

Original Paper

Protecting Heritage Trees in Weifang City, Shandong Province, Northern China

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Abstract

*Heritage trees are long-lived trees or notable trees with great historical significance, scientific value, or commemorative importance. Many heritage trees have been preserved in Weifang City, Shandong Province, Northern China. In this paper, the origin, species diversity, age structure, health, surrounding habitats, distribution, genera floristic composition, and challenges of protecting the heritage trees were investigated using literature analysis, field survey, and interview. There are 864 heritage trees in the city, composed of 49 species, 41 genera, and 25 families. The heritage trees are divided into three original types: religious trees, naturally dispersed and preserved wild trees, and trees with agricultural backgrounds or used as offerings. Particularly, *Sophora japonica*, *Ziziphus jujube*, *Ginkgo biloba*, *Sabina chinensis*, *Platycladus orientalis*, and *Osmanthus fragrans* are the six most common species. There are 208 individuals of 500 years or elder, 293 individuals of 300–499 years old, 359 individuals of 100–299 years old, and 4 individuals of notable trees. Most of them are distributed in low-urbanized areas of the 4 county-level cities and Linqu county, and few are distributed in high-urbanized areas of the 4 districts of Weifang City. There are 14, 12, and 6 genera belonging to the areal-types of Temperate, Cosmopolitan, and Tropic, respectively, similar to that of wild seed plants in Yishan Mountain. There are some challenges in protecting heritage trees, such as urbanization, habitat deterioration, natural disasters, anthropic activities, health decline, and inadequate management. Some protection measures that have been taken previously are summarized, and some measures that should be taken in the future are proposed.*

Keywords

Heritage Trees, Quantity, Age Structure, Distribution, Weifang City

1. Introduction

Heritage trees are long-lived trees with great historical significance, scientific value, or commemorative importance (Mathaux, Mandin, Oberlin, Edouard, Gauquelin, & Guibal, 2016). They are also named ancient and famous trees, old and notable trees (*gushu* and *mingmu* in Chinese) in China. Generally, heritage trees refer to trees aged 100 years or elder, as well as notable trees, such as friendship trees given or planted by foreign leaders, commemorative trees planted by domestic leaders to celebrate a particular event, legendary trees as a part of scenic spots mentioned in historical stories and anecdotes, and trees of rare or endangered species confirmed by the government (Ministry of Construction of the People's Republic of China, 2000; State Forestry Administration of China, 2020). Heritage trees have witnessed history, made scenic spots fascinating, and provided biological evidence for the research on the changes in regional climate and environment (Gough, Sverdrup-Thygeson, Milberg, Pilskog, Jansson, Jonsell, & Birkemoe, 2015). They have great ecological, scientific, historical, cultural, and aesthetic significance (Duinker, Ordonez, Steenberg, Miller, Toni, & Nitoslowski, 2015; Liu, 2013; Martin, 2013; Criscuolo, Guarino, Angelini, Castiglione, Caruso, & Cikatelli, 2019).

Much work has been performed to protect heritage trees worldwide in recent decades. North America and UK emphasized tree size, champion trees were ranked and systematic registered according to height, crown spread, trunk circumference in US, Canada and UK (Lai, Jim, Tang, Hong, & Zhang, 2019). The champion trees were registered on their height, diameter, crown spread, age and heritage significance in South Africa, Trees of Public Interest were identified by their species representativeness, rarity, size, age, historical, cultural and landscaping significance and public interest in Portugal. Significant trees with scientific, social, historic or aesthetic values were nominated by the public, and assessed by the Significant Tree Committees in Australia (Jim, 1994). In Hong Kong, champion trees were evaluated on age, dimensions, tree form, health, species rarity, ecological importance, landscape contribution, or association with notable historical or personnel events (Jim, 2006).

Researchers have studied heritage trees in various aspects, such as species and diversity (Capotorti, Del Vico, Anzellotti, & Celesti-Grapow, 2017; Nero, Kwapong, Jatta, & Fatunbi, 2018), individuals of heritage trees and their distribution in Hong Kong and Shenzhen City (Lai, Jim, Tang, Hong, & Zhang, 2019; Liu, Wang, Chen, Yi, Zeng, & Xing, 2008), age structure (Xu, Guan, Zhang, Li, Zhao, Ross, & Shen, 2021), health condition and functional diversity (Czortek & Pielech, 2020; Townsend & Barton, 2018), monetary environmental value, protecting status and challenges (Childers, Cadenasso, Grove, Marshall, McGrath, & Pickett, 2015; Zhong, Li, & Wang, 2014), habitat improvement (Ou, Zhong, & Li, 2007; Mckinney, 2006), pest prevention, tree trunk consolidation and rejuvenation, and methods of indexing tree-related data since the 1990s (Bertheau, Brockerhoff, Roux-Morabito, Lieutier, & Jactel, 2010; Zhang, Wang, Liu, Zheng, Cao, & Liu, 2019; Zhang, Cui, Liu, Zhang, Xi, Li, & Lu, 2017). For example, the Ministry of Construction of the People's Republic of China (PRC) set up the Management Acts of Urban Heritage Trees Protection in 2000 (Ministry of Construction of the People's Republic of China, 2000); the National Afforestation Committee and the State Forestry Administration of the PRC

initiated a national survey of heritage trees in 2001 (State Forestry Administration of China, 2016). In previous studies completed by Chinese researchers, the age of heritage trees were more emphasized than their size, while the size of heritage trees were more emphasized than their age in North America, UK, South Africa and Australia.

With the rapid urbanization in recent decades, numerous heritage trees have been effectively preserved in Weifang City, northern China. Nevertheless, there are still many challenges in their conservation. For example, all these trees are influenced by rapid urbanization, prolonged droughts, soil compaction, water shortage, and air pollution; some heritage trees have suffered severe damage from kinds of natural hazards, such as typhoons, lightning strikes, rainstorms, droughts, cold damage, forest pests, and diseases; some heritage trees, such as individuals of *Sophora japonica* and *Juglans regia*, are threatened by forest pests of *Hyphantria cunea*; some heritage trees were unsuitably protected, resulting in deteriorating their habitat and weakening their vitality and physiological function. Furthermore, the main challenges regarding management are the vaguely-defined conservation responsibilities, weak law enforcement, lack of routine maintenance, and obsolete conservation techniques (Wu, 2007).

This research aims to review the species, age structure, health status, distribution, and density of heritage trees in Weifang City. Additionally, the taxonomic and floristic composition, original types, current challenges, protection measures that have been taken previously and should be taken in the future were discussed. This paper is of great significance for promoting sustainable development and constructing an ecological garden city for Weifang City.

2. Study Area and Methods

2.1 Study Area

Weifang City (118°10'–120°01'E, 35°41'–37°26'N) is located in the central part of Shandong Peninsula, Shandong Province, northern China. It is south to Taiyi Mountains, north to Laizhou Bay of Bohai Sea, east to Qingdao City and Yantai City, and west to Dongying City and Zibo City. As a large prefectural city, it has a total area of 16140 km² (Figure 1). The surface elevation rises gradually from north to south. From north to south, the city can be divided into three geomorphic regions: lowlands, plains, and hilly lands. The climate of Weifang City belongs to warm temperate monsoon climate, which is characterized by distinct seasons of cold winter, hot summer, and windy and rainless spring. There are hundreds of rivers belonging to six river systems of Weihe River, Mihe River, Bailanghe River, Nanjiaolaihe River, Beijiaolaihe River, and Zihe River in Weifang City. There are two soil groups: 1) inceptisols, whose forming process is mainly influenced by seawater or freshwater; 2) ultisols, which is formed primarily by the eluviation process. Additionally, seed plants in Weifang City are composed of 1049 species, 502 genera, and 142 families (Liu, Zhao, Wu, & Qi, 2009); Yishan Mountain in Weifang City possesses 727 species, 411 genera, and 108 families of seed plants, as well as 188 species, 106 genera, and 42 families of woody plants (Wang & Li, 2002).

Weifang City, as a larger prefectural city, consists of four districts, six county-level cities, and two counties (Weicheng District, Hanting District, Kuiwen District, Fangzi District, Changyi City, Shouguang City, Qingzhou City, Anqiu City, Zhucheng City, Gaomi City and Linqu County, and Changle County) (Figure 1).

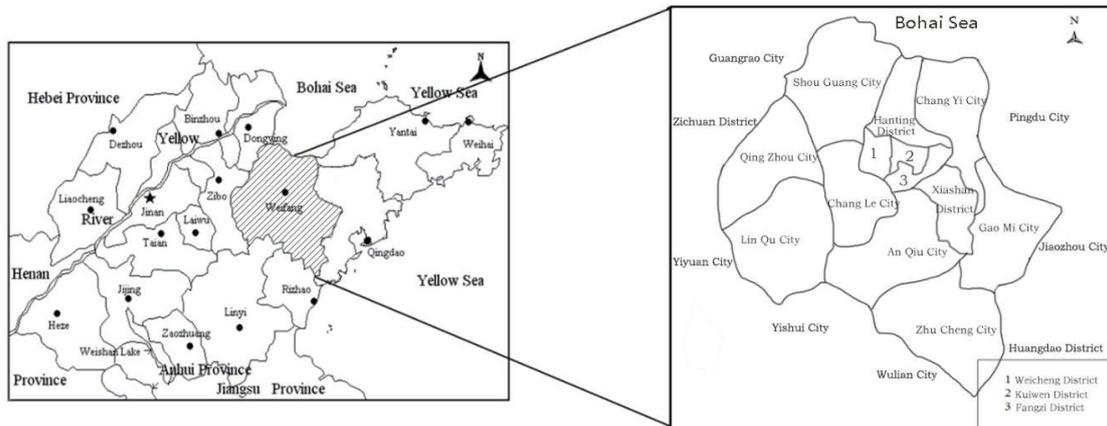


Figure 1. Location of Weifang City, Shandong Province, China

Note. 1 Weicheng District, 2 Kuiwen District

3. Methods

In this study, the composition of families, genera, and species, champion trees ranked according to height, crown spread, and trunk circumference, the distribution and density of individuals, age structure, and health grades of heritage trees in Weifang City were analysed; the original types, floristic composition, current challenges, and protection measures taken previously were discussed; some protection measures that should be taken in the future were proposed.

The original types of heritage trees were determined based on their biological characteristics and distribution; the composition of families, genera, and species of heritage trees, the individuals of each species, and the age structure of the total individuals were counted and analysed depending on the data of the field survey conducted by Bureau of Parks and Woods of Weifang City in 2001-2004 (Appendix table 1); the ages of heritage trees were obtained from the literature (Wu, 2007), where they were determined mainly according to rings and trunk circumference of the trees, and interview survey.

The health grade of heritage trees is determined according to the growing status of their leaves, branches, and trunks (State Forestry Administration of China, 2016). The health grades of some heritage trees in urban areas, scenic spots of Weifang City, was determined depending on the current growth state of leaves, branches, and trunks of heritage trees investigated in our field survey, however most of them are determined depending on previous survey data.

Moreover, the individuals, density, the individuals per 10,000 persons of heritage trees in the districts, county-level cities, and Linqu County of Weifang City, and the individuals of heritage trees distributed in various land-use types were counted according to the location of each heritage trees recorded (Wu,

2007). The rough coordinates of latitude and longitude of all heritage tree individuals are determined based on their administrative location, and the distributing figure of heritage trees was formed using their coordinates.

Their distribution in different land-use types and the ownership and protection measures of each heritage tree are determined according to its habitats and the surrounding environment. The composition of genera areal-types of heritage trees is analysed and compared with that of the natural vegetation in Yishan Scenic Spot of Weifang City based on related literature (Zhang, Wang, Liu, Zheng, Cao, & Liu, 2019; Wu, 2007; Wang & Li, 2002; Wu, 1991).

Besides, literature analysis, interview, and field survey were conducted to obtain the coordinates of latitude and longitude, protection measures, the health grades of 51 individuals heritage trees in Shouguang City and Linqu County; figures and texts acquired through the internet were employed to investigate 56 individuals of national first-class heritage trees, 27 individuals of national second-class heritage trees, and 7 individuals of the national third-class heritage trees.

4. Results

4.1 Diversity of Heritage Trees in Weifang City

There are 864 heritage trees belonging to 49 species, 41 genera, and 25 families in Weifang City. Among the existing heritage trees, native heritage trees of *Sophora japonica* (401 individuals), *Ziziphus jujuba* (186 individuals), *Sabina chinensis* (43 individuals), *Platyclusus orientalis* (42 individuals), *Ginkgo biloba* (34 individuals), and *Osmanthus fragrans* (33 individuals) are the six most common species, accounting for 12.24% and 85.53% of the total species and individuals of the heritage trees in Weifang City, respectively (Figure 2, Table 1). This demonstrates that the heritage trees in Weifang City are mainly native trees, and trees introduced from southern China and abroad are the minority. Regarding the number of families, genera, and species, the heritage trees account for 17.61%, 8.13%, and 4.67% of all seed plants in Weifang City, as well as 43.1%, 32.28%, and 28.16% of woody, respectively (Liu, Zhao, Wu, & Qi, 2009). The diversity of heritage trees in Weifang City is comparatively large owing to their high percentage of native woody plants of Weifang City, though the relative number percentages of families, genera, and species of heritage trees among all seed plants in Weifang City are low.

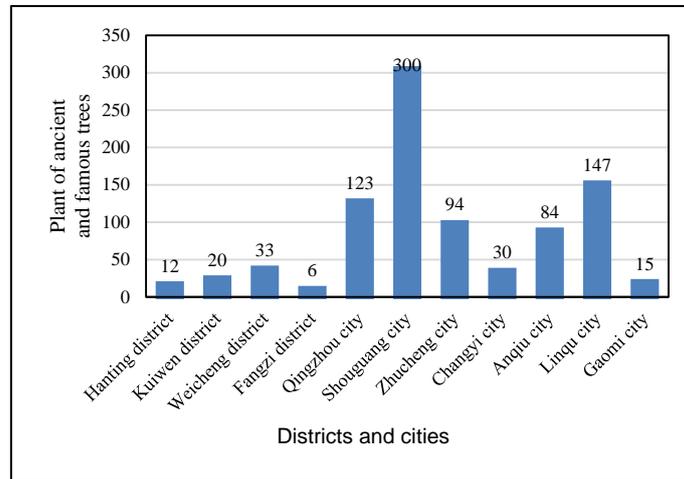


Figure 2. Distribution of Heritage Trees in Weifang City

Table 1. The Heritage Trees in Weifang City

Family	Genus	Species	Number	Percentage
I Ginkgoaceae	1 <i>Ginkgo</i>	(1) <i>Ginkgo biloba</i> Linn.	34	3.94%
II Pinaceae	2 <i>Pinus</i>	(2) <i>Pinus densiflora</i> Sieb. et Zucc.	1	0.12%
		(3) <i>Pinus parviflora</i> Sieb. et Zucc.	2	0.23%
		(4) <i>Pinus tabuliformis</i> Carr.	5	0.58%
	3 <i>Cedrus</i>	(5) <i>Cedrus deodara</i> (Roxb.) G. Don	3	0.35%
III Cupressaceae	4 <i>Platycladus</i>	(6) <i>Platycladus orientalis</i> (L.) Franco	42	4.86%
	5 <i>Sabina</i>	(7) <i>Sabina chinensis</i> (Linn.) Ant.	43	4.98%
	6 <i>Juniperus</i>	(8) <i>Juniperus formosana</i> Hayata	1	0.12%
IV Salicaceae	7 <i>Populus</i>	(9) <i>Populus tomentosa</i> Carr.	2	0.23%
	8 <i>Salix</i>	(10) <i>Salix matsudana</i> Koidz.	2	0.23%
		(11) <i>Salix badylonica</i> Linn.	1	0.12%
V Juglandaceae	9 <i>Juglans</i>	(12) <i>Juglans regia</i> Linn.	2	0.23%
VI Fagaceae	10 <i>Castanea</i>	(13) <i>Castanea mollissima</i> BL.	12	1.39%
	11 <i>Quercus</i>	(14) <i>Quercus dentata</i> Thunb	1	0.12%
		(15) <i>Quercus acutissima</i> Carruth	1	0.12%
VII Ulmaceae	12 <i>Celtis</i>	(16) <i>Celtis bungeana</i> BL.	6	0.69%
		(17) <i>Celtis sinensis</i> Pers	3	0.35%
VIII Moraceae	13 <i>Cudrania</i>	(18) <i>Cudrania tricuspidata</i> (Carr.) Bur. ex Lavalley	1	0.12%
	14 <i>Morus</i>	(19) <i>Morus alba</i> L.	1	0.12%
IX Calycanthaceae	15 <i>Chimonanthus</i>	(20) <i>Chimonanthus praecox</i> (L.) Link	1	0.12%

X Rosaceae	16 <i>Photinia</i>	(21) <i>Photinia serrulata</i> Lindl	1	0.12%
	17 <i>Chaenomeles</i>	(22) <i>Chaenomeles sinensis</i> (Thouin) Koehne	1	0.12%
	18 <i>Pyrus</i>	(23) <i>Pyrus bretschneideri</i> Rehd.	1	0.12%
		(24) <i>Pyrus betulaefolia</i> Bunge.	1	0.12%
XI Leguminosae	19 <i>Sophora</i>	(25) <i>Sophora japonica</i> Linn.	401	46.41%
		(26) <i>Sophora japonica</i> Linn. var. <i>japonica</i> f. <i>pendula</i> Hort.	5	0.58%
	20 <i>Dalbergia</i>	(27) <i>Dalbergia hupeana</i> Hance	3	0.35%
	21 <i>Gleditsia</i>	(28) <i>leditsia sinensis</i> Lam.	6	0.69%
	22 <i>Wisteria</i>	(29) <i>Wisteria sinensis</i> (Sims) Sweet	3	0.35%
XII Rutaceae	23 <i>Poncirus</i>	(30) <i>Poncirus trifoliata</i> L. Rafin.	1	0.12%
XIII Buxaceae	24 <i>Buxus</i>	(31) <i>Buxus sinica</i> (Rehd. et Wils.) Cheng	2	0.23%
XIV Anacardiaceae	25 <i>Pistacia</i>	(32) <i>Pistacia chinensis</i> Bunge	4	0.46%
	26 <i>Cotinus</i>	(33) <i>Cotinus coggygria</i> Scop.	2	0.23%
	27 <i>Toxicodendron</i>	(34) <i>Toxicodendron vernicifluum</i> (Stokes) F. A. Barkl.	1	0.12%
XV Aceraceae	28 <i>Acer</i>	(35) <i>Acer mono</i> Maxim	1	0.12%
XVI Sapindaceae	29 <i>Koelreuteria</i>	(36) <i>Koelreuteria paniculata</i> Laxm.	1	0.12%
	30 <i>Xanthoceras</i>	(37) <i>Xanthoceras sorbifolium</i> Bunge	2	0.23%
XVII Rhamnaceae	31 <i>Ziziphus</i>	(38) <i>Ziziphus jujuba</i> Mill.	186	21.53%
		(39) <i>Ziziphus jujuba</i> Mill. var. <i>spinosa</i> (Bunge) Hu ex H. F. Chow	4	0.46%
XVIII Vitaceae	32 <i>Parthenocissus</i>	(40) <i>Parthenocissus tricuspidata</i> (S. Et Z.) Planch.	1	0.12%
XIX Theaceae	33 <i>Camellia</i>	(41) <i>Camellia japonica</i> Linn.	1	0.12%
XX Lythraceae	34 <i>Lagerstroemia</i>	(42) <i>Lagerstroemia indica</i> Linn.	2	0.23%
XXI Cornaceae	35 <i>Swida</i>	(43) <i>Swida walteri</i> (Wanger.) Sojak	2	0.23%
XXII Oleaceae	36 <i>Osmanthus</i>	(44) <i>Osmanthus fragrans</i> (Thunb.) Lour.	33	3.82%
	37 <i>Chionanthus</i>	(45) <i>Chionanthus retusus</i> Lindl. et Paxt.	22	2.55%
	38 <i>Syringa</i>	(46) <i>Syzygium oblata</i> Lindl.	1	0.12%
XXIII Bignoniaceae	39 <i>Catalpa</i>	(47) <i>Catalpa bungei</i> C.A. Mey	5	0.58%
XXIV Caprifoliaceae	40 <i>Lonicera</i>	(48) <i>Lonicera maackii</i> (Rupr.) Maxim.	1	0.12%
XXV Ebenaceae	41 <i>Diospyros</i>	(49) <i>Diospyros kaki</i> Thunb.	6	0.69%
Total			864	100.00%

4.2 Age Structure of the Heritage Trees in Weifang City

Most of the heritage trees except for notable trees were classified into three classes according to their ages in China: the national first-class heritage trees (500 years old or elder), the national second-class heritage trees (300–499 years old), and the national third-class heritage trees (100–299 years old). Age was not considered for notable trees. There are 208 national first-class heritage trees (24.07% of the total), 293 national second-class heritage trees (33.91%), 359 national third-class heritage trees (41.55%), and 4 notable trees (0.46%) in Weifang City. Among them, only 26 individuals are over 1000 years (3.01% of the total) (Figure 3). There are 10 individuals of *Sophora japonica* and 9 individuals of *Ginkgo biloba* over 1000 years, accounting for 38.46% and 34.62% of the total heritage trees aged 1000 years or elder, respectively. *Sophora japonica* is a widely distributed local species of heritage trees with great resistance to drying cold, high temperature, and drought in Weifang City. The individuals of *Sophora japonica* have strong sprout ability after pruning and are easy to survive after transplantation. Moreover, they also have a strong resistance to sulfur dioxide, smoke, and dust. Consequently, they have a long life span. The heritage trees of *Ginkgo biloba* are naturally long-lived species with few insect pests and well preserved in temples and courtyards (Ou, Zhong, & Li, 2007; Liu, 2014). The oldest heritage trees in Weifang City are two couple trees of *Ginkgo biloba* aged 2500 years or elder in Gongyechang Academy on Chengding Mountain, Shibuzi town, Anqiu City.

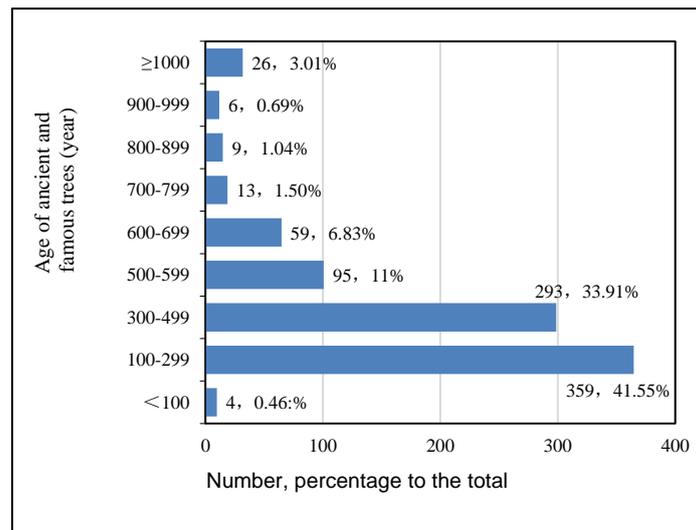


Figure 3. Age Structure of Heritage Trees in Weifang City

4.3 Health Grades of the Heritage Trees in Weifang City

The health grades of heritage trees are divided into four grades: strong, general, poor, and endangered according to the growth potential of their leaves, brunches and trunks, and the judgement standards of health grades issued by the state forestry administration of China are below (Table 2) (State Forestry Administration of China, 2016). There are 616, 172, 69, and 7 individuals of heritage trees with health

grades of strong, general, poor, and endangered, accounting for 71.30%, 19.91%, 7.99% and 0.81% of the total heritage trees in Weifang City, respectively. The 76 individuals with health grades of poor and endangered should be well protected. Among the existing 864 individuals, 3 individuals of heritage trees (an individual of *Ginkgo biloba* aged 200 years in Qingzhou City, an individual of *Ginkgo biloba* aged 650 years in Gaomi City, and an individual of *Platycladus orientalis* aged 500 years in Anqiu City) were transplanted somewhere else for urbanization since 2007. An individual of *Sophora japonica* aged 410 years in Linqu County and an individual of *Sophora japonica* aged 500 years in Shouguang City died in 2017.

Table 2. Health Grades and Judgement Standards of Heritage Trees

Grades of health	Leaf	Branch	Trunk
Strong	Normal leaves account for more than 95% of the total leaves	The tree has many new brunches; all brunches grow normally; no brunch dries totally or partly	Trunk is generally intact and not necrotic
General	Normal leaves account for 80%– 95% of the total leaves	New brunches grow weakly; a few brunches dry and die	Trunk is slightly damaged or necrotic
Poor	Normal leaves account for 50%– 80% of the total leaves	Many brunches dry and die	Trunk is obviously damaged or necrotic
Endangered	Normal leaves account for less than 50% of the total leaves	All brunches dry and die, no new brunches	Trunk is seriously damaged, vacuous or dry

4.4 Distribution and Density of Heritage Trees in County-level Administrative Regions of Weifang City

There are only 33 individuals of heritage trees in Weicheng District, 20 individuals in Kuiwen District, 12 individuals in Hanting District, 6 individuals in Fangzi District, 30 individuals in Changyi City, and 15 individuals in Gaomi City. In contrast, there are 300 individuals of heritage trees in Shouguang City, 147 individuals in Linqu County, 123 individuals in Qingzhou City, 94 individuals in Zhucheng City, and 84 individuals in Anqiu City (Table 2). No heritage tree is distributed in Changle County. Qingzhou City is a famous ancient city with a long history. The urban green spaces and public spaces in Scenic Spots of the city, such as Fangongting Park, Ouyuan Palace, and Zhenjiao Temple, provide suitable habitats for heritage trees. Weicheng District and Kuiwen District are the political, economic, and cultural centres of Weifang City and have extensive urban green spaces, including Dongyuan Park, Guangwen middle school, and Second middle school of Weifang City, providing preferable habitats for heritage trees. Due to the large land area and the low standard of urbanization, Shimenfang Scenic Spot,

Laolongwan Scenic Spot, Xuanquan Temple in Shijiahe Town, East Town Temple, and Fayunsi Temple of Yishan 5A Scenic Spot in Linqu County also contain many heritage trees. However, the heritage trees are scattered widely in this county.

There is a significant difference in the distribution of heritage trees between urban areas and suburban areas (Table 3). Generally, the heritage trees in the suburban county-level cities and Linqu County are characterized by considerable individuals, high density, and more individuals per capita. In contrast, the heritage trees in the four highly urbanized districts are characterized by few individuals, low density, and fewer individuals per capita. There are only 71 heritage trees in the four urban districts (2635 km² in total) and 793 heritage trees in the six suburban county-level cities and Linqu County (12408 km² in total), accounting for 8.22% and 91.78% of the total individuals in Weifang City, respectively. The density of heritage trees in Weifang City is 0.057 individual/km², which is 19.15 times the national average density (0.003 individual/km²). The density of heritage trees in the four districts is 0.03 individuals/km², with 0.38 individuals/10,000 people. The density of heritage trees in the six suburban county-level cities and Linqu County is 0.06 individuals/km², with 1.21 individuals/10,000 people.

Table 3. The Individuals, Density and Individuals per Capita of Heritage Trees in the County-level Administrative Regions in Weifang City

Administrative region	Acreage (km ²)	Population (×10 ⁴ capita)	Individuals	Density (individuals/km ²)	Individuals per capita (individuals/1×10 ⁴ capita)
Weicheng District	270	35.8	33	0.12	0.92
Hanting District	1301	40.0	12	0.01	0.30
Kuiwen District	168	55.2	20	0.12	0.36
Fangzi District	896	55.4	6	0.01	0.11
Changyi City	1628	58.7	30	0.02	0.51
Shouguang City	1990	110.3	300	0.15	2.72
Qingzhou City	1569	95.5	123	0.08	1.29
Anqiu City	1712	97.6	84	0.05	0.86
Zhucheng City	2151	110.9	94	0.04	0.84
Gaomi City	1527	89.6	15	0.01	0.17
Linqu County	1831	92.6	147	0.08	1.59

The distribution of heritage trees is different in different areas because fewer heritage trees in the four urban districts and two county-level cities (Changyi City and Gaomi City) were protected compared to the other four county-level cities and Linqu County as the four urban districts and two county-level cities are traditional industrial area and underwent urbanization and industrialization early. There are fewer heritage trees in the northern coastal lowland and plain with salinized inceptisols. Most of the

heritage trees are distributed in the central and western hilly lands with diversified habitats and ultisols formed mainly by eluviation in Weifang City.

4.5 Distribution of Heritage Trees in Different Land-use Types of Weifang City

The distribution of heritage trees varies in different land-use types. Most of them are distributed in country construction lands, parks, and green spaces. There are 669 individuals in country construction lands and 74 individuals in parks and urban green spaces, accounting for 86.00% of the total individuals in Weifang City. On the contrary, there are fewer heritage trees in educational lands (34 individuals), scenic and historic areas (27 individuals), and religious lands (21 individuals), accounting for 9.49% of the total. Moreover, only 39 individuals are discovered in agricultural lands and forest lands (14 individuals), traffic lands (11 individuals), municipal facility lands (6 individuals), residential lands (5 individuals), and industrial lands (3 individuals), accounting for 4.51% of the total (Table 4).

Table 4. Distribution of Heritage Trees in the Different Land-use Types in Weifang City

Land-use type	Land-use status	Number	Percentage
Country construction land	Countryside homestead, courtyard, public service land, etc.	669	77.43%
Scenic and historic area	Yishan Scenic Spot, Laolongwan Scenic Spot, etc., and related used land	27	3.13%
Park and green space	Gangwan park, Fangongting park, Huaixiang Garden, Dongyuan park, etc.	74	8.56%
Residential land	Common residence, ground of the old building	5	0.58%
Educational land	Kindergarten, primary school, middle school, university, and related sites land	34	3.94%
Agricultural land and forest land	Farm land, forest land, orchard, mountain, agricultural facilities land, etc.	14	1.62%
Religious land	Temple, taoist abbey, church, etc.	21	2.43%
Municipal facility land	Museum, enterprise and public institution, art gallery, hospital, etc.	6	0.69%
Traffic land	Road in different classes	11	1.27%
Industrial land	Industrial land in urban and rural area, Enterprise unit	3	0.35%

The country construction land has a large area and the advantages of high vegetation coverage and little anthropic influences, providing suitable habitats for local heritage trees. The heritage trees around the county houses or in gardens are protected as geomantic omens (*fengshui trees* in Chinese). The scenic and historic areas of Yishan Scenic Spot and Laolongwan Scenic Spot and the green spaces of Gangwan Park and Fangongting Park have excellent natural environments, long histories, and great

cultural and economic value. The numerous heritage trees in these areas are well protected and managed by departments of agriculture, tourism, and forestry. Specifically, Huaixiang Garden was established in Shouguang City, and lots of other trees have been planted to protect the heritage trees of *Sophora japonica* aged more than 2000 years.

4.6 Taxonomic and Floristic Composition of Heritage Trees in Weifang City

The family, genera, and species of the heritage trees in Weifang are highly diverse. The six large families of Pinaceae, Rosaceae, Leguminosae, Cupressaceae, Anacardiaceae, and Oleaceae have the most genera and species of heritage trees in Weifang City. Pinaceae has 2 genera with 4 species, Rosaceae has 3 genera with 4 species, Leguminosae has 4 genera with 5 species, Cupressaceae has 3 genera with 3 species, Anacardiaceae has 3 genera with 3 species, and Oleaceae has 3 genera with 3 species. To sum up, the six large families have 17 genera with a total of 22 species, and each family is composed of three or more species. The numbers of species, genera, and families of the six families account for 44.90%, 41.46% and 24.0% of the total heritage trees in Weifang City, respectively.

The genera of seed plants in China have been classified into 15 areal-types (Wu, 1991). The 41 genera of the heritage trees in Weifang City belong to 10 areal-types. Among them, 12 and 2 genera (34.15% of the total) belong to the areal-types of North Temperate and Old World Temperate, respectively, suggesting that the heritage trees in Weifang City are mainly composed of temperate genera with evident areal characterization. Besides, 12 genera (29.27% of the total) belong to the areal-type of Cosmopolitan, reflecting that many genera of heritage trees in Weifang City are widely distributed in the world. Additionally, 6 genera (14.63% of the total) belong to three tropical areal-types of Pantropic, Tropical Asia to Tropical Africa, and Tropical Asia (Indo-Malesia). This finding confirms that Weifang City's climate has four distinct seasons and abundant rainfall in summer, contributing to fewer restrictions on the heritage trees from tropical areas. Furthermore, 2 genera (4.88% of the total) belong to the areal-type of East Asia, 3 genera (7.31% of the total) are endemic to China, 2 genera (4.88% of the total) belong to the areal-type of Old World Temperate, 3 genera (7.32% of the total) belong to the areal-type of East Asia & North America disjointed, 1 genus (2.44% of the total) belongs to the areal-type of Mediterranean, West Asia & Central Asia (Table 5).

Table 5. The Areal-types of Genera of Heritage Trees in Weifang City

Areal-type	Genera	Percentage to the total (%)
Cosmopolitan	12	29.27
Pantropic	4	9.76
Trop. Asia to Trop. Africa	1	2.44
Trop. Asia (Indo-Malesia)	1	2.44
North Temperate	12	29.27
E. Asia & N. Amer. disjointed	3	7.32

Old World Temperate	2	4.88
Mediterranean, W. Asia & C. Asia	1	2.44
E. Asia	2	4.88
Endemic to China	3	7.32

The 411 genera of wild seed plants in the area of Yishan Mountain are distributed among genera areal-types of Cosmopolitan, Temperate, Tropical, East Asia, and others with 55, 182, 107, 25, and 42 genera, accounting for 13.38%, 44.28%, 26.03%, 6.08%, and 10.22% of the total, respectively (Liu, 2014). This is similar to the composition of genera areal-types of the heritage trees in Weifang City. Most genera of heritage trees belong to Temperate; the percentage of Comopolitan genera of heritage trees in Weifang City is significantly higher than that in Yishan Mountain, indicating that the areal characteristics of heritage trees in Weifang City are lower.

5. Discussion

5.1 Origin of Heritage Trees in Weifang City

The origin of heritage trees is influenced by natural and anthropic factors, such as natural environment, folk customs, religion, and economy. The heritage trees in Weifang City can be classified into three original types: religious trees, naturally dispersed and preserved wild trees, and trees with agricultural backgrounds or used as offerings according to their biological characters and distribution in different land-use types. The naturally dispersed and preserved wild heritage trees and the heritage trees with agricultural backgrounds have the most individuals.

Sophora japonica is a local tree species with wide adaptability and strong regeneration. Most of *Sophora japonica* individuals belong to original types of naturally dispersed and preserved wild heritage trees and are distributed along walls and roads (Wu, 2007). *Ginkgo biloba*, as a kind of living fossil, is a species with strong stress resistance and is seldom influenced by pollutants, pests, and diseases. Since its fresh branches and leaves are not easy to burn, it can survive for a long time even under the influence of natural or artificial disasters. Most individuals of the species are religious trees or trees with agricultural backgrounds to gain fruit for food before. There is a heritage tree of *Ginkgo biloba* aged 1100 years in Xiaoheya Village, Baicheng Town of Gaomi City. It has intact trunk and flourishing branches and leaves.

There are 4 individuals of notable trees (3 *Cedrus deodara* and 1 *Sabina chinensis*) in Dongyuan Park of Kuiwen District. As a symbol of friendship, these trees were planted by local leaders to indicate the friendly relationship between Weifang City and Rixiang City in Japan, Anyang City in Korea, Pueblo City in American, and Fulaixing District in Germany, respectively. These notable trees are symbols of friendship between Weifang City and the foreign cities and district (Wu, 1991; Liu, 2014; Fan, Liang, Pang, Wang, Gao, & Bai, 2018; Liu, Zhao, Wu, & Qi, 2009).

5.2 Current Challenges in Protecting the Heritage Trees in Weifang City

Urbanization decreased the heritage trees in Weifang City. The heritage trees in the suburban county-level cities are characterized by considerable individuals, high density, and more individuals per capita. In contrast, the heritage trees in the four highly urbanized districts are characterized by few individuals, low density, and fewer individuals per capita.

There are still some challenges in protecting heritage trees in Weifang City, including habitat deterioration, health decline, inadequate protection, and natural disasters (such as lightning strokes, continued drought, insect attacks, and cold waves), as well as land use changes. Among the total heritage trees, 76 individuals have the health grades of poor or endangered, 491 individuals are not well protected, and 24 individuals are unsuitably protected using tree pool or concrete floor, reducing the acreage of ventilating and dank ground surface around the roots of the heritage trees and thus influencing the growth of the trees.

The research on the diversity, age structure, growth potential, distribution, density, and taxonomic and floristic composition of heritage trees is of great significance for protecting them. In this study, we researched more heritage trees than the similar researches of other countries, we emphasized more age of heritage trees than their size, it is in favour of protecting more heritage trees. However, the data of age structure and health grades of heritage trees is not accurate enough since not all heritage trees in the study region were surveyed. The research methods and protection measures recommended in this study can be used to protect heritage trees in other regions.

5.3 Previous Protection Measures

The local governments have taken some measures to protect the existing heritage trees, such as formulating related local laws and regulations, conducting field surveys, and rejuvenating weak and endangered heritage trees. For example, the Landscape Management Bureau of Weifang City had organized the county-level landscape management departments to conduct a comprehensive survey and registration on heritage trees in 2001–2004 and determine the management units and responsible persons. Besides, the corresponding leaders and professional technicians of the county-level landscape management departments were convened. Following the meeting spirit of Shandong Landscape Architecture Association on the investigation of heritage trees in December 2002 and the meeting spirit of the Fourth Council of Shandong Landscape Architecture Association in August 2003, a working conference on the census of heritage trees was held in late August 2003 to deeply conduct field investigations of heritage trees. This contributed to archiving, compiling, and publishing books and prepared for the secondary general survey of heritage trees based on the data of Cultural Bureau and Forestry Bureau of Weifang City. Furthermore, the Municipal Government of Weifang City issued the Notice on Strengthening the Protection and Management of Heritage Trees in Urban Areas (NO. 2001181) (Mckinney, 2006).

5.4 Protection Measures should be Taken in the Future

To protect heritage trees more effectively, we should formulate local laws and regulations on the

protection of heritage trees, conduct periodic investigations and registration of all heritage trees, wise use them as tourism attraction, rejuvenate the 76 individuals of heritage trees with the health grades of poor or endangered, improve the site habitat, enlarge the tree pool or change the concrete floor into large tree pool or rail of the 24 unsuitably protected individuals, enhance pest control and natural disaster prevention, strengthen the management of protecting heritage trees, increase financial input, intensity law enforcement efforts and research on the technology of regular surveys and patrols, and establish Dynamic Electronic Archives and other effective measures (Wu, 2007; Liu, Lin, & Liu, 2012; Bell & Williamson, 2017; Nero, 2017).

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References

- Bell, B. R., & Williamson, I. T. (2017). Fossil trees, tree moulds and tree casts in the Palaeocene Mull Lava Field, NW Scotland: context, formation and implications for lava emplacement. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 107(1), 53-71. <http://doi.org/10.1017/S175569101700007X>
- Bertheau, C., Brockerhoff, E. G., Roux-Morabito, G., Lieutier, F., & Jactel, H. (2010). Novel insect-tree associations resulting from accidental and intentional biological ‘invasions’: a meta-analysis of effects on insect fitness. *Ecology Letters*, 13(4), 506-515. <http://doi.org/10.1111/j.1461-0248.2010.01445.x>
- Capotorti, G., Del Vico, E., Anzellotti, I., & Celesti-Grapow, L. (2017). Combining the conservation of biodiversity with the provision of ecosystem services in urban green infrastructure planning: critical features arising from a case study in the metropolitan area of Rome. *Sustainability*, 9(1), 10. <http://doi.org/10.3390/su9010010>
- Childers, D. L., Cadenasso, M. L., Grove, J. M., Marshall, V., McGrath, B., & Pickett, S. T. A. (2015). An Ecology for Cities: A Transformational Nexus of Design and Ecology to Advance Climate Change Resilience and Urban Sustainability. *Sustainability*, 7(4), 3774-3791. <http://doi.org/10.3390/su7043774>
- Criscuolo, N., Guarino, F., Angelini, C., Castiglione, S., Caruso, T., & Ciatelli, A. (2019). High biodiversity arises from the analyses of morphometric, biochemical and genetic data in ancient olive trees of south of Italy. *Plants-Basel*, 8(9), 297. <http://doi.org/10.3390/plants8090297>
- Czortek, P., & Pielech, R. (2020). Surrounding landscape influences functional diversity of plant species in urban parks. *Urban Forestry & Urban Greening*, 47, 126525. <http://doi.org/10.1016/j.ufug.2019.126525>

- Duinker, P. N., Ordonez, C., Steenberg, J. W. N., Miller, K. N., Toni, S. A., & Nitoslawski, S. A. (2015). Trees in Canadian Cities: Indispensable life form for urban sustainability. *Sustainability*, 7(6), 7379-7396. <http://doi.org/10.3390/su7067379>
- Fan, X. L., Liang, Y., Pang, Y., Wang, Q., Gao, L., & Bai, S. W. (2018). The current situation of ancient and famous trees in Shandong Province and suggestions for their protection. *Journal of Jiangsu forestry science and technology*, 45(2), 55-57. (in Chinese). <http://doi.org/10.3969/j.issn.1001-7380.2018.02.015>
- Gough, L. A., Sverdrup-Thygeson, A., Milberg, P., Pilskog, H. E., Jansson, N., Jonsell, M., & Birkemoe, T. (2015). Specialists in ancient trees are more affected by climate than generalists. *Ecology and Evolution*, 5(23), 5632-5641. <http://doi.org/10.1002/ece3.1799>
- Jim, C. Y. (1994). Evaluation and preservation of champion trees in urban Hong Kong. *Arboricultural Journal*, 18, 25-51. <http://doi.org/10.1080/03071375.1994.9746996>
- Jim, C. Y. (2006). Formulaic expert method to integrate evaluation and valuation of heritage trees in compact city. *Environmental Monitoring and Assessment*, 116, 53-80. <http://doi.org/10.1007/s10661-006-7245-x>
- Lai, P. Y., Jim, C. Y., Tang, G. D., Hong, W. J., & Zhang, H. (2019). Spatial differentiation of heritage trees in the rapidly-urbanizing city of Shenzhen, China. *Landscape and Urban Planning*, 181(1), 148-156. doi.org/10.1016/j.landurbplan.2018.09.017
- Liu, C. S., Lin, D. W., & Liu, J. Q. (2012). The diversity of ancient and famous trees in Fuzhou and its analysis and evaluation. *Journal of Anhui Agricultural Science*, 40(34), 16664-16666. <http://doi.org/10.13989/j.cnki.0517-6611.2012.34.149>
- Liu, D. M., Wang, F. G., Chen, H. F., Yi, Q. F., Zeng, Q. W., & Xing, F. W. (2008). A preliminary study on the old and valuable trees in Hong Kong. *Ecology and Environment*, 17(4), 1560-1565. <http://doi.org/10.16258/j.cnki.1674-5906.2008.04.070>
- Liu, H. S. (2013). *Ancient and famous trees of Gulangyu*. Beijing: Chinese Forestry Press. (in Chinese)
- Liu, Z. G. (2014). *Studies on flora and resources of wild woody plants in Yi Mountain*. Tai'an: Shandong Agricultural University. (in Chinese with English abstract).
- Liu, Z. L., Zhao, L. Y., Wu, X. C., & Qi, H. Y. (2009). The study of organization concerning the protecting program for biodiversity in Weifang. *Chinese Agricultural Science Bulletin*, 25(16), 255-258.
- Liu, Z. L., Zhao, L. Y., Wu, X. C., & Qi, H. Y. (2009). The study of organization concerning the protecting program for biodiversity in Weifang. *Chinese Agricultural Science Bulletin*, 25(16), 255-258.
- Martin, J. (2013). Ancient Trees in the Landscape: Norfolk's Arboreal Heritage. *Agriculture History*, 87(3), 419-420.
- Mathaux, C., Mandin, J. P., Oberlin, C., Edouard, J. L., Gauquelin, T., & Guibal, T. (2016). Ancient juniper trees growing on cliffs: toward a long Mediterranean tree-ring chronology.

- Dendrochronologia*, 37, 79-88. <http://doi.org/10.1016/j.dendro.2015.12.005>.
- Mckinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation*, 127(3), 247-260. <http://doi.org/10.1016/j.biocon.2005.09.005>
- Ministry of Construction of the People's Republic of China. Measures for the administration of the urban ancient and famous trees protection and management; 2000. (in Chinese). Retrieved March 10, 2020, from http://www.mohurd.gov.cn/wjfb/200611/t20061101_157014.html
- Nero, B. (2017). *Urban Green Spaces Enhance Carbon Sequestration and Conserve Biodiversity in Cities of the Global South: Case of Kumasi, Ghana*. Bonn: University of Bonn.
- Nero, B. F., Kwapong, N. A., Jatta, R., & Fatunbi, O. (2018). Tree Species Diversity and Socioeconomic Perspectives of the Urban (Food) Forest of Accra, Ghana. *Sustainability*, 10(10), 3417. <http://doi.org/10.3390/su10103417>
- Ou, Y. T., Zhong, M. J., & Li, H. S. (2007). Protection of ancient and famous trees in city based on the theory of ecology—taking the protection of the oldest ancient bischofia polycarpa in Dongguan City as an example. *Chinese landscape architecture*, 12, 71-74.
- State Forestry Administration of China. Regulation for identification of old and notable trees; 2016 (in Chinese). Retrieved March 15, 2020, from <https://max.book118.com/html/2017/0904/131841707.shtm>
- Townsend, J. B., & Barton, S. (2018). The impact of ancient tree form on modern landscape preferences. *Urban Forestry & Urban Greening*, 34, 205-216. <http://doi.org/10.1016/j.ufug.2018.06.004>
- Wang, X. H., & Li, J. D. (2002). Studies on flora of seed plants in Yi Mountains of Shandong Province. *Bulletin of Botanical Research*, 22(2), 156-162.
- Wu, X. C. (2007). *Weifang ancient and famous trees*. Ji'nan: Shandong University Press. (in Chinese).
- Wu, Z. Y. (1991). Genera areal-types of seed plants of China. *Acta Botanica Yunnanica, Supplement IV*, 14-139.
- Xu, P. F., Guan, C., Zhang, H. J., Li, G. H., Zhao, D., Ross, R. J., & Shen, Y. L. (2021). Application of nondestructive testing technologies in preserving historic trees and ancient timber structures in China. *Forests*, 12(3), 318. <http://doi.org/10.3390/f12030318>
- Zhang, X. L., Cui, G. M., Liu, X. J., Zhang, Z. H., Xi, M., Li, J., & Lu, J. (2017). The characteristics of famous and ancient trees in Qingdao City, Shandong Province, China and possible conservation. *Fresenius Environmental Bulletin*, 26(3), 2016-2024.
- Zhang, X., Wang, L., Liu, Z., Zheng, T., Cao, Y., & Liu, X. (2019). The current situation and countermeasures for conservation of ancient and famous trees in Laoshan, Qingdao, China. *Ciencia Rural*, 49(10), e20190051. <http://doi.org/10.1590/0103-8478cr20190051>
- Zhong, Y., Li, X. Q., & Wang, J. C. (2014). The study on the protection of the living space and the cultural space of ancient and famous trees in Jiujiang City. *Ecological Economy*, 30(11), 115-118.