China including Yunnan    | 97                | 44.29 |
| S Asia to Mainland SE Asia (SE Himalaya) | 59             | 26.94 |
| Mainland SE Asia to S China           | 26                | 11.87 |
| India–Malaysia                        | 26                | 11.87 |
| Total number of species               | 219               | 100.00 |

Floristic similarities at the family, generic and species levels.

Table 6
Comparison of floristic similarities at the family, generic and specific levels between these plots.

| Compared plots | Daheishan I | Daheishan II | Gaoligong | Qianjzahai | Xujia | Nanhua |
|----------------|-------------|--------------|-----------|------------|-------|--------|
|                | Shared/similarity coefficient (%) | Shared/similarity coefficient (%) | Shared/similarity coefficient (%) | Shared/similarity coefficient (%) | Shared/similarity coefficient (%) | Shared/similarity coefficient (%) |
| Similarity coefficients at family level | 100/100 | 27/90 | 25/83.33 | 16/84.21 | 11/73.33 | 10/66.67 | 100/100 |
| Daheishan I    | 24/80 | 16/84.21 | 13/86.67 | 12/80 | 12/84.21 | 11/73.33 | 10/66.67 | 100/100 |
| Daheishan II   | 100/100 | 24/80 | 16/84.21 | 12/80 | 100/100 | 100/100 | 100/100 |
| Gaoligong      | 25/83.33 | 16/84.21 | 11/73.33 | 100/100 | 100/100 | 100/100 |
| Qianjzahai     | 27/90 | 16/84.21 | 13/86.67 | 12/80 | 12/84.21 | 11/73.33 | 10/66.67 | 100/100 |
| Xujia          | 25/83.33 | 16/84.21 | 11/73.33 | 100/100 | 100/100 | 100/100 |
| Nanhua         | 27/90 | 16/84.21 | 13/86.67 | 12/80 | 100/100 | 100/100 |
| Similarity coefficients at generic level | 100/100 | 31/60.78 | 27/75 | 20/71.43 | 15/53.57 | 100/100 |
| Daheishan I    | 24/80 | 29/80.56 | 24/85.71 | 24/85.71 | 16/57.14 | 100/100 |
| Daheishan II   | 100/100 | 24/85.71 | 14/50 | 14/50 | 16/57.14 | 100/100 |
| Gaoligong      | 25/83.33 | 29/80.56 | 18/84.29 | 12/84.21 | 16/57.14 | 100/100 |
| Qianjzahai     | 31/60.78 | 29/80.56 | 22/78.57 | 22/78.57 | 13/46.43 | 100/100 |
| Xujia          | 27/75 | 24/85.71 | 22/78.57 | 22/78.57 | 13/46.43 | 100/100 |
| Nanhua         | 20/71.43 | 20/71.43 | 22/78.57 | 22/78.57 | 13/46.43 | 100/100 |
| Similarity coefficients at specific level | 100/100 | 27/75 | 20/71.43 | 20/71.43 | 15/53.57 | 100/100 |
| Daheishan I    | 59/75.64 | 16/23.33 | 102/12.2 | 102/12.2 | 102/12.2 | 102/12.2 |
| Daheishan II   | 59/75.64 | 16/23.33 | 102/12.2 | 102/12.2 | 102/12.2 | 102/12.2 |
| Gaoligong      | 59/75.64 | 16/23.33 | 102/12.2 | 102/12.2 | 102/12.2 | 102/12.2 |
| Qianjzahai     | 59/75.64 | 16/23.33 | 102/12.2 | 102/12.2 | 102/12.2 | 102/12.2 |
| Xujia          | 59/75.64 | 16/23.33 | 102/12.2 | 102/12.2 | 102/12.2 | 102/12.2 |
| Nanhua         | 59/75.64 | 16/23.33 | 102/12.2 | 102/12.2 | 102/12.2 | 102/12.2 |

* Similarity coefficient between A and B – the number of taxa shared by both A and B divided by the lowest number of taxa of A or B, multiplied by 100%.

floristic similarities at the family and the genus levels, which suggests that the flora could also have a tropical floristic origin. At the species level, however, elements from southwest and southeast China, including Yunnan, are represented by the highest percentage (Zhu, 2016). It is possible that the flora in Yunnan could have originated from a tropical lowland flora, and these tropical elements have since adapted to cooler temperatures with uplift of the Himalayas; subsequently, temperate elements immigrated from the north temperate and east Asian regions, and rapid speciation occurred with the rising elevation of this region (Zhu, 2012).

5. Conservation implications

Montane cloud forests are sensitive to climate (Foster, 2001). They are very rich in epiphytic species, which are sensitive to air humidity and are considered excellent environmental indicators (Li et al., 2013). They are also strongly linked to regular cycles of cloud formation (Still et al., 1999). The upper montane forest in Yunnan has high endemism and a great sensitivity to climate. The conservation of the upper montane forest against globe warming is exceptionally important. Due to geographical isolation and habitat heterogeneity, the floristic composition and species diversity of this kind of forest display variation across its distribution area and species complementarity is high. The regional conservation of the upper montane forest, not just of several sites, is therefore needed. The plots in western Yunnan have more species richness and more rare species than the plots in central Yunnan. Therefore, it is also important to pay more attention to the upper montane forest in western Yunnan for conservation.

6. Conclusion

The upper montane forest in Yunnan is dominated by the families Fagaceae, Lauraceae, Theaceae and Magnoliaceae, but is very diverse in species. Only a few species were shared between separate sites. Floristic similarities at the family and generic level were high, but they were low at the specific level, with species complementarity between plots. Diversity varied greatly among sites, with both species richness and rare species more in western

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Yunnan than central Yunnan, suggesting a possibility of a long history of anthropogenic disturbance in central Yunnan. The flora is dominated by tropical biogeographical elements, mainly the pantropical and the tropical Asian distributions at the family and genus levels, but the southwest or to southeast China distribution, including Yunnan endemics at the species level. This suggests that the flora of the upper montane forest in Yunnan could have a tropical floristic origin, and has adapted to cooler temperatures with the uplift of the Himalayas, and then undergone rapid speciation in response to the rising elevation of this region. Regional conservation of these forests is needed due to a number of factors: high sensitivity to climate; high endemism and species complementarity; as well as discontinuous, island-like distributions.

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