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SPECIES DIVERSITY AND DISTRIBUTION PATTERN OF OLD TREES IN WUZHONG DISTRICT, SUZHOU CITY

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Abstract

Old trees are a natural and cultural heritage resource, and they often provide a wide variety of tangible and intangible benefits to people. At the same time, old trees are living fossils that can disclose information on vegetation succession, climate change, origin of species, regional environmental change, social development, and other factors. Therefore, old trees play a significant role in many research fields. Based on a field investigation and the literature, the species diversity, distribution pattern, and growth status of old trees in Wuzhong District were analysed. The results indicated that 339 old trees belonged to 41 species, 34 genera and 26 families. *Ginkgo biloba* was overwhelmingly dominant, followed by *Cinnamomum camphora*, *Zelkova serrata* and *Juniperus chinensis*. The spatial distribution patterns implied that there were more old trees in rural towns than in urban areas, and temples were the main places that accommodated old trees. In terms of the DBH (diameter at breast height), the old tree structures were similar to the spindle shape; however, the third-grade (100-299 years) old trees were more abundant than the other grades (300-499 years and over 500 years). There were four grades of old tree growth status, including vigorous, normal, weak and dying, which accounted for 41.3%, 49.3%, 7.4% and 2.1% of total tree count, respectively. The height and crown attributes were also discussed in this paper. Based on our investigation and analysis, the conservation issues related to old trees were analysed and corresponding countermeasures and suggestions were proposed.

Key words: Species diversity, Old tree, Distribution pattern, conservation strategies, Wuzhong district.

Introduction

Large and old trees play a vital roles in the ecosystem and biodiversity, but they are rapidly declining in many parts of the world (Lindenmayer *et al.*, 2012). Targeted research is urgently needed to better reveal the key threats to large and old trees and devise strategies to counter them. In China, administrative departments at all levels have paid close attention to large and old trees (Zhou & Wang, 2007), which are also known as anceint trees or heritage trees. To be an old tree, it is defined that the tree ages should be over 100 years; simultaneously, old trees are divided into three grades based on the age: first-grade (over 500 years), second-grade (300-499 years) and third-grade (100-299 years) (Xu *et al.*, 2012). Old trees are regarded as valuable biological resources and crucial historical relics. They can record the changes of the world in a certain region, for example, climate, hydrology, vegetation succession, natural conditions; at the same time, they reflect human activities and social development (Xie *et al.*, 2012). In fact, old trees have a rhythm in nature, a symbiotic relationship with other organisms, and maintain ecological balance, all are crucial for ecosystem integrity (Mahmoud *et al.*, 2015). Human beings always focus on the tangible value of old trees, whereas the intangible values are also very important, including aesthetic, religious, and symbolic characteristics (Blicharska & Mikusinski, 2014). Therefore, the conservation of old trees is an urgent need.

Since the '*Technical Guidelines for Document Establishment of General Survey of National Old – Famous Trees*' was announced in 2001 in China (Zhang *et al.*, 2017), an overall old tree conversation network from the central to the local governments has come into shape with relevant departments in charge at different levels. At the same time, many researchers have already heavily invested in research on the present direction of old trees. Those studies have mainly incorporated several key topics; for instance, spatial patterns (Huang *et al.*, 2015; Jim, 2004; Zhang *et al.*, 2017), assessments of tree age (Xie *et al.*, 2011; Zhong, 2016), investigation of old tree resources (Ren *et al.*, 2013; Shi *et al.*, 2014; Zhao *et al.*, 2017), rejuvenation technology (Yan, 2006; Yuan *et al.*, 2011), physiology (WANG *et al.*, 2016; Zhang *et al.*, 2010), risk assessment (Xiao *et al.*, 2016; Zheng *et al.*, 2013; Zhu *et al.*, 2015), landscape evaluation (Dong *et al.*, 2011; Lan *et al.*, 2015), conservation measures (Wei *et al.*, 2011; Zhan & Zhou, 2016), and culture value (Wang *et al.*, 2016; Zhong *et al.*, 2014). In the same climate zone as Wuzhong District, local researchers have paid much attention on the basic work in the investigation of old trees, such as in Shanghai City (Huang, 2012), Hangzhou City (Bao *et al.*, 2009), Wuxi City (Zhu & Huang, 2018), Changshu City (Li *et al.*, 2017), etc. These studies have provided an effective boost for the conservation of old trees. However, the research on old trees in Wuzhong District is still in the beginning stages (Dong *et al.*, 2013).

Species, number of individuals and distribution of old trees are usually affected by multiple factors, including natural habitat, social customs, historical movement, and economic progress (Lu *et al.*, 2008). As one of the most densely populated and highly industrialized regions in East China, the scales of urban construction and urban land development in Wuzhong District have substantially increased with the quick pace of economic growth and urbanization, resulting in the habitats of old trees become polluted and occupied. These changes will certainly cause staggering damage to the old tree resources. The purposes of this study were to (1) evaluate the species composition of the old trees in Wuzhong District, (2) assess the spatial pattern and species diversity of the old trees in different towns and (3) evaluate the performance and growth status of old trees in the study area. The findings could be helpful in management decisions for old trees in East China, especially those regions affected by urbanization and industrialization.

Materials and Methods

Study area: The study was conducted in Wuzhong District (established over 2000 years ago), located south of Suzhou City and covers an area of 745 km^2 (Fig. 1). The topography of the district is generally characterized by smooth plains with many rivers; however, there are low hills in the west of this area. The major soil types found in this district are paddy soil, yellow-brown earth boggy soil and limestone. The district experiences a north subtropical monsoon oceanic climate with four distinct seasons and mild and abundant rainfall (approximately 1100 mm annually). The mean annual temperature is approximately 15.7°C, with a maximum temperature of 35°C (July) and a minimum of -2°C (January). Approximately 230 days of the year are frost-free. The total registered population of the district is 605000, but there are over 1150000 permanent residents. Since old times, the district has been the centre of business in East China and has had an advanced culture and prosperous economy.

Field investigation: In the study area, we observed each old tree according to the document provided by the local forest administration; therefore, 339 old trees older than 100 years were surveyed and sorted by Gymnosperms classification system of Zheng Wanjun and Angiosperm Phylogeny Group IV (APG IV). The attributes of the old trees were recorded and evaluated in the field, including nomenclature (by Flora of Jiangsu), location (by GPS), site conditions, tree diameter at breast height (DBH, by diameter tape), tree crown (by taping the projected drip line of the tree canopy), tree height (by total station), and tree condition (divided into four categories: vigorous, normal, weak and dying) (Huang *et al.*, 2015).

To protect the old trees, we did not estimate the tree age directly by using an increment borer from the trunk, but the ages were determined from (1) literature and historical records, (2) interviews of the elders, (3) reference of the same species of old trees in the surrounding areas and (4) imaging technology (Xie *et al.*, 2011).

During the interviews with local people, each species was assigned to four use categories: ornamental, medicine, wood and food.

Data and statistical analysis: Species importance value (IV) was calculated on the basis of relative dominance (RD) and relative abundance (RA), IV = (RD+RA)/2, where RD = basal area of a single species / total basal area of all individuals in the study area, and RA = number of individuals of a single species / total number of individuals of all species in the study area (Jim & Zhang, 2013; Welch, 1994); the method used to calculate the family importance value (FIV) was similar to that used to calculate IV. The Shannon-Wiener species diversity index was calculated: $H' = -\sum_i^N P_i \ln P_i$ ($P_i = n_i/N$), where N is the total number of old tree species in the different administrative territories, and n_i is the number of individuals in the administration territory that belong to tree species i (Deka *et al.*, 2012).

Pearson correlation test analyzed the relationships between tree age, Height, Crown and DBH, as well as old tree status and habitats. The data were analysed with proprietary software packages: IBM SPSS Statistics Version 22, MS Excel 2010.

Evaluation of old tree status: Old trees are classified into four grades according to their growth conditions and pest and disease damage: vigorous, common, weak and dying. The vigorous grade denotes that the old tree is in a good status and is flourishing without any damage; the common grade denotes that little damage was observed on the tree trunk, the damage was not obvious, and the tree continued to grow normally; the weak grade denotes that the trunk exhibits an apparent lean with missing crown and damage from pests and disease; the dying grade denotes that the tree exhibits a poor condition with a bare trunk, worse form, scarce leaves, and damage, and this tree would die in the near future.

Results

Species composition and importance value: A total of 339 old trees represented by 41 species from the study site were enumerated (Table 1), these trees were divided into four frequency classes: dominant (>50 individuals/ species), common (10–50 individuals/species), rare (2–9 individuals/species) and solitary (one individual/species). The rare group with 24 species was the largest, followed by solitary (10), common (6), and dominant (1). The most dominant species was *Ginkgo biloba*, which had 93 individuals and the highest relative abundance (RA) at 27.43%, and this species was followed by the common species *Cinnamomum camphora, Zelkova serrata* and *Juniperus chinensis*. Six common species each had 12 to 45 individuals with aggregate RA values of approximately 45.7%. Thirty-four species had less than 10 individuals with each species displaying a bias towards rare and solitary occurrence.

The six most common species contributed to approximately 80% of the RD, whereas the remaining 35 species constituted approximately 20% of the RD (Table 1). The importance values (IVs) of the six most common old trees were significantly different from each other, with an aggregate IV of approximately 74.5%. Specifically, both *Ginkgo biloba* and *Cinnamomum camphora* achieved overwhelming dominance by constituting 32.03% and 17.85% of the IVs, respectively. The remaining 35 old tree species collectively contributed to only 20.6% of the RD or 25.5% of the IV. Therefore, considering the RD, RA and IV, the conclusion could be drawn that the top six old trees constituted the main part of the study area, and these trees represented the structural characteristics of the old trees.

Table 1. Indices denoting the quantity and importance values of 41 old tree species in Wuzhong District.

Species	Family	Growth form	Number	RD	RA	IV	Usage
Ginkgo biloba	Ginkgoaceae	Conifer	93	36.62	27.43	32.03	Ornamental, Medicine
Cinnamomum camphora	Lauraceae	BLE	45	22.43	13.27	17.85	Wood, Ornamental
Zelkova serrata	Ulmaceae	BLD	36	8.28	10.62	9.45	Wood, Ornamental
Juniperus chinensis	Cupressaceae	Conifer	27	6.11	7.96	7.03	Ornamental
Celtis sinensis	Cannabaceae	BLD	18	3.87	5.31	4.59	Ornamental
Ilex chinensis	Aquifoliaceae	BLE	17	2.14	5.01	3.58	Ornamental
Buxus microphylla subsp. *sinica*	Buxaceae	BLE	12	1.41	3.54	2.48	Ornamental
Osmanthus fragrans	Oleaceae	BLE	9	1.93	2.65	2.29	Ornamental, food
Podocarpus macrophyllus	Podocarpaceae	Conifer	7	2.28	2.06	2.17	Ornamental
Castanea mollissima	Fagaceae	BLD	4	2.03	1.18	1.61	Food
Myrica rubra	Myricaceae	BLE	3	1.78	0.88	1.33	Food
Dalbergia hupeana	Fabaceae	BLD	6	0.72	1.77	1.25	Wood
Chimonanthus praecox	Calycanthaceae	BLD	5	0.72	1.47	1.10	Ornamental
Acer palmatum	Sapindaceae	BLD	5	0.57	1.47	1.02	Ornamental
Camellia japonica	Theaceae	BLE	4	0.81	1.18	1.00	Food
Lagerstroemia indica	Lythraceae	BLD	4	0.68	1.18	0.93	Ornamental
Wisteria sinensis	Fabaceae	BLD	2	0.98	0.59	0.79	Ornamental
Ulmus parvifolia	Ulmaceae	BLD	3	0.68	0.88	0.78	Ornamental, wood
Quercus acutissima	Fagaceae	BLD	3	0.53	0.88	0.71	Wood
Liquidambar formosana	Altingiaceae	BLD	3	0.42	0.88	0.65	Wood, Ornamental
Phoebe sheareri	Lauraceae	BLE	3	0.36	0.88	0.62	Wood
Cyclobalanopsis glauca	Fagaceae	BLE	2	0.63	0.59	0.61	Wood
Gleditsia sinensis	Fabaceae	BLD	2	0.27	0.59	0.43	Ornamental, Medicine
Sophora japonica	Fabaceae	BLD	2	0.26	0.59	0.43	Ornamental, food
Michelia figo	Magnoliaceae	BLE	2	0.26	0.59	0.42	Ornamental
Magnolia denudata	Magnoliaceae	BLE	2	0.24	0.59	0.42	Ornamental
Punica granatum	Lythraceae	BLD	2	0.21	0.59	0.40	Ornamental, food
Acer erianthum	Sapindaceae	BLD	2	0.19	0.59	0.39	Ornamental
Chimonanthus salicifolius	Calycanthaceae	BLD	2	0.17	0.59	0.38	Ornamental
Pinus bungeana	Pinaceae	Conifer	2	0.17	0.59	0.38	Ornamental, wood
Citrus reticulata	Rutaceae	BLE	1	0.42	0.29	0.36	food
Photinia serratifolia	Rosaceae	BLE	2	0.12	0.59	0.35	ornamental
Chimonanthus nitens	Calycanthaceae	BLD	1	0.33	0.29	0.31	ornamental
Eriobotrya japonica	Rosaceae	BLE	1	0.30	0.29	0.30	Food, ornamental
Magnolia grandiflora	Magnoliaceae	BLE	1	0.30	0.29	0.30	Ornamental
Quercus variabilis	Fagaceae	BLD	1	0.19	0.29	0.24	Wood
Catalpa ovata	Bignoniaceae	BLD	1	0.17	0.29	0.23	Wood
Sapium sebiferum	Euphorbiaceae	BLD	1	0.15	0.29	0.22	Ornamental
Quercus fabri	Fagaceae	BLD	1	0.13	0.29	0.21	Wood
Illicium verum	Schisandraceae	BLE	1	0.09	0.29	0.19	Food
Lycium chinense	Solanaceae	BLD	1	0.05	0.29	0.17	Food
Total			**339**	**100**	**100**	**100**	

By growth form (Table 1), twenty-two species were broadleaved deciduous, and fifteen species were broadleaved evergreen, and both had the same number of individuals with 105 old trees. Although only four species were conifers, they contributed 129 individuals, taking up approximately 38% of the RA. By the usage (Table 1), the largest proportion of the 41 reported old trees registered in the study area was designated as ornamental (28 species and 68.3%), followed by wood (11, 26.8%) and food (10, 24.4%), while the number of trees designated for medicine was significantly lower (2, 4.9%).

The 41 old trees belong to 25 families and 34 genera (Table 2). The most common family was Fagaceae (5 species), followed by Fabaceae, Calycanthaceae and Magnoliaceae (3 or 4 species each); the remaining families contained only one or two species. The dominant Ginkgoaceae family had an importance value (FIV) of 32.03%, but this family had only one species, *Ginkgo biloba*; furthermore, *Ginkgo biloba* plays an important role in old trees group of Wuzhong District. Both Lauraceae and Ulmaceae had FIVs over 10%, with 18.48% and 10.23%, respectively. Cupressaceae, Cannabaceae, Aquifoliaceae, Fagaceae Buxaceae, Oleaceae and Podocarpaceae followed with FIVs between 2% and 10%. Fourteen families had FIVs<2% and equal species and genus counts except for Calycanthaceae (1:3), Sapindaceae (1:2), Magnoliaceae (2:3) and Rosaceae (2:2). As a consequence, it was difficult for one plant family to contribute many species growing for a long period.

Attributes of old trees*:* The distribution characteristics of the attributes of the old trees according to the survey in Wuzhong District are shown in Figure 2. In terms of old tree age (Fig. 2a), there was a typical pyramid-shape, and the average age was 361 years. In light of the law of old trees in China, the largest part of old trees was accumulated in the third-grade, contributing 64.5% of the individuals, followed by the first-grade (18.9%) and second-grade (16.6%). Among them, over 5.0% of individuals were older than 1000 years; the oldest individual was a 2000-year-old *Ginkgo biloba* located in the Beiwang village of Dongshan Town. The heights of the old trees (Fig. 2b) exhibited a normal distribution, and the average height was 16 m. The most dominant height class was 10-19 m with 148 individuals and 43.9%, followed by 20≤height<30 (32.6%), 2≤height<9 (19.0%) and height≥30 (4.5%). The tallest old tree was *Ginkgo biloba* found in Forest Farm at 60 metres in height, and the shortest tree was *Lagerstroemia indica* at 2 metres found in Cangshu Town. According to the structure of the crown (Fig. 2c), 4≤crown<100 m^2 represented the majority and contributed 47.2% and 160 individuals. The rest of the crown class percentages decreased successively from 100 m^2 to 500 m^2 and constituted 25.4%, 12.4%, 5.3% and 4.4% of the individuals. The DBH distribution histogram (Fig. 2d) also indicated a normal distribution, and the average DBH was 79 centimetres; the group of 8≤DBH<50 with 129 individuals was the largest contributor at 38.1%, followed by 50≤DBH<99 (35.1%), 100≤DBH<150 (17.4%), 150≤DBH<199 (4.7%) and DBH≥200 (4.7%). *Chimonanthus praecox* var. *concolor* had the smallest DBH in Dongshan Town, and the largest DBH was measured from an individual of *Ginkgo biloba*, located on Xiangshan Street.

The Pearson correlation test gauged the significance and magnitude of the association among the tree age, height, crown and DBH. The results showed that there was a highly significant correlation among all variables ($p<0.01$) except tree age and height, but this correlation was still significant ($p<0.05$). Moreover, the Pearson correlation test revealed that the old trees had reasonable biological characteristics and good statuses in this region.

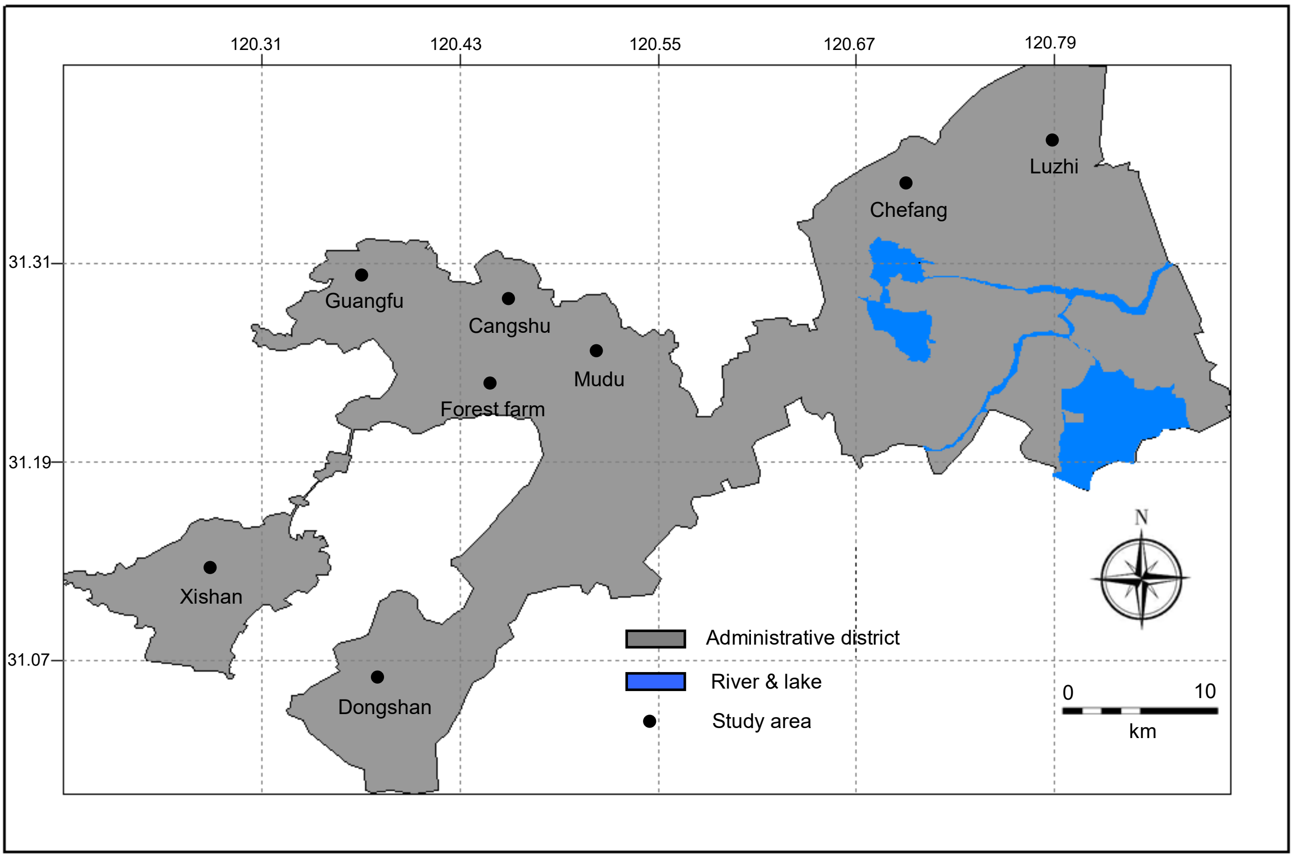

Fig. 1. Map of Wuzhong District and the distribution of old trees.

Spatial distribution pattern: There were approximately 15 towns and streets belonging to the area under the administration of Wuzhong District; however, old trees were distributed in only half of the towns, which denoted a highly uneven distribution (Table 3 and Fig. 1). More species and individuals of old trees were located in suburban or countryside areas. Dongshan Town accommodated the highest number of species (27) and trees (154), followed by Forest Farm (23, 60) and Xishan Town (10, 52). Xishan Town is a small island, and Dongshan Town is a peninsula located at Tai Lake, these areas are free from disturbance, which created favourable environments for old trees. The other towns had no more than 10 species and 23 individuals. The attributes of old trees in different places are also shown in Table 3. We did not discuss the other locations because the old trees had been moved to the urban park and the original locations could not be determined. Dongshan Town and Forest

Farm had the tallest trees (average height of 18 metres in each), but this difference was not significant compared to the other locations. It was obvious that the DBH values of the trees in Xishan Town at 130 cm were larger than those in the other locations, particularly when compared to the DBH values at Mudu Town (56) and Forest Farm (58). The old trees of Mudu Town had the smallest crown values, and Xishan Town had the largest crown values. On the basis of old tree ages, the oldest old trees were clustered in Guangfu Town (965 years on average) and Luzhi Town (799 years on average). The Shannon indices were higher in Forest Farm (2.91), Dongshan Town (2.46) and Cangshu Town (1.97), whereas the Shannon indices were lower in Luzhi Town (1.07), Xishan Town (1.38) and Chefang Town (0.00). However, Chefang Town (1.00) and Mudu Town (0.95) had the highest evenness index values, and Xishan Town (0.40) and Dongshan Town (0.43) had the lowest.

To disclose the favourable habitat for old trees, habitat characteristics were determined by referencing the main land use types (Jim, 2004), for instance, temple, village, public square, farmland, park, house and roadside. Among the land use types, temple accommodated the largest share of old trees (121 individuals or 35.7%) and the most number of species (25). In the temples, several species had higher frequencies, including *Ginkgo biloba*, *Juniperus chinensis*, *Zelkova serrata* and *Cinnamomum camphora*; in addition, *Ginkgo biloba* and *Podocarpus macrophyllus* are very famous as notable religious species. The park was another important place for the accommodation of old trees, such as country parks, forest parks and leisure parks; the parks had 64 individuals of old trees and 16 species recorded. The Farmland and roadside land use types had the smallest number of not only old trees but also species, with 8 and 12 individuals and 5 and 6 species, respectively. Compared to the other land use environments, farmlands were disturbed by agriculture activities and roadsides were stressed by hardened soil and less fertile environments.

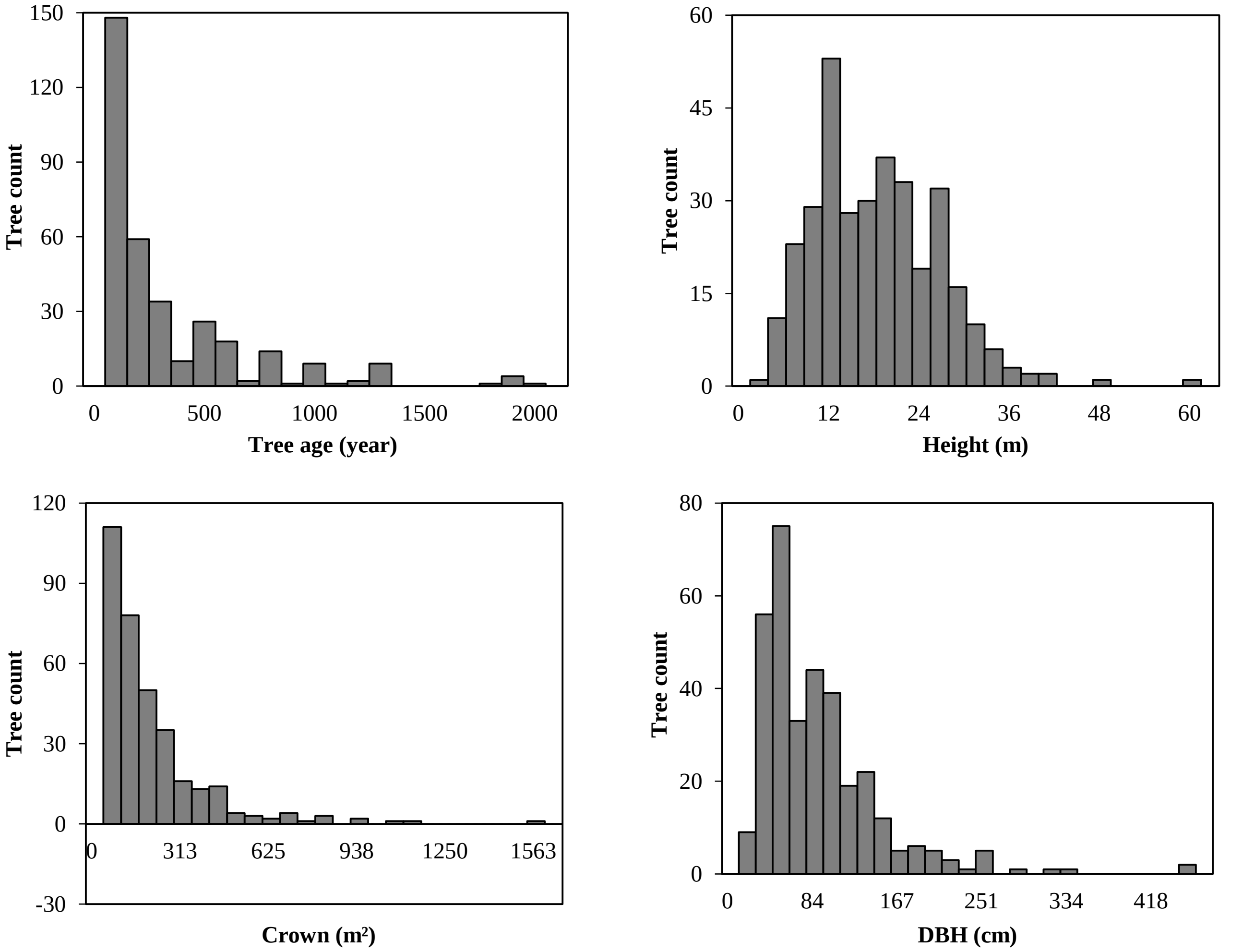

Fig. 2. Frequency of old trees by age, height, crown and DBH.

Growth status of old trees*:* The 339 old trees were classified into four groups: vigorous, normal, weak and dying. In light of the statistics, the growth status of the old trees in Wuzhong District indicated that 140 old trees belonged to vigorous (41.3% of the tree count), followed by normal (167, 49.3%), weak (25, 7.4%) and dying (7, 2.1%). The main causes of old tree damage in Wuzhong District included strong winds, frosts, lightning, trunk hollowing, bark stripping and pests (especially termites). Several *Juniperus sabina* individuals older than 1800 years seriously suffered from lightning strikes and had weak or normal statuses. Among the old trees of *Ginkgo* *biloba*, 54.8% of the trees were normal, followed by vigorous (38.7%), weak (4.3%) and dying (2.2%); *Cinnamomum camphor* also experienced a similar situation. If damages were not artificially maintained, the wounds of the old trees could induce decay and affect the long-term health and survival.

The results of the Pearson correlation coefficient indicated that the growth status of old trees was positively and significantly correlated with habitat ($p<0.01$); moreover, the preferred habitats were in temples and forest farms. Within all religious traditions of China, people believe that the trees had been planted in the temples with spirit, and the trees are associated with myth or legend; most people regard the trees of the temple with reverence. However, the Pearson correlation coefficient showed no correlation between tree age and growth status ($p>0.05$). This result could be due to a convoluted reason that incorporated species biology, habitat and maintenance. In Shenzhen City, it was found that the growth status of old trees was affected by the planting pool because the absorption of nutrients from the soil by the tree roots was restricted (Huang *et al.*, 2015). However, it was other way round in Wuzhong District; some old trees without fencing were destroyed by vandalism, such as branch breakages, carving, smoking, and fires. The old trees of the study area demonstrated and overall degradation status. Therefore, there is an obvious sign that reasonable conservation is imminent.

Table 2. The importance values at the family level and the relative frequencies of genus and species.

Family	Tree count	RD	RA	IV	Genus	Species
Ginkgoaceae	93	36.62	27.43	32.03	1	1
Lauraceae	48	22.79	14.16	18.48	2	2
Ulmaceae	39	8.96	11.50	10.23	2	2
Cupressaceae	27	6.11	7.96	7.03	1	1
Cannabaceae	18	3.87	5.31	4.59	1	1
Aquifoliaceae	17	2.14	5.01	3.58	1	1
Fagaceae	11	3.51	3.24	3.38	3	5
Fabaceae	12	2.24	3.54	2.89	4	4
Buxaceae	12	1.41	3.54	2.48	1	1
Oleaceae	9	1.93	2.65	2.29	1	1
Podocarpaceae	7	2.28	2.06	2.17	1	1
Calycanthaceae	8	1.23	2.36	1.80	1	3
Sapindaceae	7	0.76	2.06	1.41	1	2
Myricaceae	3	1.78	0.88	1.33	1	1
Lythraceae	6	0.89	1.77	1.33	2	2
Magnoliaceae	5	0.79	1.47	1.13	2	3
Theaceae	4	0.81	1.18	1.00	1	1
Altingiaceae	3	0.42	0.88	0.65	1	1
Rosaceae	3	0.41	0.88	0.65	2	2
Pinaceae	2	0.17	0.59	0.38	1	1
Rutaceae	1	0.42	0.29	0.36	1	1
Bignoniaceae	1	0.17	0.29	0.23	1	1
Euphorbiaceae	1	0.15	0.29	0.22	1	1
Schisandraceae	1	0.09	0.29	0.19	1	1
Solanaceae	1	0.05	0.29	0.17	1	1
Total	**339**	**100.00**	**100.00**	**100.00**	**35**	**41**

Discussion

In term of species abundance, we found that *Ginkgo biloba* had the richest number of individuals in the study area. It is very interesting for us to know why this occurred. First, Wuzhong District is located in Jiangsu Province, which is rich in *Ginkgo biloba* from the south to the north. It is a tradition for people to plant *Ginkgo biloba* in Jiangsu Province, and it had formed three cultivated distribution centres. Wuzhong District is one of the cultivated centres (Fu *et al.*, 2014). Every year, the female *Ginkgo biloba* bear many seeds, which is almost identical to the conventional Chinese thought: more children bring more happiness. Second, *Ginkgo biloba* is the oldest tertiary relict gymnosperm plant that originated from the early Jurassic period (Yang *et al.*, 2011), and it is called a living fossil, which is in accordance with the meaning of longevity. Third, *Ginkgo biloba* has particular religious meaning as *Ficus religiosa* and can be found in many temples of China (Wang, 2007), especially in subtropical and temperate regions. In addition to the above reasons, *Ginkgo biloba* is also an ornamental and economic species in China, which has led to it being planted in many home gardens (Qi *et al.*, 2008). As a consequence, it was clear that the traditional practices resulted in the cultivation of more *Ginkgo biloba* individuals in this area.

The old trees in Wuzhong District have not only endured natural selection but also possess unique biological attributes. Furthermore, the old trees exhibited strong resistance to various natural conditions, which also implied that they performed well in the current habitats, and hence, could be added to the planting palette of urban-tree managers (Jim & Zhang, 2013). Consequently, *Ginkgo biloba*, *Cinnamomum camphora*, *Zelkova serrata*, *Juniperus chinensis*, *Celtis sinensis*, *Ilex chinensis*, *Osmanthus fragrans*, and *Podocarpus macrophyllus* could be regarded as excellent resources for landscaping in the future.

Factors other than the origin of the species and local growth conditions affect the species diversity and species selection of old trees. Cultural or historical reasons, as well as personal preferences for some species, might explain the high occurrences of certain species in the region (Thomsen *et al.*, 2016). Suzhou City is a classical Chinese garden centre (Wang, 2007); hence, the species with ornamental value are more popular than species with other functions. Therefore, the related municipal administration departments should pay more attention to ornamental plants as the potential resources for old trees. Due to the lack of diversity value of old trees in other cities, Wuzhong District is compared with other cities by species number directly. Under the approximately administrative area, number of old tree species are higher than Wuxi City (Zhu & Huang, 2018) and close to Changshu City (Li *et al.*, 2017). Hence, species diversity of old trees in Wuzhong District maintain a good level in this climate zone.

The identification of the ages of old trees is a difficult challenge in practice. Although researchers have proposed some measures (Zhong, 2016), the applications of these measures in particular cases can be imperfect. Based on the correlation between tree age (x) and DBH (y) in Wuzhong District, the linear equation was y=57.04+0.06x (R^2=0.147, p<0.01). For the common species, we suggest that a tree could be regarded as the old one if the DBH is over 63 centimetres.

In this study, the results indicated that the old tree species were more concentrated within small ranges far from the urban centre (Fig. 1 and Table 3). However, a nearly universal truth is that urbanization strongly affects the distribution pattern of species diversity, and a significantly positive correlation between species richness and regional-level urbanization has been proven (Ricketts & Imhoff, 2003). Urbanization is becoming one of the greatest impacts on biodiversity, especially because of habitat fragmentation, man-made interference, industrial pollution, heat island, soil quality degradation, etc. (De Sanctis *et al.*, 2010; Stewart *et al.*, 2009; Zhang *et al.*, 2015). For example, in Macau, species composition, diversity, tree health and age were associated with tree-habitats, while the oldest trees mainly dwelled in low-stress and spacious urban parks and religious sites (Zhang *et al.*, 2017). A similar situation occurred in other cities of China (Huang *et al.*, 2015; Jim, 2004; Jim & Zhang, 2013; Zhang *et al.*, 2017). Therefore, it is vital to build a more favourable environment without interference for old trees.

Table 3. Distribution patterns of old trees in Wuzhong District.

Location	No. of species	Individuals	Average height	Average DBH	Average crown	Average age	Shannon diversity	Evenness index	Status
Cangshu	10	23	13	80	141	172	1.97	0.72	8.17
Dongshan	27	154	18	64	112	314	2.46	0.43	8.41
Guangfu	8	17	13	81	146	965	1.71	0.69	7.53
Forest Farm	23	60	18	58	221	202	2.91	0.80	8.73
Xishan	10	52	17	130	293	511	1.38	0.40	8.19
Chefang	1	12	12	94	101	355	0.00	1.00	7.33
Luzhi	4	8	16	100	146	799	1.07	0.73	8.75
Mudu	5	6	14	56	60	205	1.56	0.95	9.33
Other	2	7	23	185	296	417	0.41	0.75	10.00

There are several problems facing the conservation of old trees in Wuzhong District. (1) Habitat deterioration. Some old trees are surrounded by concrete or rigid materials, which has resulted in severe population degradation due to poor permeability and penetration of the soil. Beyond that, some old trees were too close to construction and did not have sufficient space for strength. (2) Inadequate management and technology. In the field investigation, we found that one part of the old trees did not have any fencing or routine maintenance. The other part of the old trees exhibited root decomposition and hollow trunks, but no effective measures were implemented because of insufficient funds and technological issues. The existing regulation and legislation established by the municipal administration did not work very well. (3) Lack of publicity. Some people were unaware of conservation, and the public was not involved in the activity. In particular, when the structures of the old trees that belonged to collective ownership were damaged, these instances were not reported to the management on time.

As a matter of fact, landscape and forestry department at all administrative levels worked hard for the conservation of old trees. The Government of China had authorized Urban Construction Department also set national policies and drafted bills, for example '*Measures for the Protection and Management of Old and Famous Trees in Cities*'. At the same time, there were other corresponding laws and regulations promulgated by the relevant ministries, such as '*The Environmental Protection Law of the People's Republic of China*', '*The Forest Law of the People's Republic of China*' etc. At provincial level, the Government of Jiangsu Province drafted provincial legislation for development management and conservation of old trees, like '*Protection and Management Measures for Old and Famous Trees of Jiangsu Province*'. Local government of Wuzhong District also enacted some administrative measures to protect the old trees. Therefore, great importance was given for the conservation work of old trees.

However, conservation is urgently needed to protect the existing old trees from threats also. We suggest (1) it is essential for management to establish documentation and a database of the old trees, and the growth status should be regularly monitored. New technology should be applied to conservation, as remote sensing and GIS technologies have become highly developed, user-friendly and fairly cheap. (2) More focus should not only be given to tree age and location but also expanded to encompass more qualities, such as tree structure and form, species rarity, botanical interest, ecological contribution, habitat uniqueness, location value, and cultural, religious, and historical significance (Jim, 2004). (3) Habitat improvement and rejuvenation. Creating adequate space for tree growth and improving soil conditions are critical to maintaining the existing population. Several methods, such as fencing, filling hollow trunks, repairing broken branches, and supporting trunks, could be applied to the conservation. (4) Management should comprehensively consider the biology and actual location conditions of each species to designate conservation plans and not implement uniform plans in all cases.

Conclusion

On the basis of the field investigations, the following conclusion can be drawn: 339 individuals of old trees were found in Wuzhong District, constituting 41 species belonging to 34 genera and 26 families. When considering the abundance of old trees in the study area, *Ginkgo biloba* was the most common in the habitat and administrative region, followed by *Cinnamomum camphora*; this result implies that these species will require more conservation attention. At the same time, the results of this study provide information to management that the young trees are more likely old trees in the future. The old trees could also be ornamental resources. The distribution of old trees age showed that third-grade (100-299 years old) was more common than first-grade (over 500 years old) and second-grade (300-499 years old), and the distribution exhibited a pyramid shape. However, the ages and DBH of the old trees exhibited a significant linear correlation. The spatial distribution pattern denotes that there are more old trees in rural towns than in the urban centre, and temples are the main places that accommodate the trees. The growth status of old trees in Wuzhong District presents the tendency of degradation; at the same time, the growth status is positively and significantly correlated with the habitats.

The lessons from Wuzhong District could alert other municipal authorities to establish an effective system to safeguard their old trees and provide effective measures that would allow more trees to qualify as old trees in the future. This study of the distribution pattern and species diversity of old trees in Wuzhong District may also provide new insights for future studies in the cities of East China.

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