Heritage Trees of Lingshui, China: Diversity, Distribution, and Conservation Challenges

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Heritage trees, as vital bioresources, enhance urban ecosystems and cultural heritage in Lingshui, Hainan, China. Yet, urbanization and environmental shifts threaten their persistence, necessitating detailed studies for conservation. From 2023 to 2024, the authors surveyed 133 heritage trees across 18 species, 14 genera, and 10 families. *Tamarindus indica* L. dominated (importance value 37.60), followed by *Ficus microcarpa* L. f. (14.37) and *Bombax ceiba* L. (12.55), comprising 64.52% of the total importance value. Diversity varied across twelve towns, with Yingzhou showing the highest despite fewer trees. Most trees, aged 100-150 years with 60-150 cm diameters, indicated an aging population. Kernel density mapping revealed central-eastern distribution hotspots, hinting at historical or environmental influences. Termite infestation (45.1%) and trunk decay (36.4%) were primary threats, with pests and diseases less impactful (6.8%). Compared to other Hainan cities, Lingshui's lower tree diversity reflects topography, typhoons, and human pressures including urbanization and agriculture. Targeted conservation addressing biological and socioeconomic factors is critical to sustain these bioresources, which support biodiversity through microhabitats, ecological continuity, and genetic diversity in urbanizing landscapes.

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INTRODUCTION

Heritage trees, which are defined by their age of 100 years or more, function as ecological keystones in urban environments, embodying resilience while connecting historical and contemporary landscapes (Blicharska and Mikusiński 2014; Lai *et al.* 2019). These venerable specimens support diverse biotic communities, provide essential ecosystem services including temperature regulation and carbon sequestration, and enhance soil stability through extensive root systems (Tan *et al.* 2016; Lindenmayer and Laurance 2017). Beyond their ecological value, heritage trees embody cultural significance, strengthening place identity and community connections through their association with local traditions and histories (Chen *et al.* 2009; Huang *et al.* 2021; Chen *et al.* 2024). Despite their multifaceted importance to urban biodiversity conservation (Le Roux *et al.* 2014; Lindenmayer 2017), these irreplaceable natural assets face mounting threats from urbanization, land-use changes, and climate instability, highlighting the urgent need for targeted conservation strategies (Gilhen-Baker *et al.* 2022).

Heritage trees face multiple threats that compromise their health, longevity, and ecological significance. Climate change poses significant risks through increasing temperature extremes, altered precipitation patterns, and greater frequency of severe weather events (Piovesan and Biondi 2021; Cannon *et al*. 2022). Urbanization and development pressures often result in soil compaction, altered hydrology, and direct physical damage to roots and canopy structures (Chen 2020). Biological threats include pest outbreaks, pathogen infections, and invasive species competition, which may be exacerbated by climate-induced stress (Lindenmayer and Laurance 2017; Gunn and Orwig 2018). Additionally, inappropriate management practices such as excessive pruning, improper restoration techniques, and inadequate protection measures can accelerate decline (Le Roux *et al.* 2014; Fröhlich *et al.* 2024). In tropical regions such as Hainan, these pressures are often intensified by rapid economic development, tourism expansion, and agricultural intensification, creating a complex challenge for conservation efforts (Cui *et al*. 2022; Xie *et al.* 2024). Effective protection strategies must therefore address these multifaceted threats through integrated approaches that consider both ecological processes and socioeconomic contexts.

Effective conservation and management strategies should be guided by comprehensive research on the diversity and distribution patterns of heritage trees (Jim 2017; Lai *et al.* 2019; Chi *et al.* 2020). Identifying the species present, their relative abundance, and their spatial distribution offers crucial insights into the ecological health of urban environments (Jim and Zhang 2013; Li and Zhang 2021). This information aids in prioritizing areas for conservation efforts and informs urban planning decisions that harmonize development with environmental preservation (Hou *et al.* 2022; Fröhlich *et al.* 2024). Furthermore, understanding the factors that affect the survival and distribution of heritage trees facilitates the development of strategies to alleviate the impacts of urbanization, agriculture, and climate change (Orłowski and Nowak 2007; Chen 2020). Addressing these challenges through well-informed conservation and management practices ensures the long-term persistence of heritage trees, preserving their ecological and cultural value for future generations.

Heritage tree conservation requires not only protection of existing specimens but also strategic planning for succession. As trees inevitably age and decline, proactive replacement planting ensures continuity of ecological functions and cultural significance across generations (Endreny 2018; Hilbert *et al*. 2019). Municipal governments can implement scheduled replacement programs that identify declining specimens and establish nursery-grown saplings of appropriate species before heritage trees reach hazardous conditions (Roman *et al.* 2015). Such succession planning must consider species selection criteria including climate resilience, cultural significance, and potential size at maturity to ensure compatibility with urban infrastructure (Conway and Vander Vecht 2015). Centralized municipal nurseries can maintain genetic stock of historically significant trees while developing saplings adapted to local conditions, thereby preserving both biological and cultural heritage through planned transitions (Morgenroth *et al*. 2016). Without these forward-thinking approaches, urban landscapes risk abrupt canopy losses when heritage trees reach senescence simultaneously or require emergency removal due to structural hazards.

Most existing studies have concentrated on cataloging the diversity of heritage trees while neglecting their distribution patterns in China (Tian *et al.* 2018; Xu *et al.* 2022), resulting in a substantial gap in our understanding of their presence and significance in urban environments. This issue is especially pronounced in rapidly urbanizing cities (Li and Zhang 2021), where pressures on these trees are most severe. The lack of research in urban contexts leaves policymakers and conservationists with incomplete information, impeding effective conservation and management efforts (Jim 2004). While existing studies catalog heritage tree diversity, the spatial distribution patterns critical for urban planning remain underexplored, particularly in rapidly urbanizing regions like Lingshui.

In Lingshui Li Autonomous County (hereafter referred to as Lingshui), Hainan, rapid urbanization is even more evident (Cui and Zhang 2009; Liang *et al.* 2023). Comprehensive studies on the diversity and distribution patterns of heritage trees in this rapidly developing urban area are strikingly absent. In Lingshui, rapid urbanization, frequent typhoons, and a unique tropical biodiversity shaped by planar topography and agricultural history create distinct challenges for heritage tree conservation, justifying its selection as a critical study area. Understanding distribution patterns and the factors influencing them is essential for devising effective conservation measures. The absence of such studies in Lingshui highlights the pressing need for targeted research to bridge this gap and establish a foundation for informed conservation and urban planning efforts.

By evaluating species composition, spatial distribution, and influencing factors, this study aims to inform biodiversity conservation, urban spatial planning, and heritage tree management frameworks, enhancing ecological resilience in Lingshui’s urbanizing landscape. To achieve this goal, the study defines three specific objectives: (1) species composition and diversity patterns of heritage trees in Lingshui, Hainan; (2) spatial distribution characteristics of heritage trees in Lingshui; and (3) ecological and anthropogenic factors influencing the distribution patterns of heritage trees in Lingshui.

EXPERIMENTAL

Study Area

Lingshui, situated in southeastern Hainan Island, lies between 18°22'-18°47'N latitude and 109°45'-110°08'E longitude. The county extends 40 km from north to south and 32 km from east to west, encompassing approximately 1,128 km^2. Lingshui’s terrain exhibits significant variation, with elevations decreasing from the northwest to the southeast. The landscape comprises three primary geographical features: mountains, hills, and plains. The northwest is predominantly mountainous, the central region consists of hills, and the southeast features plains, forming a gradual slope toward the southeast. Lingshui has a tropical monsoon marine climate, with a mean annual temperature of 25.6°C. The county receives an annual average rainfall of 1,760.3 mm and experiences approximately 2,069 hours of sunshine per year (Wang *et al.* 2012). The northern and northeastern mountainous regions, along with the southwestern highlands, are primarily composed of fertile ferralsols, characterized by clay-rich texture and high fertility. In contrast, the southeastern and southern coastal terraces consist of sandy soil and low hills (Wu and Chen 2012). The region is susceptible to heavy rainfall, particularly during tropical storms and typhoons, which constitute the primary natural disasters impacting Lingshui.

Data Source and Field Survey

Based on preliminary background data on heritage trees provided by the Lingshui County Forestry Bureau, the research team conducted a comprehensive field survey across the county from 2023 to 2024, focusing primarily on areas with significant human activity, such as roads, villages, and urban centers, excluding the Diaoluo Mountain natural forest area. Following the "Regulation for identification of old and notable trees" (LY/T 2737-2016) (hereinafter referred to as regulation), each heritage tree was identified and documented (Fig. 1), with essential data—including breast height diameter (DBH), tree height, crown spread, and geographic coordinates—recorded in situ. In China, heritage trees are defined as those aged 100 to 299 years (grade 3), 300 to 499 years (grade 2), or over 500 years (grade 1) under the regulation (Lai *et al*. 2019). The condition of each heritage tree was assessed visually, considering factors such as termite infestation, trunk decay, and other diseases or pest infestations. The age of the trees was primarily estimated using data provided by the forestry department. Unlisted or uncertain heritage trees were identified through literature reviews and interviews with local stakeholders. Fieldwork was conducted across 12 towns, which vary in urban development and ecological settings, influencing heritage tree distribution. In addition, semi-structured interviews with 10 local stakeholders, including forestry officials and village elders, were conducted in 2023 to verify unlisted tree identities, with responses cross-referenced against literature.

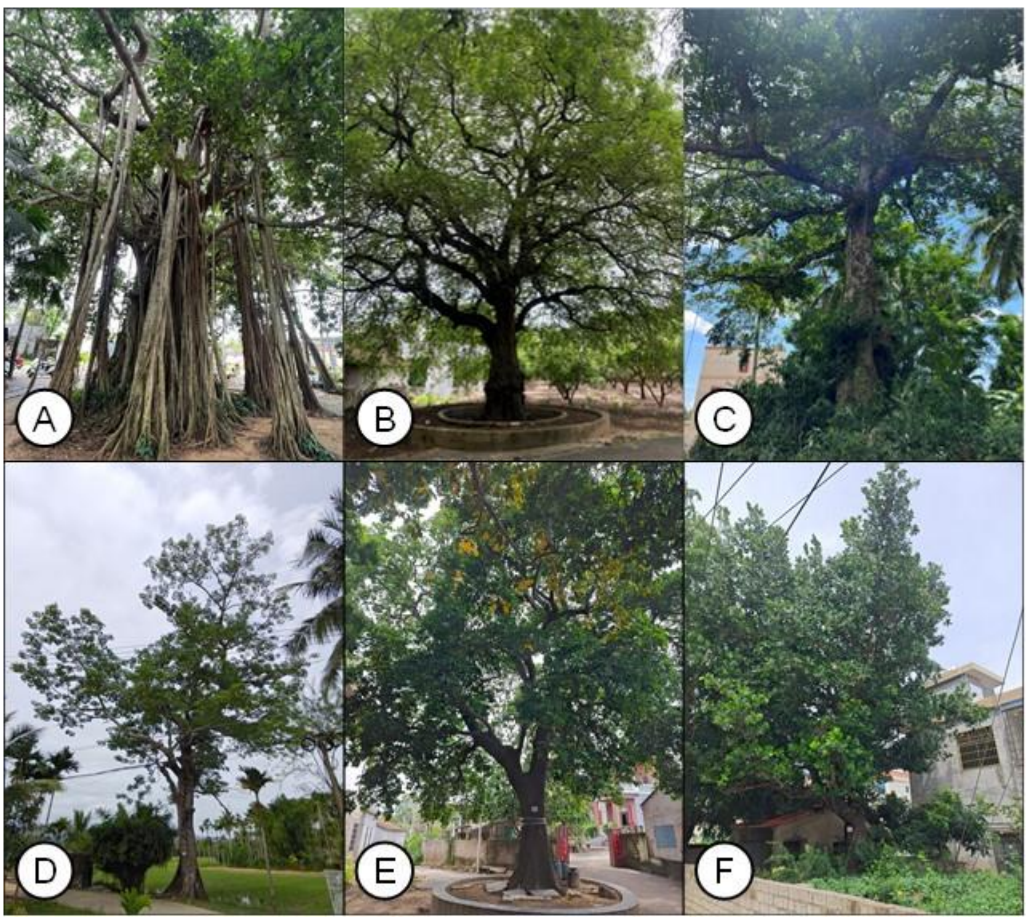

Fig. 1. Representative heritage tree species documented in Lingshui.. A to F denote various heritage tree species, respectively: *Ficus altissima* Blume, *Tamarindus indica* L., *Antiaris toxicaria* Lesch., *Bombax ceiba* L., *Artocarpus parvus* Gagnep. and *Calophyllum inophyllum* L.

Statistical Analysis

The heritage trees included in this study are primarily located in human settlements, where their habitats tend to be relatively homogeneous (Zhang *et al.* 2017). As a result, the formula for calculating the importance value is modified to IV = (RA + RD) / 2(Jim and Zhang 2013), where relative abundance (RA) = (the number of individuals of a specific heritage tree / the total number of heritage trees) × 100%, and relative dominance (RD) = (the sum of the diameters at breast height of a specific heritage tree / the sum of the diameters at breast height of all heritage trees) × 100% (Welch 1994). The Simpson index, Shannon index, Pielou index, and Margalef index were used to compare and analyze the diversity of heritage trees across different townships in the study area (Xie 2018; Xu *et al.* 2022; Hammer and Harper 2001). Kernel density analysis in QGIS 3.42 used point data of tree locations (species occurrence, not abundance) to map distribution hotspots, employing a quadratic kernel function, a 500-meter bandwidth, and a 50-meter cell size, selected to balance spatial resolution within study area (Moyroud and Portet 2018). No spatial smoothing assumptions were applied beyond standard QGIS settings.

RESULTS AND DISCUSSION

Species Composition and Importance Value

A total of 133 heritage trees were documented in Lingshui, representing 18 species across 14 genera and 10 families (Table 1).

Table 1. Species Composition and Importance Value (IV) of Heritage Trees in Lingshui

Species	Family	Growth form	RA	RD	IV
Tamarindus indica L.	Caesalpiniaceae	Evergreen	42.11	33.09	37.60
Ficus microcarpa L. f.	Moraceae	Evergreen	12.03	16.72	14.37
Bombax ceiba L.	Bombacaceae	Deciduous	12.03	13.08	12.55
Antiaris toxicaria Lesch.	Moraceae	Evergreen	6.77	9.46	8.11
Ficus altissima Blume	Moraceae	Evergreen	4.51	7.71	6.11
Artocarpus parvus Gagnep.	Moraceae	Evergreen	5.26	4.45	4.86
Ficus benjamina L.	Moraceae	Evergreen	3.01	4.23	3.62
Litchi chinensis Sonn.	Sapindaceae	Evergreen	3.76	2.73	3.25
Ficus virens Aiton	Moraceae	Deciduous	1.50	1.55	1.53
Calophyllum inophyllum L.	Guttiferae	Evergreen	1.50	1.26	1.38
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	Evergreen	1.50	1.02	1.26
Terminalia catappa L.	Combretaceae	Semi-evergreen	1.50	1.00	1.25
Trevia nudiflora L.	Euphorbiaceae	Deciduous	0.75	1.03	0.89
Ormosia pinnata (Lour.) Merr.	Papilionaceae	Evergreen	0.75	0.61	0.68
Beilschmiedia appendiculata (C. K. Allen) S. K. Lee & Y. T. Wei	Lauraceae	Evergreen	0.75	0.59	0.67
Celtis philippensis var. *wightii* (Planch.) Soepadmo	Ulmaceae	Evergreen	0.75	0.54	0.64
Streblus asper Lour.	Moraceae	Evergreen	0.75	0.48	0.62

Dimocarpus longan Lour.	Sapindaceae	Evergreen	0.75	0.45	0.60
Total			100	100	100

Tamarindus indica L. emerged as the predominant species, exhibiting the highest importance value (IV = 37.6), accounting for 42.1% of relative abundance (RA) and 33.1% of relative dominance (RD). *Ficus microcarpa* L. f. and *Bombax ceiba* L. ranked second and third in importance, with IVs of 14.4 and 12.6, respectively. These three species collectively constituted 64.5% of the total IV, indicating their ecological dominance within the heritage tree community. The majority of documented species (83.3%, 15 species) were evergreen, with only two deciduous species (*B. ceiba* and *Trevia nudiflora* L.) and one semi-evergreen species (*Terminalia catappa* L.). Notably, species with low IVs (< 1.00) included *T. nudiflora* (IV = 0.89), *Ormosia pinnata* (Lour.) Merr. (IV = 0.68), *Beilschmiedia appendiculata* (C. K. Allen) S. K. Lee & Y. T. Wei (IV = 0.67), *Celtis philippensis* var. *wightii* (Planch.) Soepadmo (IV = 0.64), *Streblus asper* (IV = 0.62), and *Dimocarpus longan* Lour. (IV = 0.60), suggesting their relative rarity in the heritage tree population of Lingshui.

The distribution and diversity of heritage trees exhibited substantial variation across the twelve towns surveyed in Lingshui (Table 2). Yingzhou demonstrated the highest species richness with 10 species and 22 individuals, corresponding to the highest Shannon diversity index (2.25) and Margalef index (2.91). In contrast, Lingcheng and Xincun displayed minimal diversity, each harboring only a single species. Notably, Yelin, despite having the highest number of individual trees (n = 51), showed relatively low diversity indices (Shannon = 0.68, Pielou = 0.40), indicating significant dominance by few species. The Pielou evenness index revealed that Wenluo (1.28), Timeng (1.21), and Qunying (1.20) exhibited the most equitable species distribution, although these towns had relatively few species (2 to 4 species). The Simpson diversity index ranged from 0.00 to 1.00, with Wenluo showing maximum diversity (1.00) and Lingcheng showing minimum diversity (0.00). Benhao town maintained a relatively balanced diversity profile with moderate to high values across all indices (Simpson = 0.80, Shannon = 1.71, Pielou = 0.92, Margalef = 1.85), suggesting a well-distributed community structure among its six species and 15 individuals. These findings indicate that the spatial distribution of heritage tree diversity in Lingshui is heterogeneous, potentially influenced by historical land use patterns and urbanization processes.

Table 2. Species Diversity of Heritage Trees in Various Towns in Lingshui

Town	Species	Tree Count	Simpson Index	Shannon Index	Pielou Index	Margalef Index
Benhao	6	15	0.80	1.71	0.92	1.85
Guangpo	3	6	0.73	1.18	1.08	1.12
Li’an	2	5	0.60	0.77	1.08	0.62
Lingcheng	1	2	0.00	0.00	1.00	0.00
Longguang	5	11	0.71	1.48	0.88	1.67
Qunying	4	7	0.86	1.57	1.20	1.54
Sancai	3	5	0.80	1.26	1.17	1.24
Timeng	4	6	0.87	1.58	1.21	1.67
Wenluo	2	2	1.00	0.94	1.28	1.44
Xincun	1	1	-	0.00	1.00	0.00
Yelin	5	51	0.31	0.68	0.40	1.02
Yingzhou	10	22	0.87	2.25	0.95	2.91

Spatial Distribution Pattern

The map revealed a heterogeneous distribution of 18 species, with notable clustering in certain regions (Fig. 2). Yelin town demonstrated the highest density of heritage trees, particularly dominated by specific species, which aligns with its high tree count (n=51) but relatively low diversity indices. The eastern regions, including Guangpo and Timeng, showed a more diverse species composition despite lower tree densities. Notably, *T. indica*, *F. microcarpa*, and *B. ceiba* displayed widespread distribution across multiple towns, while species such as S. asper and *B. appendiculata* were more localized in their occurrence. The kernel density analysis (inset map) highlighted several hotspots of tree concentration, particularly in the central-eastern region, suggesting potential historical or environmental factors influencing tree distribution patterns. The western regions, particularly in Qunying and parts of Yingzhou, exhibited more dispersed distribution patterns with greater inter-species spacing.

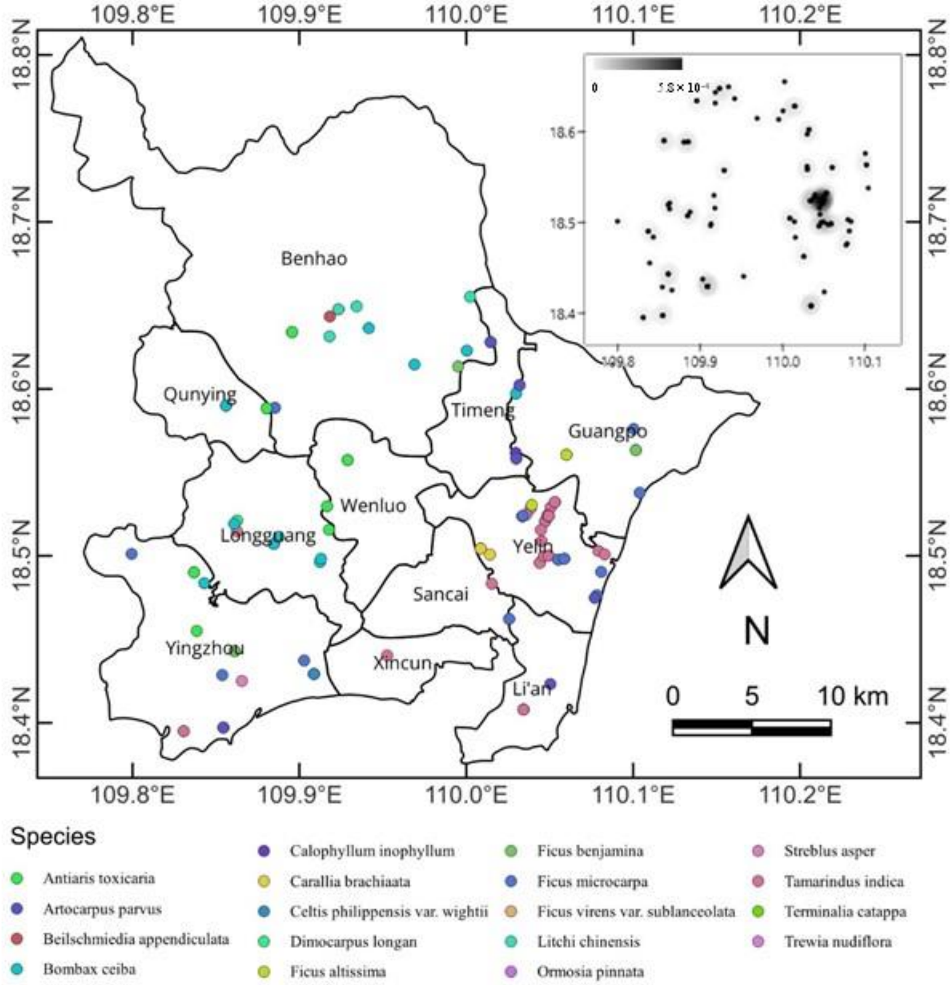

Fig. 2. Distribution pattern and Kernel density of heritage trees in Lingshui

Structure Characteristics

The structural characteristics of heritage trees in Lingshui exhibited distinct distribution patterns across multiple parameters (Fig. 3). The age structure demonstrated a significant negative logarithmic relationship ($R^2 = 0.92$), with the majority of trees concentrated in the 107-to-137-year range, declining sharply thereafter, and only a few specimens exceeding 234 years (Fig. 3a)). Similarly, the diameter at breast height (DBH) distribution followed an exponential decay pattern (R^2 = 0.85), with most individuals falling within 75 to 135 cm DBH class, while trees with DBH >330 cm were rare (Fig. 3b). Tree height and crown width distributions both displayed approximately normal distributions, albeit with different degrees of symmetry. Height measurements showed a polynomial relationship (R^2 = 0.52) with a peak frequency between 16-18 m (Fig. 3c), while crown width followed a quadratic distribution (R^2 = 0.62) with maximum frequency occurring in the 17.5 to 20.5 m range (Fig. 3d). These structural patterns suggest a mature but aging population, with implications for succession planning and conservation strategies. The relatively strong correlations in age and DBH distributions (R^2 > 0.85) provide reliable indicators for age estimation and conservation prioritization of heritage trees in the region.

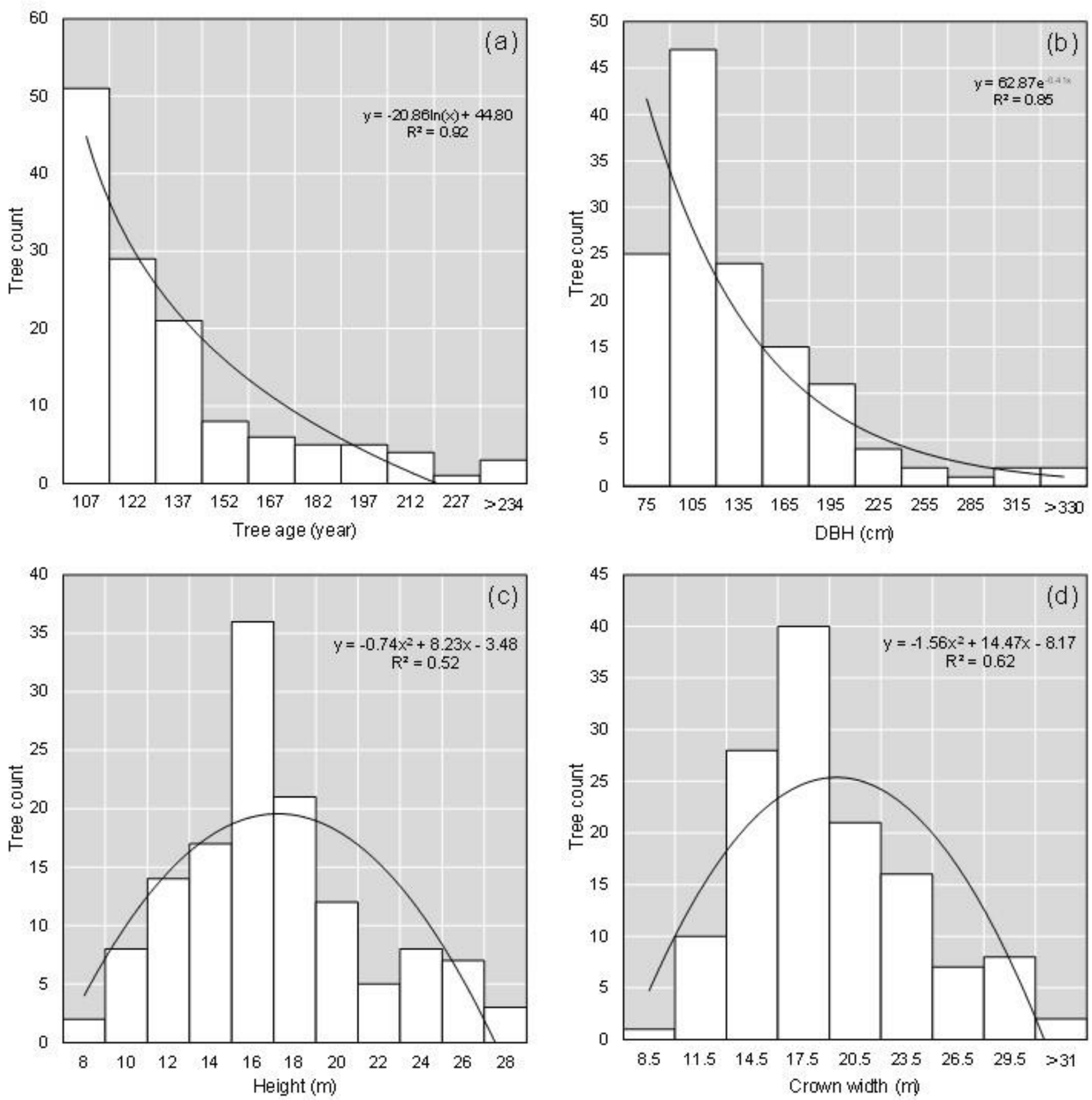

Fig. 3. Structure characteristics of age (a), DBH (b), height (c), and crown width (d) of heritage trees in Lingshui

External Threats

Termites and trunk decay pose the primary threats to the survival of local heritage trees (Fig. 4). Statistical data indicate that 60 heritage trees (approximately 45.1%) were infested with termites, while 48 heritage trees (approximately 36.4%) exhibited trunk decay or hollowness. Regarding pests and diseases, 9 heritage trees (approximately 6.8%) were confirmed to be affected, with over 90% remaining unaffected. The primary pests and diseases identified include trunk borers, banyan brown root disease, banyan egg mole psyllids, and sooty mold. Among the heritage trees threatened by pests and diseases, banyan trees in Jianwen Village, Yingzhou Town, and sour bean trees in Taoyuan Village, Yelin Town, exhibit poor growth. It is recommended that relevant departments prioritize rejuvenation and management efforts for these trees moving forward.

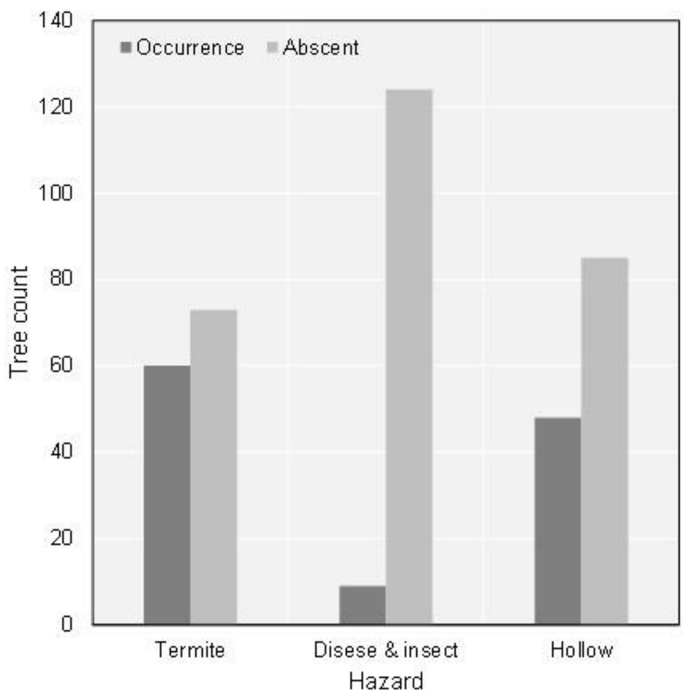

Fig. 4. The hazard to heritage trees in Lingshui

DISCUSSION

The diversity and distribution patterns of heritage trees are shaped by multiple factors. At a macro scale, climate change, topography, and soil type act as the primary driving factors (Lindenmayer and Laurance 2017; Huang *et al.* 2021). Climate variables such as temperature, precipitation, and light intensity directly influence plant growth and distribution, particularly in high-altitude and extreme environments, where heritage trees exhibit distinctive physiological characteristics compared to those in low-altitude regions (Pasques and Munné-Bosch 2024). Topographic variations have facilitated the development of distinct niche patterns, allowing heritage trees to adapt and evolve in specific environments, thus influencing biodiversity (Hemp *et al.* 2017). Moreover, anthropogenic factors, including cultural practices, traditional customs, human activities, protection policies, and management strategies, also shape the diversity and distribution patterns of heritage trees (Blicharska and Mikusiński 2014; Tian *et al.* 2018).

The importance value analysis indicates that *T. indica*, *F. microcarpa*, and *B. ceiba* are the dominant heritage tree species in Lingshui (Table 1). *T. indica*, as a positive colonizer, is heliophilous, drought-resistant, and possesses an extensive root system, enabling the efficient utilization of water and soil nutrients (Bourou *et al.* 2010), thereby adapting well to Lingshui's dry season and monsoon climate. Moreover, *T. indica* exhibits robust reproductive mechanisms; its flowering period attracts numerous pollinators, enhancing its reproductive success. Its seeds exhibit exceptional longevity (MacDonald *et al.* 2002), promoting population expansion. From a utilitarian perspective, *T. indica* fruits serve both culinary and medicinal purposes, thus incentivizing cultivation and conservation efforts (De Caluwé *et al.* 2010). Furthermore, *T. indica*'s minimal edaphic requirements enable it to thrive across diverse soil conditions. Consequently, ecological adaptability, reproductive biology, and economic utility collectively contribute to the high abundance of large and old *T. indica* trees in this region.

F. microcarpa and *B. ceiba* are also prevalent in Lingshui, partly due to local cultural and religious significance. On Hainan Island, *Ficus* spp., which symbolize longevity and prosperity, are often planted at temples and significant public spaces for devotional practices (Chen *et al.* 2009). *B. ceiba*, known for their striking inflorescence and resilient properties, are often incorporated into traditional festivals and folkloric activities, representing an important cultural symbol (Xiang *et al.* 2023; Chen *et al.* 2024). Based on the species composition of heritage trees in Lingshui, it is recommended that relevant authorities implement scientific selection criteria, strategic planning, and effective management to identify suitable species for local landscaping, thereby promoting the sustainable development of heritage tree conservation resources and ornamental tree cultivation.

From a cultivation and economic utility perspective, trees with higher edible value are more likely to achieve older status (Huang *et al.* 2020). However, the heritage tree composition in Lingshui includes only four *L. chinensis* and one *D. longan* individuals, none of which have achieved dominant status. Similarly, these species do not constitute dominant heritage trees in Sanya, Haikou, or other regions in Hainan Island (Dai *et al.* 2020; Liu *et al.* 2013). This phenomenon may be attributed to the higher incidence of arboreal pathogens and insect pests in tropical zones, leading to the reduced longevity of such species.

Comparative to other cities, heritage tree diversity in Lingshui is lower than that in Wuzhishan (21 species) (Cui *et al.* 2022), Sanya (32 species) (Liu *et al.* 2013), and Haikou (51 species) (Dai *et al.* 2020), but slightly exceeds that of Baisha (16 species) (Xie *et al.* 2024). The abundance of heritage trees in Lingshui (133) is substantially lower than that in Wuzhishan (216), Baisha (301), Sanya (968), and Haikou (1,590). Topographical characteristics and climatic conditions likely constitute the primary determinants of the reduced diversity and abundance of heritage trees in Lingshui. From a geomorphological perspective, the traditional habitation zone of Lingshui lacks topographic complexity (excluding the northern mountainous region). This predominantly planar terrain typically constrains the development of biodiversity while favoring agriculture. Generally, complex topography generates diverse microenvironments and habitats, thereby supporting greater plant diversity (Moeslund *et al.* 2013). Conversely, regions such as Wuzhishan and Baisha exhibit more complex topographical structures. The altitudinal and slope variations in these areas facilitate the diversification of heritage trees. Additionally, climatic factors, particularly the high frequency of typhoon occurrences in this region (Wu and Chen 2012), significantly impact the development of heritage trees in Lingshui. The intense winds and precipitation associated with typhoons not only inflict physical damage on heritage trees but may also induce soil erosion and nutrient depletion (Tzeng *et al.* 2018), thus affecting the viability of heritage trees. Furthermore, recurrent typhoons may engender instability in the community structures of heritage trees (Lin *et al.* 2011), preventing certain species from adapting to rapidly changing environmental conditions, thereby reducing their abundance and diversity. The prolonged absence of effective ecological restoration protocols for heritage trees in this region has further diminished the adaptive capacity of heritage tree populations facing extreme weather events.

Human activities represent another significant factor influencing heritage tree populations. The acceleration of urbanization in Lingshui has led to extensive infrastructure development and urban expansion, directly resulting in habitat destruction and fragmentation (Cui and Zhang 2009). Urbanization is typically accompanied by unsustainable land development practices (exemplified by rapid local real estate expansion), severely compromising heritage tree habitats. For instance, the construction of buildings, roadways, and ancillary infrastructure occupies terrain previously conducive to heritage tree growth, leading to tree displacement or mortality (Chen 2020). Lingshui's historically agriculture-dominant economy, characterized by continual agricultural land expansion and forestland conversion, has led to substantial heritage tree habitat loss (Lindenmayer *et al.* 2014). Consequently, anthropogenic activities have negatively impacted the survival of heritage trees in this region through direct and indirect land-use modifications.

Termite infestation and trunk decay are critical concerns that require urgent attention in the conservation of heritage trees in Lingshui. Both phenomena pose significant threats to the viability and longevity of heritage trees. Termites, widely recognized as primary arboreal pathogens, degrade xylem and phloem tissues, disrupting nutrient transport systems and impeding essential water and nutrient uptake, thereby compromising growth and survival (Wilcken *et al.* 2002). The cryptic nature of termite activity often delays detection until considerable damage has occurred, thereby complicating prevention and intervention strategies (Yan *et al.* 2020). Therefore, systematic monitoring and prompt treatment of termite infestations are essential conservation measures. Furthermore, trunk decay requires significant attention. Age-related deterioration manifests as internal trunk decomposition in numerous ancient specimens, typically resulting from pathogenic invasion, environmental stressors, or mechanical damage (Li *et al.* 2022). Such decay not only compromises structural integrity but may also precipitate tree failure during adverse meteorological conditions (Abbas *et al.* 2020). Therefore, pest management strategies for heritage trees in this region should adopt tailored approaches. For example, termite control strategies may include physical interventions (nest excavation, light trapping), biological control mechanisms (natural predators, pheromonal attractants), and chemical applications (imidacloprid, pyrethroids), among other diversified approaches (Tang 2022). Concurrently, addressing trunk decay requires comprehensive pathogen elimination, followed by appropriate pruning and soil amelioration to enhance the vitality of heritage trees (Zhou *et al.* 2013). Furthermore, the conservation of heritage trees requires not only substantial administrative resource allocation but also heightened public awareness regarding the importance of conservation (Huang *et al.* 2020) and increased community participation in preservation initiatives, thereby establishing collaborative mechanisms for maintaining these invaluable natural resources.

Based on these findings, the conservation approaches should include the following: First, implementing integrated pest management strategies tailored to specific tree conditions, combining biological control with targeted treatments for termites and arboricultural techniques for trunk decay. Second, developing a systematic monitoring program that includes regular health assessments and community engagement through educational initiatives. Future conservation efforts should focus on species selection for new plantings that balances cultural significance with ecological resilience, particularly considering climatic instability in this coastal region. Additionally, incorporating heritage tree conservation into urban planning frameworks would help preserve these ecological and cultural assets while enhancing urban ecosystem services. This approach acknowledges that effective conservation must address both immediate biological threats and the underlying socioecological factors driving heritage tree decline in rapidly developing landscapes.

CONCLUSIONS

1. This study provides the first comprehensive assessment of heritage tree diversity and distribution in Lingshui, revealing a community dominated by three species (*T. indica*, *F. microcarpa*, and *B. ceiba*) with significant spatial heterogeneity across townships. Distribution patterns of heritage tree reflect ecological factors such as typhoons, alongside anthropogenic influences such as cultural practices and urban development.
2. The findings demonstrate that heritage trees in Lingshui face multiple challenges, including biological threats and anthropogenic pressures from urbanization and agricultural expansion. The lower diversity and abundance compared to other Hainan cities can be attributed to Lingshui's predominantly planar topography, frequent typhoon disturbances, and intensifying land-use changes.

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Data Availability Statement

The data presented in this study are available on request from the first author.

Author Contributions

XC and LD conceived and designed the research; XC, LD, TE and HC performed research; XC, LD, HC, TE and JS curated the data; XC Wrote the original draft; LD reviewed and edited. All authors had read and agreed to the published version of the manuscript.

Conflict of Interest

The authors have no relevant financial or non-financial interests to disclose.

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