Research Article

Changes in the diversity of evergreen and deciduous species during natural recovery following clear-cutting in a subtropical evergreen-deciduous broadleaved mixed forest of central China

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Abstract

Clear-cutting has been a widespread commercial logging practice, causing substantial changes of biodiversity in many forests throughout the world. Forest recovery is a complex ecological process, and examining the recovery process after clear-cutting is important for forest conservation and management. In the present study, we established fourteen 20 m × 20 m plots in three recovery stages (20-year-old second growth, 35-year-old second growth and old growth) and explored the changes in evergreen and deciduous species diversity after clear-cutting in a subtropical evergreen-deciduous broadleaved mixed forest in central China. The results showed that total species richness was highest at the intermediate recovery stage. The species richness and stem abundance of evergreen species increased, while total and deciduous species stem abundance decreased with forest recovery. The basal area of both total and evergreen species increased, while that of the deciduous species showed a unimodal pattern. The abiotic conditions varied with the recovery process. Changes in species compositions were generally correlated with soil pH, total phosphorus, and CO. Our results suggest that deciduous species richness and stem abundance can recover after 20-35 years, but evergreen species need more time to recover following clear-cutting.

Keywords: Abiotic environment; Clear-cutting; Evergreen/deciduous species; Natural recovery; Subtropical evergreen-deciduous broadleaved mixed forest

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Introduction

With the continuing disappearance of primary old-growth forests, secondary forests have become one of the main forest types in the world [1]. Over half of temperate and tropical forests have been classified as regenerating, young secondary forests [2]. The dominance of secondary forest ecosystems has stimulated research on patterns of diversity, structure, and dynamics in tropical [3], subtropical [4] and temperate regions [5]. Because second growth forests are dynamic, any point on the landscape could represent a different stage of forest recovery [2]. Understanding how the structure and composition of secondary forests change as they age and which variables control recovery are central questions in forest ecology and management [6].

Secondary forests are often subject to multiple and compounded disturbances. Understanding how forest disturbances such as fire, insect attack and logging affect succession is essential for developing ecologically sustainable forest management strategies [7]. In general, the number of coexisting species is low following major disturbance, as only a few species survive. Post-disturbance, species richness should increase to a maximum, beyond which only a few highly competitive species become dominant and suppress other species, reducing species richness once again [8]. The disturbances are both natural and human-induced [9]. Anthropogenic disturbances, such as logging, agriculture, and shifting cultivation, play key roles in the trajectory of secondary growth forests [10]. For example, Pykälä [11] reported higher species diversity in clear-cut areas than in old growth areas.

The concept of succession was introduced in 1916 by Frederick E. Clements, who stated that all bare places give rise to new communities except those with the most extreme conditions of water, temperature, light, or soil [12]. The ecological theory of succession is the basis for restoration and vegetation management.

Two main approaches are used to explore secondary succession: indirect measures (chronosequences and space-for-time substitution), and vegetation dynamics monitoring. Indirect measures compare plots with different successional ages, while vegetation dynamics monitoring documents the development of the vegetation in permanent plots, through re-census [13]. Permanent plots and long-term study can provide actual observation of successional vegetation changes, but because few studies extend beyond several decades, indirect measures are frequently used to reconstruct forest succession [14].

Secondary forests of different ages vary in species composition and structure due to changes in environmental conditions as succession proceeds [15]. Disturbance may change environmental conditions or modify organism composition, influencing forest successional processes [16]. Abiotic factors such as light and soil nutrients have significant influences on plant growth and development. Light is a limiting resource in the understory of forests, and light levels generally decline during succession. Shade-intolerant species are gradually reduced and replaced by shade-tolerant species [17]. Soil nutrients affect species richness, which generally peaks at intermediate nutrient levels and declines gradually at high nutrient levels [18]. Vegetation development and changes in environmental parameters in the successional course have been studied in various types of landscapes [19, 20]. However, there are few studies on vegetation succession in the subtropical evergreen-deciduous broadleaved forest that directly link vegetation dynamics to environmental conditions.

Evergreen broad-leaved forests are a major forest type in the subtropical region of China and are a globally distinct forest ecosystem at latitudes of 25–35°N. With increasing altitude and decreasing temperature, subtropical evergreen-deciduous broadleaved forests become the dominant vegetation type. Evergreen and deciduous species typically have distinct morphological and functional features. The most obvious trait for distinguishing evergreen and deciduous species is that evergreen species have a longer leaf-life span than deciduous species. Evergreen and deciduous species represent different life strategies for coping with environmental conditions [21]. For example, evergreen species may be better adapted to harsh environments in the understory than deciduous species, due to the lower resource-loss ratios of the former [22].

In this study we examine species composition and structure in established permanent plots along a chronosequence. We tracked changes in diversity of evergreen and deciduous woody species and associated abiotic factors during secondary succession following clear cutting in a subtropical evergreen-deciduous broadleaved mixed forest in central China. Understanding the recovery processes in this forest type will be useful in designing conservation and management plans for forest ecosystems in human-dominated landscapes. We asked the following questions: (1) how does species diversity change during natural recovery following clear cutting? And (2) What environmental factors are significantly correlated with species composition at different stages of recovery?

Methods

Study site

The study area is located in the 208 km^2 Mulinzi National Nature Reserve (29°55′–30°10′ N, 109°59′–110°17′ E) in south-west Hubei Province, central China (Fig.1). Elevation ranges from 1,100 to 2,095.6 m asl. The climate is humid subtropical monsoon with a mean annual precipitation of 1,733 mm, which mostly falls from June to September. The mean annual temperature is 15.5℃, with the mean monthly maximum of 26℃ in July and the mean monthly minimum of 4.6℃ in January. The dominant soils are yellow-brown earth (Alfisols) [23] , which are well drained soils without spectacular differentiation of horizons, although many have illuvial horizons commonly of clay.

The dominant vegetation type is subtropical evergreen-deciduous broadleaved mixed forest. Historically, most of the forests clear cut, especially before 1978, after which almost all areas were left to regenerate naturally as a secondary forest.

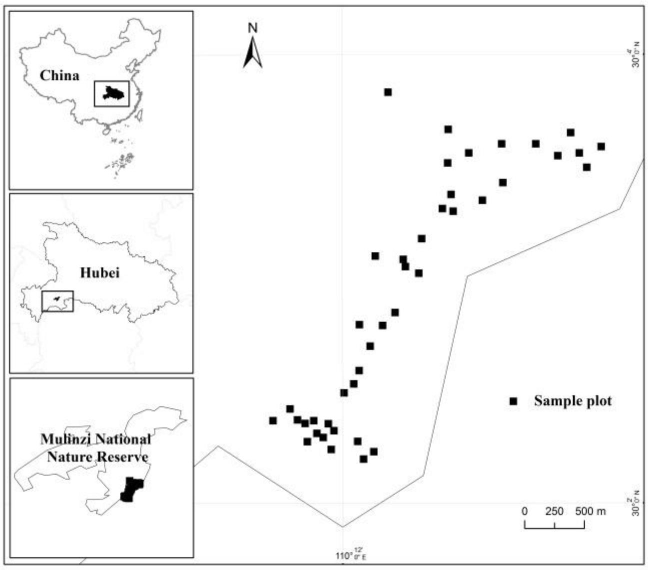


Fig. 1. Diagram of the sample plots and study site in the southwest of Hubei Province, central China.

Data collection

Fieldwork was conducted from August of 2013 to September of 2014. Two recovery stages of 20 years (SF20) and 35 years (SF35) since clear cutting were selected and compared to old-growth forest (OG). We established 42 permanent plots 20 m × 20 m in size, with 14 plots in each recovery stage. Each of the 14 plots was randomly selected and environmental conditions (elevation, slope) were similar in all. All woody stems including trees, shrubs and lianas ≥ 1 cm DBH (diameter at breast height) were tagged and mapped, with their species names and DBH recorded for each plot. The nomenclature and leaf phenology (deciduous or evergreen) of the species followed *Flora of China* (English edition; http://www.efloras.org). Surface soil samples (0–20 cm depth) were collected from five randomly selected points in each plot and mixed them into one sample for each plot. Soil samples were air-dried and then sieved through 2 mm mesh. Soil water content (SWC), soil pH, and soil nutrients were analyzed in the laboratory. Soil pH was measured using a 1:2.5 soil/water mixture and a digital pH meter; soil available nitrogen (AN) was determined by the Cornfield method; soil total nitrogen (TN) was determined by the semimicroKjeldahl method; soil organic matter (SOM) was determined by the $K_2Cr_2O_7$ titration method after digestion; soil total phosphorus (TP) was determined colorimetrically after wet digestion with H_2SO_4 plus $HClO_4$; and soil available phosphorus (AP) and available potassium (AK) were extracted with 3% $(NH_4)_2CO_3$ solution [24]. We took a hemisphere photograph at 1.5 m above ground in the center of each plot, using a fisheye lens (SIGMA 8mm F3.5 EX DG fisheye and Canon 450D digital camera). The canopy openness (CO) was calculated using the Gap Light Analyzer software.

Data analysis

Species were grouped into evergreen and deciduous species according to the *Flora of China*. The following forest stand characteristics of each recovery stage were calculated: species richness, stem abundance, and basal area. Stand characteristics and environmental factors among the three recovery stages were compared by one-way ANOVAs. We performed multiple comparisons using Tukey Honest significant differences (HSD) to determine the significances of differences among different recovery stages. Species richness was compared among the recovery stages using individual-based rarefaction species accumulation curves to eliminate the effect of stem density on species richness.

To illustrate similarities among plots, a non-metric multidimensional scaling (NMDS) was made using species abundance data from the three recovery stages, based on a dissimilarity matrix generated using Bray–Curtis distance.

To assess the relationship between environmental factors and the compositions of species in each recovery stage, redundancy analysis (RDA) was used. The relationship between environmental variables and species abundance was tested with 999 permutations using the "envfit" function in the "vegan" package of R 3.1.3 [25], and only predictors that significantly ($p < 0.05$) influenced the variation in species composition were included in the RDA model.

All data were transformed with a natural logarithm function in order to improve the normality. For all analyses, we used the statistical package R, version 3.1.3, with the additional packages "vegan" and "ade4".

Results

Changes in environmental conditions during recovery following clear cutting

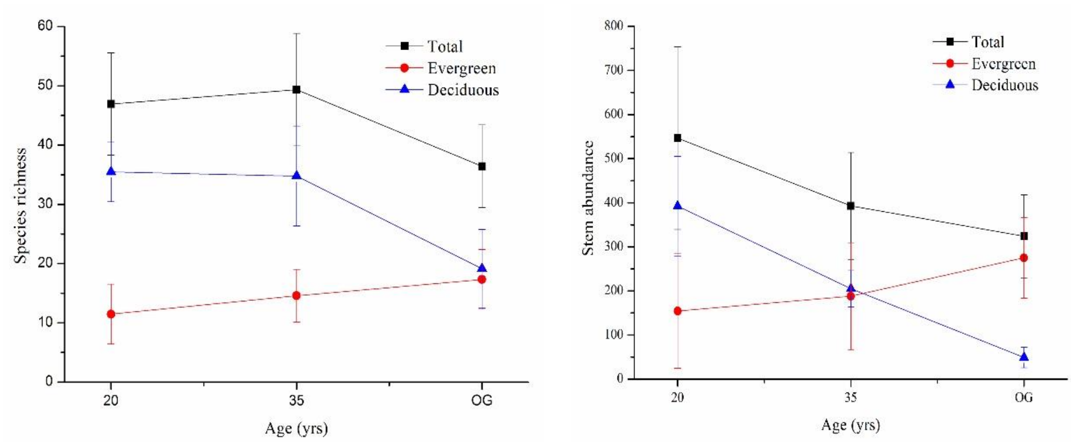
Differences in environmental factors were found among different recovery stages (Table 1). Generally, soil water content and all the nutrients (SOM, TN, TP, AN, AP, AK) initially decreased and then increased with recovery. Soil water content and nutrients were not significantly different between SF20 and OG. CO decreased with recovery and was lowest in old growth forests ($p < 0.05$). Soil pH value did not show any significant change during the recovery.

Table 1. Environmental variables (mean ± SD) in the three recovery stages. Means with different letters are significantly different ($p < 0.05$).

Recovery stage	Environmental variables								
	SWC (%)	pH	SOM (g/kg)	TN (g/kg)	AN (mg/kg)	TP (g/kg)	AP (mg/kg)	AK (mg/kg)	CO (%)
SF20	0.38±0.1b	4.67±0.1a	86.2±15b	6.17±1.2 ab	359.1±68.5a	0.59±0.1 ab	0.17±0.04a	163.75±36.4 a	15.1±1.7b
SF35	0.33±0.1a	4.68±0.3a	69.0±18a	5.2±0.9b	308.6±63.3a	0.47±0.1b	0.14+0.02a	132.66±37.7 a	12.77±1.9a
OG	0.41±0.1ab	4.65±0.2a	81.2±17ab	6.86±2.6a	365.3±98.0a	0.67±0.3a	0.16+0.03a	139.57±53.9 a	10.27±1.3a

Changes in species diversity and composition during recovery following clear cutting

In the 42 investigated plots, a total of 17,791 stems representing 245 species were found, including 79 evergreen and 166 deciduous species (Appendix 1). The species richness generally increased and then decreased with recovery (Fig. 2). Total species richness and deciduous species richness in SF35 and SF20 were significantly higher than OG, but evergreen species richness in OG was significantly higher than SF20 ($p < 0.01$). The abundance of total and deciduous stems declined, while evergreen stem abundance increased gradually with recovery. Total stem abundance in SF20 was significantly higher than SF35 and OG ($p < 0.01$). There were significant differences ($p < 0.001$) in the deciduous stem abundance among the different stages. The basal area of total and evergreen species gradually increased, while deciduous species basal area increased and then declined with recovery. The basal area of total and evergreen species in the OG was significantly higher than SF20 and SF35 ($p < 0.001$).



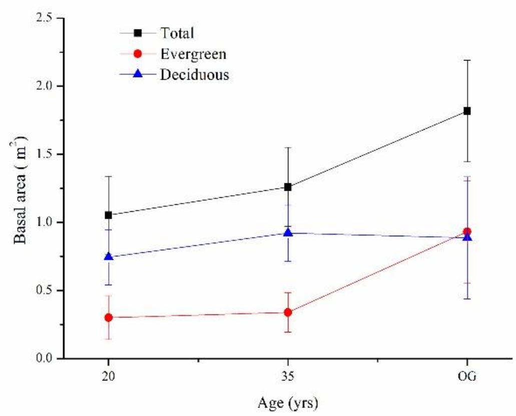


Fig. 2. Species richness, stem abundance, and basal area per plot (400 m^2) in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages.

Deciduous species dominated the SF20, but the evergreen species gradually increased with increasing recovery age. At the OG stage, evergreen and deciduous species contributed equally to the species richness and basal area, but stem abundance of evergreen species was significantly higher than that of deciduous species ($p < 0.05$).

According to the species accumulation curves (Fig. 3), species richness increased with stem abundance and approached stabilization after 2,000 stems within each stage. The species accumulation rate after rarefication was highest in SF35 for both total species and evergreen species. The species rank-abundance curves revealed the same patterns of changes in diversity for the three recovery stages.

The NMDS ordination clearly separated forest plots in different stages of recovery (Fig. 4). The NMDS ordination showed more similarities between evergreen species in OG and SF35, and between deciduous species in SF35 and SF20.

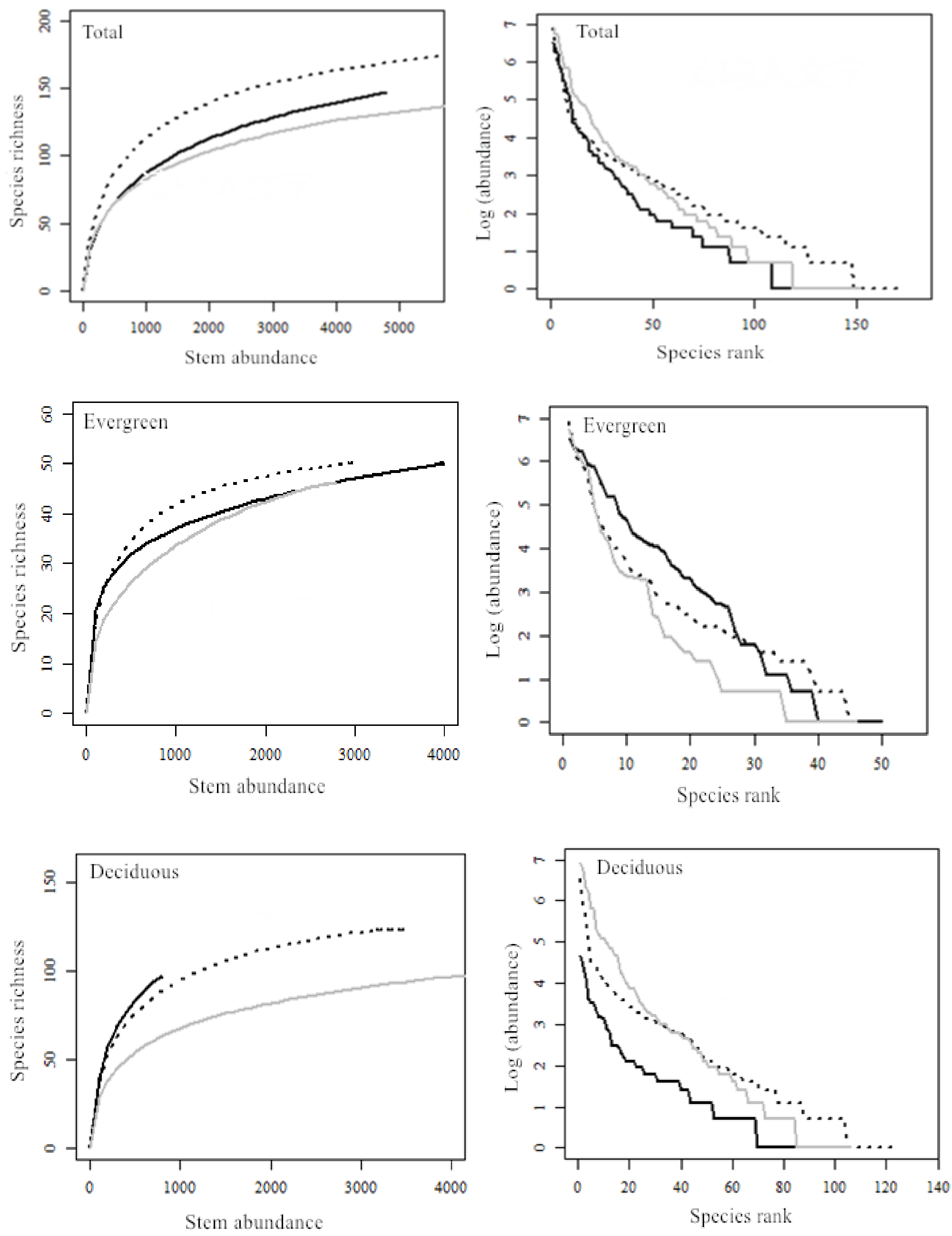


Fig. 3. Species-individual accumulation curves and species rank-abundance diagrams in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages. Gray lines represent 20-year-old second growth forest. Dotted lines represent 35-year-old second growth forest. Black lines represent old growth forest.

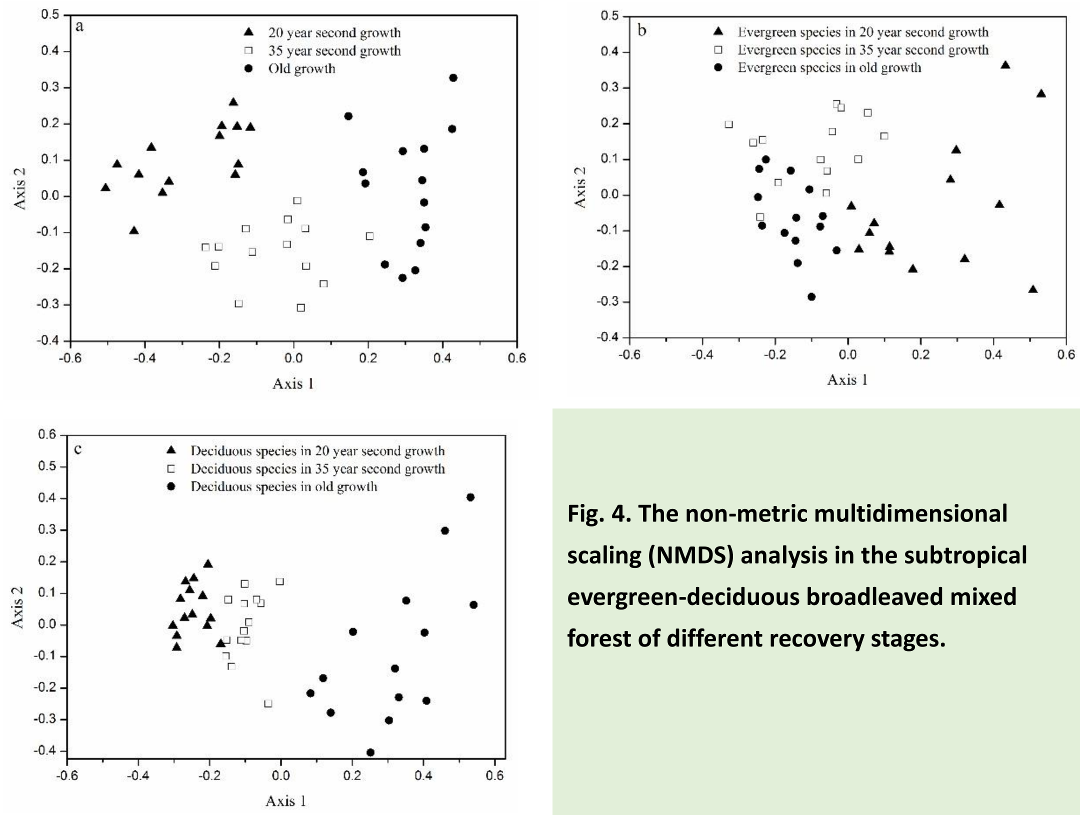


Fig. 4. The non-metric multidimensional scaling (NMDS) analysis in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages.

Relationship between species composition and environmental factors during recovery following clear-cutting

The results of RDA showed different environmental factors were related to species composition at different recovery stages (Fig. 5). Soil pH, TP and CO were the significant factors affecting species composition in SF20. Evergreen species in SF20 were only significantly affected by soil pH, while deciduous species were affected by soil pH and CO. Soil AK, TP, and CO were the factors significantly affecting species composition in SF35. Evergreen and deciduous species in SF35 were both significantly correlated with soil AK. The total species and evergreen species in OG were significantly affected by soil pH, AN, and TP. Deciduous species composition was also affected by soil AK.

Discussion

Patterns of recovery in species diversity and composition after clear cutting

We found that although the total species richness and stem abundance recovers after 20-35 years, evergreen species require more time to recover following clear cutting. Species richness was greater in the disturbed sites than in the undisturbed sites, a finding that is also reported in other studies [13, 26]. Species richness increased up to 35 years post-disturbance and then decreased (Fig.2). The peak in species richness in the intermediate stage likely results from a maximum overlap between early and late successional species [27]. Small numbers of coexisting species observed at the youngest and oldest stages are associated with respective high and low disturbances [8]. Similar trends had been reported in other studies [8, 28], which support the intermediate disturbance hypothesis that species richness is maximized at intermediate or moderate disturbance levels. This unimodal relationship between species richness and disturbance or recovery is a well-recognized ecological paradigm [29]. Chapin [30] and Tang [31] reported that in the early successional stages, forests are colonized by pioneer species with a strong light requirement, most of which are deciduous. As succession progresses, canopy openness decreases and shade-tolerant evergreen species invade the area, with intermediate regeneration stages composed of a high number of evergreen and deciduous species. The intermediate successional species have slower growth rate, are more shade-tolerant, and live longer than pioneer species. As the forest matures towards a climax community, shade-tolerant evergreen species increase slowly, and early or mid-successional deciduous species are shaded out with decreasing light availability. This causes a decrease in species richness in the late or old growth forest, as it is dominated by fewer long-lived pioneer deciduous or shade-tolerant climax evergreen species [32].

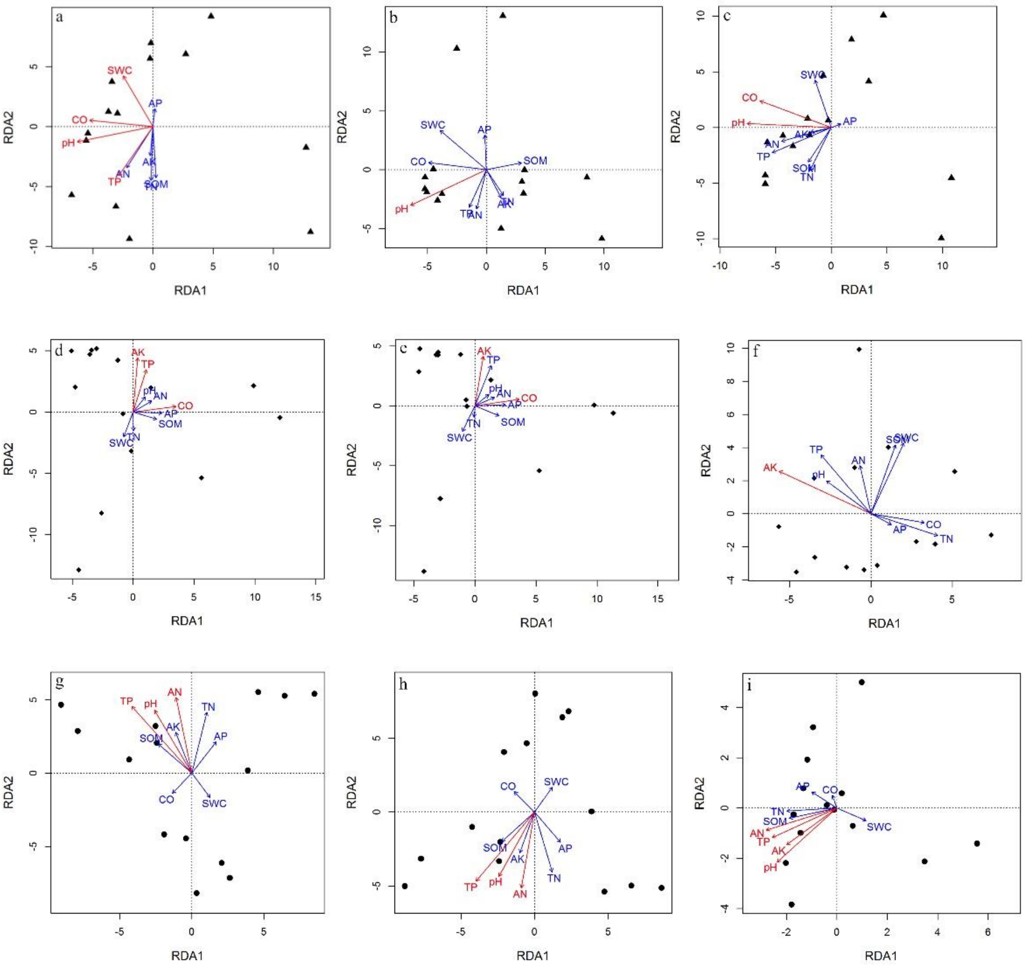


Fig. 5. Redundancy analysis (RDA) showing the relationship between the environmental variables and species composition in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages. Red arrows indicate that the variable is significantly (p < 0.05) related to species composition: a, total species in 20-year-old second growth; b, evergreen species in 20-year-old second growth; c, deciduous species in 20-year-old second growth; d, total species in 35-year-old second growth; e, evergreen species in 35-year-old second growth; f, deciduous species in 35-year-old second growth; g, total species in old growth; h, evergreen species in old growth; i, deciduous species in old growth.

Stem abundance is often high and basal area is low in the early and intermediate stages of recovery. As basal area gradually increases with forest age, stem abundance decreases [33, 34]. Our results corroborated these studies. Evergreen stem abundance gradually increased and deciduous stem abundance decreased with recovery (Fig. 2). Finegan [35] found that in early successional stages, communities were often dominated by relatively short-lived, multitudinous pioneer species. When these species died off after 25–30 years, or sometimes much earlier, stem abundance declined rapidly [36]. The basal area of deciduous species after 20 years of recovery approaches that of the old growth forest. This is likely because deciduous species have a higher relative growth rate than evergreens in early succession due to their higher leaf area ratio, and also partly due to their higher net assimilation rate [37]. However, in shady conditions, evergreen species grow faster than deciduous species [38], which we also observed, as the basal area of evergreen species increased quickly from 35 years of recovery to old growth. In addition, the gradual increase of evergreen stem abundance and decrease of deciduous stem abundance may also explain the change of basal area between deciduous and evergreen species.

The different roles of environmental factors in determining species composition during different recovery stages

Canopy openness was highest in SF20 as a consequence of low basal area in early successional stages [39]. Canopy openness then decreased with the increase of canopy cover and basal area as succession proceeded. Soil nutrients decreased and then increased with recovery. Parrotta [40] reported that light-to moderately-shaded understory environments in early succession effectively suppress the growth of grass while favoring the germination of many early and mid-successional forest tree species. Rapid leaf turnover and decomposition of nutrient-rich litter could significantly improve soil fertility and facilitate tree seed germination. Litter from branches and leaves after clear cutting also improves soil nutrients in the early stage. The decline of soil nutrients in the middle successional stage may be related to the complexity of plant community structure and competition among species, leading to greater uptake of soil nutrients [41]. The loss of nutrients could also be the result of soil erosion and weathering due to low vegetation cover in early successional stages. The relatively higher soil nutrients in old growth forests may be from fast nutrient cycling and its relationship with species composition and respective foliar chemical content [3, 42]. After 20 years of recovery, soil nutrients were similar to primary forests, but soil nutrients of the SF35 were significantly lower than old growth forests. This suggests that soil nutrients need a long time to fully recover in subtropical evergreen-deciduous broadleaved forest.

The RDA showed that the species composition in different recovery stages was determined by different environmental factors (Fig. 5). In many tropical and subtropical areas, soil P is largely bound to secondary minerals, leading to P-limited soils [43, 44]. In our study, soil TP was an important soil nutrient influencing species composition in all successional stages, suggesting that the low content of soil TP limits the establishment of species in this region. Soil pH is an important filter of the regional species pool and is significantly correlated with species richness and species density [45]. Changes in soil pH affect soil fertility, decomposition rates, and soil organic carbon sequestration [46]. In our study, soil pH was an important soil variable in controlling total species, evergreen, and deciduous species for both old growth and SF20 forests, but it had no effect on SF35 forests. SF35 was significantly affected by soil AK. AK is an important nutrient influencing plants growth [47]. The low content of soil AK in SF35 might limit the growth of both evergreen and deciduous species in this stage.

We found that species composition in second growth forests is affected by canopy openness. High canopy openness is important in the initial stages of succession, creating an ideal environment for light-demanding plant species in the understory. As these species establish and grow, they in turn provide shade for the establishment of mid- to late successional tree species [40, 48]. High canopy openness has positively affected deciduous species and negatively affected evergreen species in the understory [49].

Implications for conservation

Subtropical evergreen-deciduous broadleaved mixed forests are one of the high biodiversity forests in the world and are considered extremely vulnerable to global climate change [50]. These forests are important habitat for endangered species in China. After several decades of logging, secondary forest has become the main forest vegetation type in central China. We found that the natural recovery of richness and dominance of evergreen species takes longer than that of deciduous species. As many previous studies have shown, clear-cutting should be avoided in most cases to conserve the regional endemic biodiversity and the integrity of the forest landscape. Management strategies in this area should include: (1) protection of second-growth forests as they are important resources for both biodiversity and ecological functioning; (2) conservation of old-growth remnant forest patches that will be sources for the recovery of later successional species; (3) diverse planting to speed up the recovery to the old growth stage; and (4) assessment and improvement of key environmental factors constraining species recovery, especially the evergreen shade-tolerant species. The relative ratio of evergreen/deciduous species could be an important indicator in making management and restoration plans for subtropical evergreen-deciduous broadleaved mixed forests.

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Appendix 1. List of the investigated species and their characteristics in the subtropical evergreen-deciduous broadleaved mixed forest in the southwest of Hubei Province, central China. The nomenclature follows Flora of China (English edition: http://www.efloras.org and Chinese edition: http://frps.eflora.cn/). Nitrogen fixing plants follow *Encyclopedia of Chinese Resources Science*.

Species	Family	Leaf habit	Growth Form	Nitrogen Fixing capacity
Acanthopanax leucorrhizus (Oliv.) Harms	Araliaceae	Deciduous	Shrub	No
Acer amplum Rehd.	Aceraceae	Deciduous	Tree	No
Acer davidii Franch.	Aceraceae	Deciduous	Tree	No
Sabia japonica Maxim.	Sabiaceae	Deciduous	Liana	No
Acer franchetii Pax	Aceraceae	Deciduous	Tree	No
Acer henryi Pax	Aceraceae	Deciduous	Tree	No
Acer mono Maxim.	Aceraceae	Deciduous	Tree	No
Acer palmatum Thunb.	Aceraceae	Deciduous	Tree	No
Acer sinense Pax	Aceraceae	Deciduous	Tree	No
Acer wilsonii Rehder	Aceraceae	Deciduous	Tree	No
Acer maximowiczii Pax	Aceraceae	Deciduous	Tree	No
Actinidia arguta (Sieb. & Zucc) Planch. ex Miq.	Actinidiaceae	Deciduous	Liana	No
Actinidia chinensis Planch.	Actinidiaceae	Deciduous	Liana	No
Ailanthus altissima (Mill.) Swingle	Simaroubaceae	Deciduous	Tree	No
Ailanthus vilmoriniana Dode	Simaroubaceae	Deciduous	Tree	No
Akebia trifoliata (Thunb.) Koidz.	Lardizabalaceae	Deciduous	Liana	No
Alangium platanifolium (Sieb. et Zucc.) Harms	Alangiaceae	Deciduous	Tree	No
Albizia julibrissin Durazz.	Leguminosae	Deciduous	Tree	Yes
Aralia echinocaulis Hand.-Mazz.	Araliaceae	Deciduous	Tree	No
Argyreia seguinii (Levl.) Van.	Convolvulaceae	Deciduous	Liana	No
Berchemia sinica Schneid.	Rhamnaceae	Deciduous	Liana	Yes
Betula luminifera H. Winkl.	Betulaceae	Deciduous	Tree	Yes
Bothrocaryum controversum (Hemsl.) Pojark.	Cornaceae	Deciduous	Tree	No
Bretschneidera sinensis	Bretschneideraceae	Deciduous	Tree	No
Callicarpa bodinieri Levl.	Verbenaceae	Deciduous	Shrub	No
Carpinus fargesiana H. Winkl.	Betulaceae	Deciduous	Tree	Yes
Castanea henryi (Skan) Rehd. et Wils.	Fagaceae	Deciduous	Tree	No
Castanea mollissima Bl.	Fagaceae	Deciduous	Tree	No
Celastrus hypoleucus (Oliv.) Warb.ex Loes.	Celastraceae	Deciduous	Liana	No
Celastrus orbiculatus Thunb.	Celastraceae	Deciduous	Liana	No
Celastrus rosthornianus Loes.	Celastraceae	Deciduous	Liana	No
Cerasus dielsiana (Schneid.) Yu et Li	Rosaceae	Deciduous	Tree	Yes
Cerasus duclouxii (Koehne) Yu et Li	Rosaceae	Deciduous	Tree	Yes

Cerasus pseudocerasus (Lindl.) G. Don	Rosaceae	Deciduous	Tree	Yes
Cercidiphyllum japonicum Sieb. et Zucc.	Cercidiphyllaceae	Deciduous	Tree	No
Cladrastis sinensis Hemsl.	Leguminosae	Deciduous	Tree	Yes
Clethra cavaleriei Levl.	Clethraceae	Deciduous	Tree	No
Corylopsis sinensis Hemsl.	Hamamelidaceae	Deciduous	Shrub	No
Cotoneaster zabelii Schneid.	Rosaceae	Deciduous	Shrub	Yes
Crataegus wilsonii	Rosaceae	Deciduous	Shrub	Yes
Cyclocarya paliurus (Batal.) Iljinsk.	Juglandaceae	Deciduous	Tree	No
Dalbergia dyeriana	Leguminosae	Deciduous	Liana	Yes
Davidia involucrata Baill.	Nyssaceae	Deciduous	Tree	No
Decaisnea insignis (Griff.) Hook. f. et Thoms.	Lardizabalaceae	Deciduous	Shrub	No
Dendrobenthamia angustata (Chun) Fang	Cornaceae	Deciduous	Shrub	No
Dendrobenthamia hongkongensis (Hemsl.) Hutch.	Cornaceae	Deciduous	Tree	No
Dendrobenthamia japonica (DC.) Fang var.	Cornaceae	Deciduous	Tree	No
Dendropanax dentiger (Harms) Merr.	Araliaceae	Deciduous	Shrub	No
Diospyros lotus L.	Ebenaceae	Deciduous	Tree	No
Emmenopterys henryi Oliv.	Rubiaceae	Deciduous	Tree	No
Enkianthus serrulatus (Wils.) Schneid.	Ericaceae	Deciduous	Tree	No
Euonymus acanthocarpus Franch.	Celastraceae	Deciduous	Shrub	No
Euonymus alatus (Thunb.) Sieb.	Celastraceae	Deciduous	Shrub	No
Euscaphis japonica (Thunb.) Dippel	Staphyleaceae	Deciduous	Tree	No
Evodia daniellii (Benn.) Hemsl.	Rutaceae	Deciduous	Tree	No
Evodia fargesii Dode	Rutaceae	Deciduous	Tree	No
Fagus engleriana Seem.	Fagaceae	Deciduous	Tree	No
Fagus lucida Rehd. et Wils.	Fagaceae	Deciduous	Tree	No
Ficus heteromorpha Hemsl.	Moraceae	Deciduous	Tree	No
Fraxinus insularis Hemsl.	Oleaceae	Deciduous	Tree	No
Fraxinus platypoda Oliv.	Oleaceae	Deciduous	Tree	No
Helwingia japonica (Thunb.) Dietr.	Cornaceae	Deciduous	Shrub	No
Hovenia acerba Lindl.	Rhamnaceae	Deciduous	Tree	Yes
Hydrangea glabripes Rehd.	Saxifragaceae	Deciduous	Shrub	No
Hydrangea hypoglauca Rehd	Saxifragaceae	Deciduous	Shrub	No
Hydrangea strigosa Rehd.	Saxifragaceae	Deciduous	Shrub	No
Idesia polycarpa Maxim.	Flacourtiaceae	Deciduous	Tree	No
Juglans cathayensis	Juglandaceae	Deciduous	Tree	No
Ligustrum molliculum Hance	Oleaceae	Deciduous	Tree	No
Ligustrum quihoui Carr.	Oleaceae	Deciduous	Shrub	No
Lindera fruticosa Hemsl. var.	Lauraceae	Deciduous	Shrub	No
Lindera obtusiloba Bl. Mus. Bot.	Lauraceae	Deciduous	Tree	No
Lindera glauca (Sieb. et Zucc.) Bl	Lauraceae	Deciduous	Shrub	No
Liquidambar formosana	Hamamelidaceae	Deciduous	Tree	No
Liriodendron chinense (Hemsl.) Sargent.	Magnoliaceae	Deciduous	Tree	No
Litsea cubeba (Lour.) Pers.	Lauraceae	Deciduous	Tree	No

Litsea pungens Hemsl.	Lauraceae	Deciduous	Tree	No
Lonicera acuminata Wall.	Caprifoliaceae	Deciduous	Liana	No
Lonicera hypoglauca Miq.	Caprifoliaceae	Deciduous	Liana	No
Lyonia ovalifolia (Wall.) Drude var. elliptica	Ericaceae	Deciduous	Tree	No
Maclura fruticosa (Roxb.) Corner	Moraceae	Deciduous	Liana	No
Magnolia officinalis subsp.biloba (Rehd. et Wils.) Law	Magnoliaceae	Deciduous	Tree	No
Magnolia biondii Pampan	Magnoliaceae	Deciduous	Tree	No
Magnolia sprengeri Pampan.	Magnoliaceae	Deciduous	Tree	No
Mallotus japonicus (Thunb.) Muell. Arg. var.	Euphorbiaceae	Deciduous	Tree	No
Malus hupehensis (Pamp.) Rehd.	Rosaceae	Deciduous	Tree	Yes
Meliosma cuneifolia Franch.	Sabiaceae	Deciduous	Tree	No
Meliosma flexuosa Pamp.	Sabiaceae	Deciduous	Tree	No
Meliosma pinnata Roxb. ex Maxim.	Sabiaceae	Deciduous	Tree	No
Meliosma veitchiorum Hemsl.	Sabiaceae	Deciduous	Tree	No
Millettia dielsiana Harms	Leguminosae	Deciduous	Liana	Yes
Neillia sinensis Oliv.	Rosaceae	Deciduous	Shrub	Yes
Padus racemosa (Lam.) Gilib.	Rosaceae	Deciduous	Tree	Yes
Padus wilsonii Schneid.	Rosaceae	Deciduous	Tree	Yes
Paulownia fortunei (Seem.) Hemsl.	Scrophulariaceae	Deciduous	Tree	No
Photinia beauverdiana Schneid.	Rosaceae	Deciduous	Shrub	Yes
Photinia schneideriana Rehd. et Wils.	Rosaceae	Deciduous	Tree	Yes
Photinia parvifolia (Pritz.) Schneid.	Rosaceae	Deciduous	Shrub	Yes
Picrasma quassioides (D. Don) Benn.	Simaroubaceae	Deciduous	Tree	No
Platycarya strobilacea Sieb. et Zucc.	Juglandaceae	Deciduous	Tree	No
Populus lasiocarpa	Salicaceae	Deciduous	Tree	No
Populus adenopoda Maxim.	Salicaceae	Deciduous	Tree	No
Prunus salicina Lindl.	Rosaceae	Deciduous	Tree	Yes
Pterocarya insignis	Juglandaceae	Deciduous	Tree	No
Pterocarya stenoptera	Juglandaceae	Deciduous	Tree	No
Pyrus xerophila	Rosaceae	Deciduous	Tree	Yes
Quercus aliena Bl.	Fagaceae	Deciduous	Tree	No
Quercus aliena Bl. var.acuteserrata Maxim. ex Wenz.	Fagaceae	Deciduous	Tree	No
Quercus serrata Thunb.	Fagaceae	Deciduous	Tree	No
Quercus serrata Thunb. var.brevipetiolata (A. DC.) Nakai	Fagaceae	Deciduous	Tree	No
Rhamnus esquirolii Levl.	Rhamnaceae	Deciduous	Shrub	Yes
Rhamnus hupehensis Schneid.	Rhamnaceae	Deciduous	Shrub	Yes
Rhamnus sargentiana Schneid.	Rhamnaceae	Deciduous	Tree	Yes
Rhamnus utilis Decne.	Rhamnaceae	Deciduous	Shrub	Yes
Rhamnus davurica Pall.	Rhamnaceae	Deciduous	Shrub	Yes
Rhododendron mariesii Hemsl. et Wils.	Ericaceae	Deciduous	Shrub	No

Rhododendron pingianum Fang	Ericaceae	Deciduous	Shrub	No
Rhododendron simsii Planch.	Ericaceae	Deciduous	Shrub	No
Rhus chinensis Mill.	Anacardiaceae	Deciduous	Tree	No
Rosa henryi Bouleng.	Rosaceae	Deciduous	Shrub	Yes
Rosa cymosa Tratt.	Rosaceae	Deciduous	Liana	Yes
Rosa rubus Lévl. et Vant.	Rosaceae	Deciduous	Liana	Yes
Rubus corchorifolius L. f.	Rosaceae	Deciduous	Liana	Yes
Sabia campanulata subsp.	Sabiaceae	Deciduous	Liana	No
Salix psilostigma	Salicaceae	Deciduous	Shrub	No
Salix sinica	Salicaceae	Deciduous	Tree	No
Salix wilsonii Seemen	Salicaceae	Deciduous	Tree	No
Sargentodoxa cuneata (Oliv.) Rehd. et Wils.	Lardizabalaceae	Deciduous	Liana	No
Sassafras tzumu (Hemsl.) Hemsl.	Lauraceae	Deciduous	Tree	No
Schisandra tomentella	Magnoliaceae	Deciduous	Liana	No
Schisandra chinensis	Magnoliaceae	Deciduous	Liana	No
Schisandra incarnata	Magnoliaceae	Deciduous	Liana	No
Schizophragma integrifolium	Saxifragaceae	Deciduous	Liana	No
Sinofranchetia chinensis (Franch.) Hemsl.	Lardizabalaceae	Deciduous	Liana	No
Sinomenium acutum (Thunb.) Rehd. et Wils.	Menispermaceae	Deciduous	Liana	No
Sorbus caloneura (Stapf) Rehd.	Rosaceae	Deciduous	Shrub	Yes
Sorbus hemsleyi (Schneid.) Rehd.	Rosaceae	Deciduous	Tree	Yes
Sorbus megalocarpa Rehd.	Rosaceae	Deciduous	Tree	Yes
Sorbus wilsoniana Schneid.	Rosaceae	Deciduous	Tree	Yes
Sorbus folgneri (Schneid.) Rehd.	Rosaceae	Deciduous	Tree	Yes
Sphaerophysa salsula (Pall.) DC.	Leguminosae	Deciduous	Shrub	Yes
Stauntonia leucantha Diels ex Y. C. Wu	Lardizabalaceae	Deciduous	Liana	No
Swida macrophylla (Wall.) Soják	Cornaceae	Deciduous	Tree	No
Symplocos paniculata (Thunb.) Miq	Symplocaceae	Deciduous	Shrub	No
Tapiscia sinensis Oliv.	Staphyleaceae	Deciduous	Tree	No
Tetracentron sinense Oliv.	Tetracentraceae	Deciduous	Tree	No
Tilia chinensis Maxim.	Tiliaceae	Deciduous	Tree	No
Tilia oliveri Szyszyl.	Tiliaceae	Deciduous	Tree	No
Toona ciliata Roem.	Meliaceae	Deciduous	Tree	No
Toona ciliata Roem. var. ciliata var. ciliata	Meliaceae	Deciduous	Tree	No
Toona sinensis (A. Juss.) Roem.	Meliaceae	Deciduous	Tree	No
Toxicodendron succedaneum (L.) O. Kuntze	Anacardiaceae	Deciduous	Tree	No
Vaccinium bracteatum Thunb.	Ericaceae	Deciduous	Tree	No
Vaccinium japonicum Miq. var. sinicum (Nakai) Rehd.	Ericaceae	Deciduous	Shrub	No
Viburnum betulifolium Batal.	Caprifoliaceae	Deciduous	Shrub	No
Viburnum dilatatum Thunb.	Caprifoliaceae	Deciduous	Shrub	No
Viburnum plicatum Thunb. var.	Caprifoliaceae	Deciduous	Shrub	No
Viburnum setigerum Hance	Caprifoliaceae	Deciduous	Shrub	No

Viburnum sympodiale Graebn.	Caprifoliaceae	Deciduous	Shrub	No
Viburnum erosum Thunb.	Caprifoliaceae	Deciduous	Shrub	No
Vitis davidii (Roman. du Caill.) Foex	Vitaceae	Deciduous	Liana	No
Weigela japonica Thunb. var. sinica (Rehd.) Bailey	Caprifoliaceae	Deciduous	Shrub	No
Zanthoxylum dissitum Hemsl.	Rutaceae	Deciduous	Liana	No
Zelkova serrata (Thunb.) Makino	Ulmaceae	Deciduous	Tree	Yes
Berberis julianae Schneid.	Berberidaceae	Evergreen	Shrub	No
Camellia cuspidata (Kochs) Wright ex Gard.	Theaceae	Evergreen	Shrub	No
Camellia sinensis (L.) O. Ktze.	Theaceae	Evergreen	Shrub	No
Castanopsis calathiformis (Skan) Rehd. et Wils.	Fagaceae	Evergreen	Tree	No
Cephalotaxus fortunei Hook. f.	Cephalotaxaceae	Evergreen	Tree	No
Cinnamomum wilsonii Gamble	Lauraceae	Evergreen	Tree	No
Cryptomeria fortunei Hooibrenk ex Otto et Dietr.	Taxodiaceae	Evergreen	Tree	No
Cunninghamia lanceolata (Lamb.) Hook.	Taxodiaceae	Evergreen	Tree	No
Cyclobalanopsis glauca (Thunb.) Oerst.	Fagaceae	Evergreen	Tree	No
Cyclobalanopsis myrsinifolia (Blume) Oersted	Fagaceae	Evergreen	Tree	No
Cyclobalanopsis oxyodon (Miq.) Oerst.	Fagaceae	Evergreen	Tree	No
Cyclobalanopsis gracilis (Rehd. et Wils.) Cheng et T. Hong	Fagaceae	Evergreen	Tree	No
Daphniphyllum macropodum Miq.	Daphniphyllaceae	Evergreen	Tree	No
Daphniphyllum oldhami (Hemsl.) Rosenth.	Daphniphyllaceae	Evergreen	Tree	No
Elaeagnus difficilis Serv.	Elaeagnaceae	Evergreen	Shrub	Yes
Elaeagnus glabra Thunb.	Elaeagnaceae	Evergreen	Liana	Yes
Elaeagnus pungens Thunb.	Elaeagnaceae	Evergreen	Shrub	Yes
Elaeagnus henryi Warb. apud Diels	Elaeagnaceae	Evergreen	Shrub	Yes
Euonymus bockii Loes.	Celastraceae	Evergreen	Shrub	No
Euonymus cornutus Hemsl.	Celastraceae	Evergreen	Shrub	No
Euonymus myrianthus Hemsl.	Celastraceae	Evergreen	Shrub	No
Eurya alata Kobuski	Theaceae	Evergreen	Shrub	No
Eurya loquaiana Dunn	Theaceae	Evergreen	Tree	No
Glyptostrobus pensilis (Staunt.) Koch	Taxodiaceae	Evergreen	Tree	No
Hedera nepalensis K. Koch var.	Araliaceae	Evergreen	Liana	No
Holboellia grandiflora Reaub.	Lardizabalaceae	Evergreen	Liana	No
Ilex centrochinensis S. Y. Hu	Aquifoliaceae	Evergreen	Shrub	No
Ilex chinensis Sims	Aquifoliaceae	Evergreen	Tree	No
Ilex ficoidea Hemsl.	Aquifoliaceae	Evergreen	Tree	No
Ilex pedunculosa Miq.	Aquifoliaceae	Evergreen	Shrub	No
Ilex pernyi Franch.	Aquifoliaceae	Evergreen	Shrub	No
Ilex suaveolens (Levl.) Loes.	Aquifoliaceae	Evergreen	Tree	No
Ilex szechwanensis Loes.	Aquifoliaceae	Evergreen	Shrub	No
Kadsura longipedunculata	Magnoliaceae	Evergreen	Liana	No
Lindera aggregata (Sims) Kosterm	Lauraceae	Evergreen	Shrub	No
Lithocarpus cleistocarpus (Seem.) Rehd. et Wils.	Fagaceae	Evergreen	Tree	No

Lithocarpus henryi (Seem.) Rehd. et Wils.	Fagaceae	Evergreen	Tree	No
Litsea elongata (Wall. ex Nees) Benth. et Hook. f.	Lauraceae	Evergreen	Tree	No
Litsea ichangensis Gamble	Lauraceae	Evergreen	Shrub	No
Lonicera gynochlamydea Hemsl.	Caprifoliaceae	Evergreen	Shrub	No
Lonicera japonica Thunb.	Caprifoliaceae	Evergreen	Liana	No
Machilus ichangensis Rehd. et Wils.	Lauraceae	Evergreen	Tree	No
Mahonia fortunei (Lindl.) Fedde	Berberidaceae	Evergreen	Shrub	No
Neolitsea confertifolia (Hemsl.) Merr.	Lauraceae	Evergreen	Tree	No
Neolitsea aurata (Hay.) Koidz.	Lauraceae	Evergreen	Tree	No
Olax wightiana Wall. ex Wight et Arn.	Olacaceae	Evergreen	Shrub	No
Osmanthus fragrans (Thunb.) Lour.	Oleaceae	Evergreen	Shrub	No
Photinia serrulata Lindl.	Rosaceae	Evergreen	Shrub	Yes
Phyllostachys sulphurea (Carr.) A. et C. Riv.	Gramineae	Evergreen	Gramineae	No
Phyllostachys heteroclada Oliver	Gramineae	Evergreen	Gramineae	No
Pittosporum ovoideum Gowda	Pittosporaceae	Evergreen	Liana	No
Pittosporum glabratum Lindl. var.	Pittosporaceae	Evergreen	Shrub	No
Pterostyrax psilophyllus Diels ex Perk	Styracaceae	Evergreen	Tree	No
Pyracantha fortuneana (Maxim.) Li	Rosaceae	Evergreen	Shrub	Yes
Quercus engleriana Seem	Fagaceae	Evergreen	Tree	No
Rhododendron auriculatum Hemsl.	Ericaceae	Evergreen	Shrub	No
Rhododendron fortunei Lindl.	Ericaceae	Evergreen	Shrub	No
Rhododendron ovatum (Lindl.) Planch. ex Maxim.	Ericaceae	Evergreen	Shrub	No
Rhododendron stamineum Franch.	Ericaceae	Evergreen	Shrub	No
Rubus henryi Hemsl.	Rosaceae	Evergreen	Liana	Yes
Schima superba Gardn. et Champ.	Theaceae	Evergreen	Tree	No
Skimmia reevesiana Fort.	Rutaceae	Evergreen	Shrub	No
Stachyurus chinensis Franch.	Stachyuraceae	Evergreen	Shrub	No
Stranvaesia davidiana var. undulata (Decaisne) Rehder & E. H. Wilson	Rosaceae	Evergreen	Shrub	Yes
Symplocos anomala Brand	Symplocaceae	Evergreen	Shrub	No
Symplocos crassifolia Benth.	Symplocaceae	Evergreen	Tree	No
Symplocos lancifolia Sieb. et Zucc.	Symplocaceae	Evergreen	Tree	No
Symplocos multipes Brand	Symplocaceae	Evergreen	Shrub	No
Symplocos phyllocalyx Clarke	Symplocaceae	Evergreen	Tree	No
Symplocos setchuensis Brand	Symplocaceae	Evergreen	Tree	No
Symplocos sumuntia Buch.-Ham. ex D. Don	Symplocaceae	Evergreen	Tree	No
Symplocos urceolaris Hance	Symplocaceae	Evergreen	Tree	No
Vaccinium iteophyllum Hance	Ericaceae	Evergreen	Tree	No
Viburnum henryi Hemsl	Caprifoliaceae	Evergreen	Shrub	No
Viburnum cylindricum Buch. -Ham. ex D. Don	Caprifoliaceae	Evergreen	Tree	No