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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 km² 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°C, with the mean monthly maximum of 26°C in July and the mean monthly minimum of 4.6°C 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.

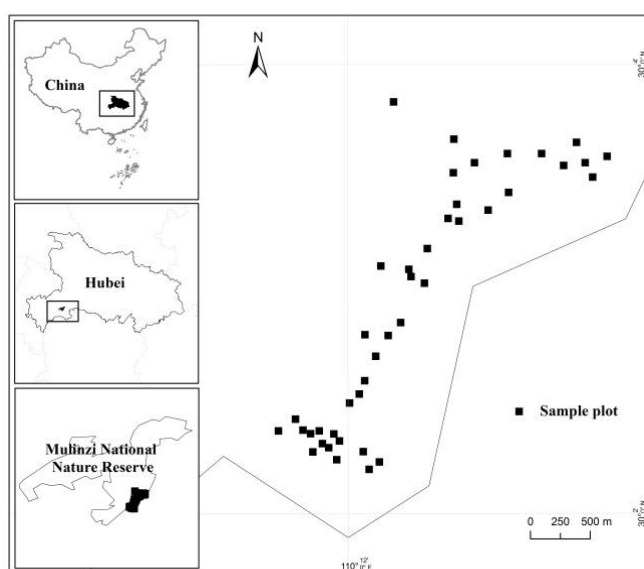


Fig. 1. Diagram of the sample plots and study site in the southwest of Hubei Province, central China.

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 K₂Cr₂O₇ titration method after digestion; soil total phosphorus (TP) was determined colorimetrically after wet digestion with H₂SO₄ plus HClO₄; and soil available phosphorus (AP) and available potassium (AK) were extracted with 3% (NH₄)₂CO₃ 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

fish-eye 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 \pm 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 \pm 0.1b	4.67 \pm 0.1a	86.2 \pm 15b	6.17 \pm 1.2ab	359.1 \pm 68.5a	0.59 \pm 0.1ab	0.17 \pm 0.04a	163.75 \pm 36.4a	15.1 \pm 1.7b
SF35	0.33 \pm 0.1a	4.68 \pm 0.3a	69.0 \pm 18a	5.2 \pm 0.9b	308.6 \pm 63.3a	0.47 \pm 0.1b	0.14 \pm 0.02a	132.66 \pm 37.7a	12.77 \pm 1.9a
OG	0.41 \pm 0.1ab	4.65 \pm 0.2a	81.2 \pm 17ab	6.86 \pm 2.6a	365.3 \pm 98.0a	0.67 \pm 0.3a	0.16 \pm 0.03a	139.57 \pm 53.9a	10.27 \pm 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 ($p < 0.001$).

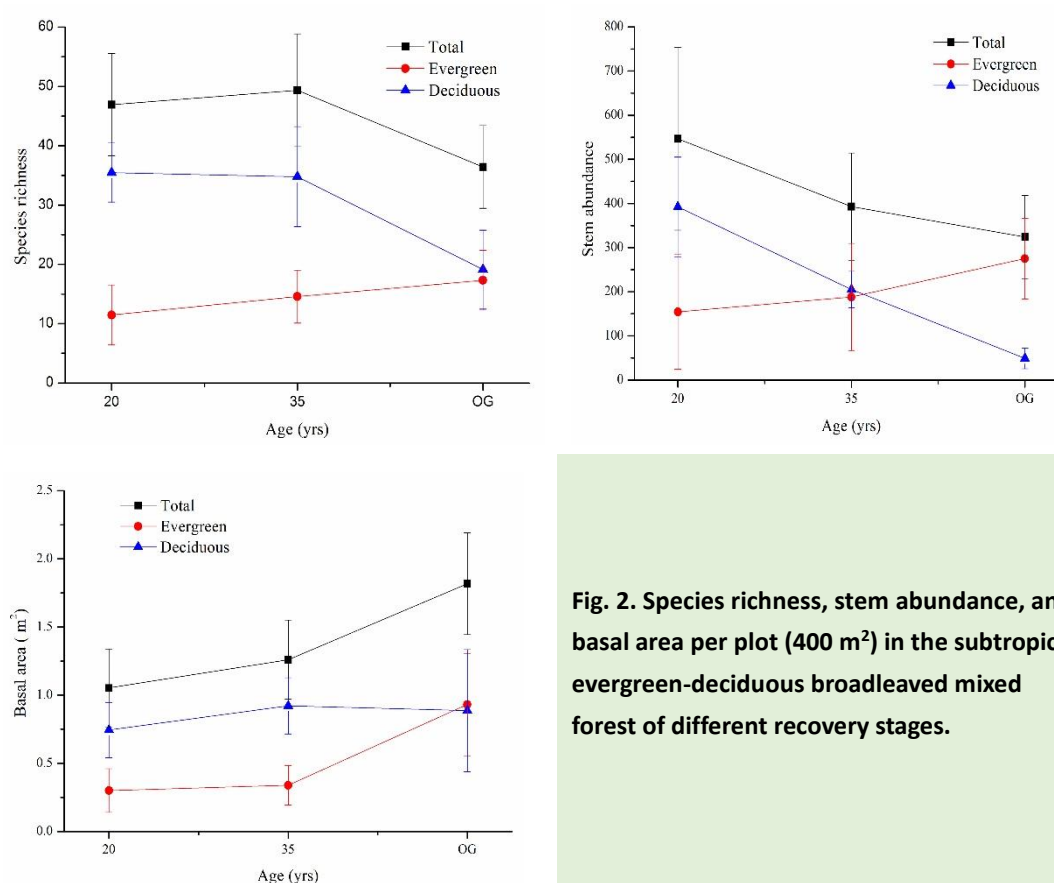


Fig. 2. Species richness, stem abundance, and basal area per plot (400 m²) in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages.

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 rarefaction 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.

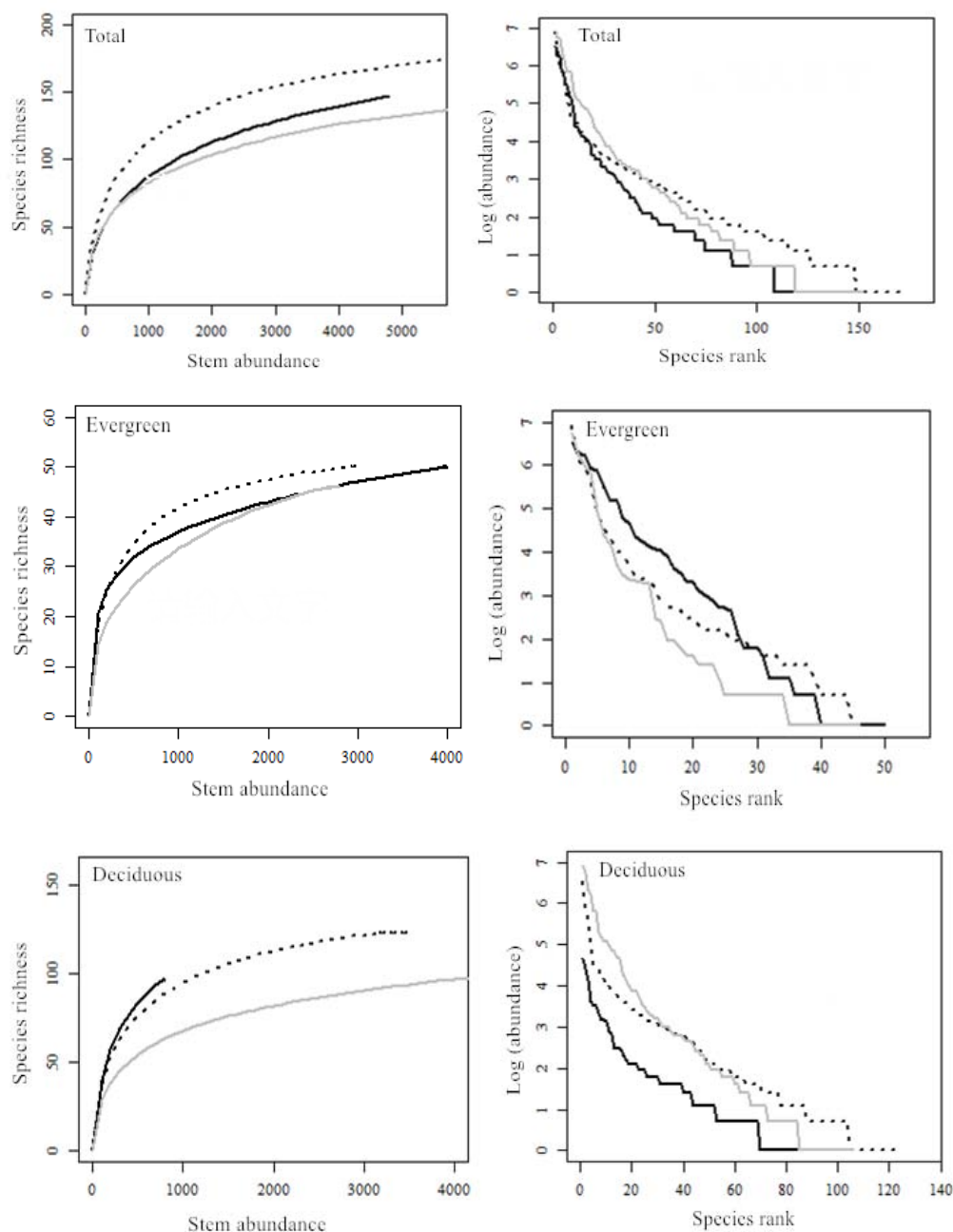


Fig. 3. Species-individual accumulation curves and species rank-abundance diagrams in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages. Gray lines represent 20-year-old second growth forest. Dotted lines represent 35-year-old second growth forest. Black lines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

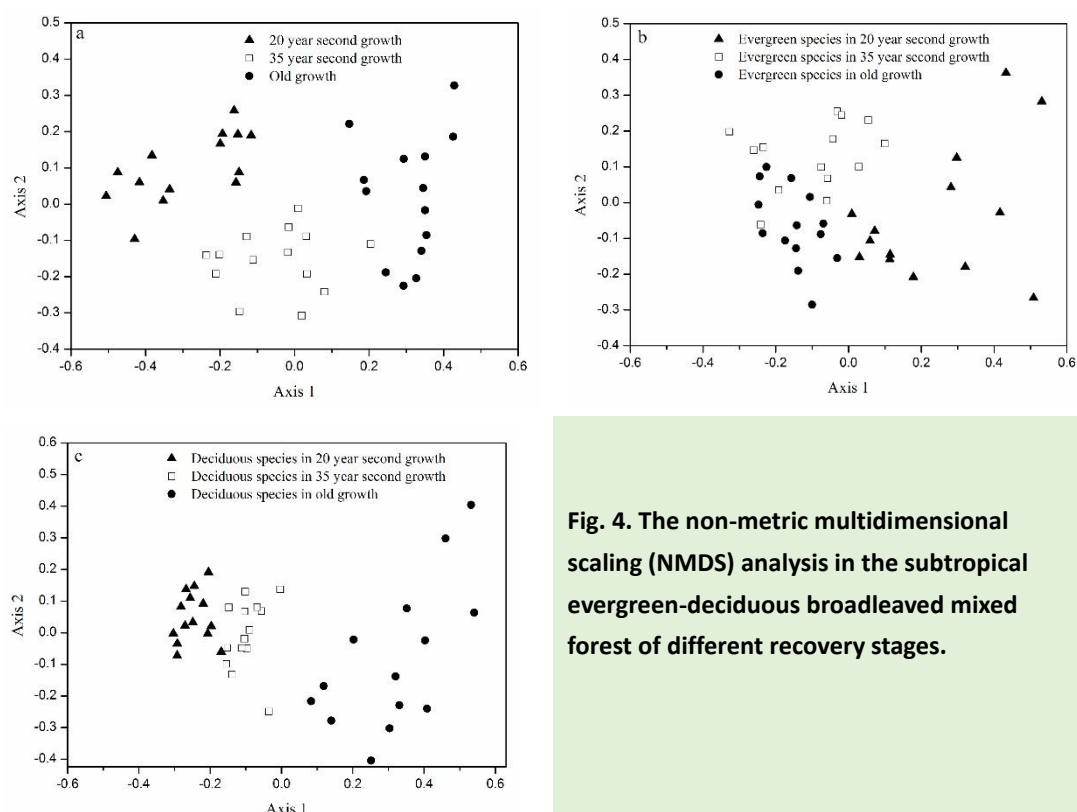


Fig. 4. The non-metric multidimensional scaling (NMDS) analysis in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages.

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].

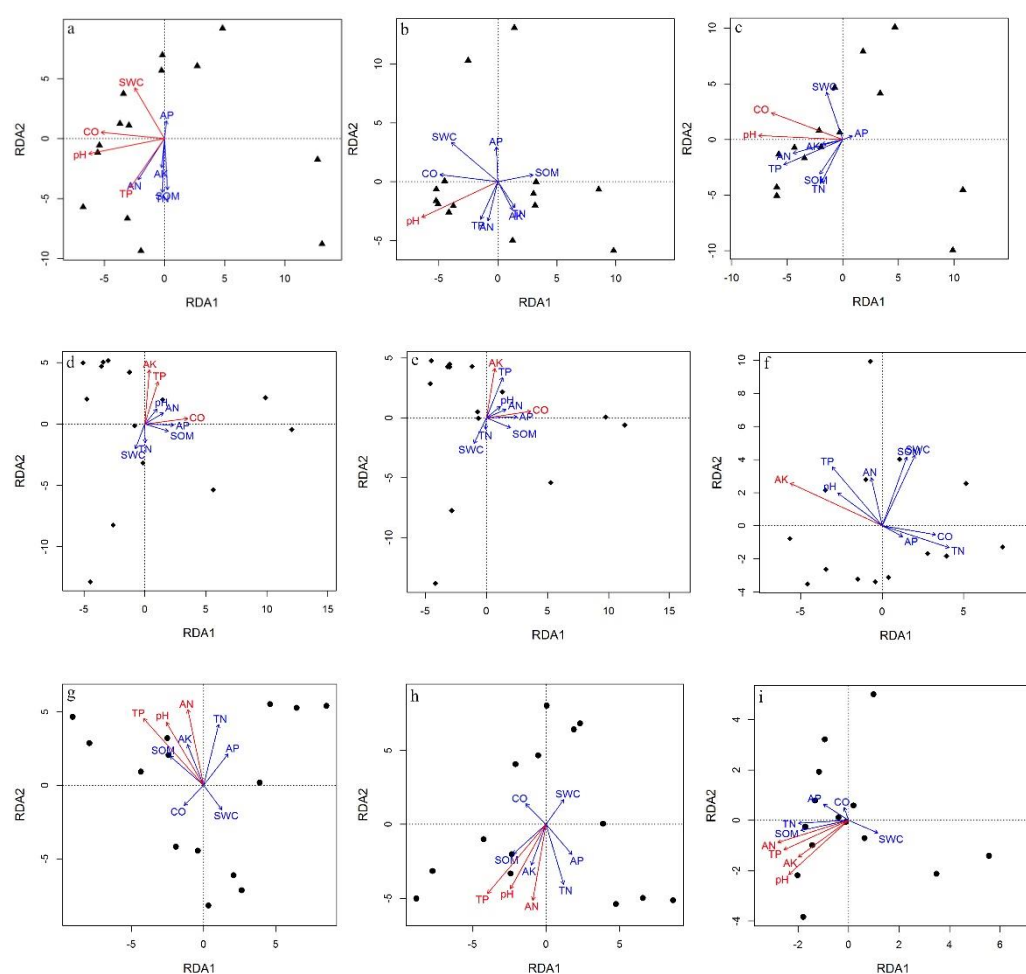


Fig. 5. Redundancy analysis (RDA) showing the relationship between the environmental variables and species composition in the subtropical evergreen-deciduous broadleaved mixed forest of different recovery stages. Red arrows indicate that the variable is significantly ($p < 0.05$) related to species composition: 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
<i>Acanthopanax leucorrhizus</i> (Oliv.) Harms	Araliaceae	Deciduous	Shrub	No
<i>Acer amplum</i> Rehd.	Aceraceae	Deciduous	Tree	No
<i>Acer davidii</i> Franch.	Aceraceae	Deciduous	Tree	No
<i>Sabia japonica</i> Maxim.	Sabiaceae	Deciduous	Liana	No
<i>Acer franchetii</i> Pax	Aceraceae	Deciduous	Tree	No
<i>Acer henryi</i> Pax	Aceraceae	Deciduous	Tree	No
<i>Acer mono</i> Maxim.	Aceraceae	Deciduous	Tree	No
<i>Acer palmatum</i> Thunb.	Aceraceae	Deciduous	Tree	No
<i>Acer sinense</i> Pax	Aceraceae	Deciduous	Tree	No
<i>Acer wilsonii</i> Rehder	Aceraceae	Deciduous	Tree	No
<i>Acer maximowiczii</i> Pax	Aceraceae	Deciduous	Tree	No
<i>Actinidia arguta</i> (Sieb. & Zucc) Planch. ex Miq.	Actinidiaceae	Deciduous	Liana	No
<i>Actinidia chinensis</i> Planch.	Actinidiaceae	Deciduous	Liana	No
<i>Ailanthus altissima</i> (Mill.) Swingle	Simaroubaceae	Deciduous	Tree	No
<i>Ailanthus vilmoriniana</i> Dode	Simaroubaceae	Deciduous	Tree	No
<i>Akebia trifoliata</i> (Thunb.) Koidz.	Lardizabalaceae	Deciduous	Liana	No
<i>Alangium platanifolium</i> (Sieb. et Zucc.) Harms	Alangiaceae	Deciduous	Tree	No
<i>Albizia julibrissin</i> Durazz.	Leguminosae	Deciduous	Tree	Yes
<i>Aralia echinocaulis</i> Hand.-Mazz.	Araliaceae	Deciduous	Tree	No
<i>Argyrea seguinii</i> (Levl.) Van.	Convolvulaceae	Deciduous	Liana	No
<i>Berchemia sinica</i> Schneid.	Rhamnaceae	Deciduous	Liana	Yes
<i>Betula luminifera</i> H. Winkl.	Betulaceae	Deciduous	Tree	Yes
<i>Bothrocaryum controversum</i> (Hemsl.) Pojark.	Cornaceae	Deciduous	Tree	No
<i>Bretschneidera sinensis</i>	Bretschneideraceae	Deciduous	Tree	No
<i>Callicarpa bodinieri</i> Levl.	Verbenaceae	Deciduous	Shrub	No
<i>Carpinus fargesiana</i> H. Winkl.	Betulaceae	Deciduous	Tree	Yes
<i>Castanea henryi</i> (Skan) Rehd. et Wils.	Fagaceae	Deciduous	Tree	No
<i>Castanea mollissima</i> Bl.	Fagaceae	Deciduous	Tree	No
<i>Celastrus hypoleucus</i> (Oliv.) Warb.ex Loes.	Celastraceae	Deciduous	Liana	No
<i>Celastrus orbiculatus</i> Thunb.	Celastraceae	Deciduous	Liana	No
<i>Celastrus rosthornianus</i> Loes.	Celastraceae	Deciduous	Liana	No
<i>Cerasus dielsiana</i> (Schneid.) Yu et Li	Rosaceae	Deciduous	Tree	Yes
<i>Cerasus duclouxii</i> (Koehne) Yu et Li	Rosaceae	Deciduous	Tree	Yes

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

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

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

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

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