

Wei Zhou

Monograph

Research on the Historical and Humanistic Values of Urban Ancient Trees and Environmental Evaluation



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The monograph examines the historical, humanistic and ecological aspects of ancient urban trees, emphasizing their role as living monuments and ecological energy sources in the urban environment. The historical significance of these trees is examined, tracing their origin and their relationship to urban development and cultural heritage. The humanistic values of ancient trees are analyzed, emphasizing their cultural, spiritual and educational contribution to the development of urban societies. In addition, the study assesses the environmental impact of ancient trees, emphasizing their ecological functions, including biodiversity support, climate regulation and carbon sequestration. Combining historical documents with dendrochronology, this monograph provides a comprehensive understanding of the significance of ancient urban trees and their conservation needs. It synthesizes perspectives from urban ecology, cultural studies, and environmental science to suggest strategies for preserving these natural monuments. This work is a valuable resource for scientists, urban planners and conservationists, offering perspectives on sustainable urban development and the integration of natural heritage into modern cities.

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Foreword

Ancient urban trees serve as quiet witnesses to millennia of human advancement, cultural development, and environmental change. Their presence in our cities is not only a natural coincidence but a monument to humanity's profound connection with the natural world. In an era of swift urbanisation and environmental decline, comprehending the historical, humanistic, and ecological importance of these ancient trees is both an academic pursuit and an urgent imperative. This monograph examines the various aspects of old urban trees, highlighting their essential significance in the cultural, historical, and ecological framework of cities. Ancient trees, due to their remarkable longevity, transcend mere botanical specimens. They are historical landmarks, encapsulating the memories and transformations of metropolitan environments. These trees have endured wars, observed festivities, and persisted through centuries of urban growth, providing a concrete link to the past and functioning as living records of urban history.

The historical accounts contained in ancient urban trees are examined through dendrochronology and historical records. The scientific accuracy of annual ring analysis, along with archival information, reconstructs the historical existence of these trees and their adjacent ecosystems. These trees have played a pivotal role in the development of cities through their contributions to climatic pattern comprehension and their connections with notable historical personalities and events. This monograph elucidates how ancient trees offer critical insights into urban development, mapping the evolution from rural settings to vibrant metropolises. Ancient trees serve as stores of collective heritage and identity. In various communities, they have functioned as important elements for spiritual activities, folklore, and artistic inspiration. These trees have been esteemed in literature, art, and oral traditions, serving as emblems of wisdom, tenacity, and community. They are essential in safeguarding intangible cultural assets, connecting generations through their persistent existence. Their capacity to cultivate a sense of place and belonging is unparalleled, reminding urban residents of life's continuity amid perpetual change.

This monograph primarily emphasises the ecological importance of old trees. These trees serve as ecological keystones, significantly enhancing urban biodiversity by providing refuge for several species. They alleviate urban heat island effects, enhance air quality, sequester carbon, and control hydrological cycles, rendering them essential in combating climate change. Their expansive canopies, complex root systems, and persistent existence underscore their ability to stabilise urban ecosystems, despite ongoing development pressures. The environmental difficulties confronting historic urban trees, such as pollution, soil compaction, and climate change, demand immediate conservation efforts. This monograph offers a comprehensive analysis of ways for safeguarding these natural monuments, reconciling preservation with urban expansion. It promotes innovative strategies, including the incorporation of ancient trees into urban planning frameworks, the utilisation of smart technologies for health monitoring, and the establishment of public-private partnerships to guarantee their survival.

Global case studies enhance the dialogue by demonstrating various difficulties and conservation approaches. The hardy Ginkgo trees of Hiroshima, which endured atomic devastation, and the renowned El Árbol del Tule in Oaxaca, Mexico, distinguished by its world-record trunk circumference, exemplify the widespread importance of old trees. They illustrate the convergence of cultural,

historical, and ecological values, rendering the conservation of these trees a global necessity. This monograph establishes a multidisciplinary framework for comprehending and conserving old urban trees through the convergence of cultural studies, environmental science, and urban planning. This study highlights the significance of collaborative endeavours among academics, urban planners, conservationists, and communities. By integrating varied views, it provides a comprehensive knowledge of the significance of ancient trees, presenting both theoretical insights and pragmatic measures for their preservation.

Public interaction is a vital element in the preservation of historic trees. Community-based activities, including educational programs, tree monitoring projects, and storytelling workshops, are emphasised as useful methods to cultivate awareness and stewardship. The monograph underscores the significance of linking humans to their natural heritage, fostering a sense of ownership and accountability for these living monuments. This study also examines the wider ramifications of ancient trees for sustainable urban development. Advocating for the incorporation of natural heritage into urban planning contests the traditional dichotomy between urbanisation and conservation. Ancient trees are regarded not as impediments to advancement but as essential resources that improve urban life quality, enrich cultural identity, and bolster environmental resilience.

This monograph is a call to action amid unparalleled environmental difficulties and cultural change. It highlights the enduring wisdom of ancient trees, whose tenacity and continuity remind humans of the necessity of cultivating a balanced relationship with environment. By studying, preserving, and celebrating historic urban trees, we can foster new avenues for innovation, sustainability, and collaboration.

Introduction

Urban ancient trees are living monuments to the history of our cities, bridging the gap between natural heritage and human development. These venerable giants, who have witnessed centuries of urban evolution, embody a unique intersection of historical significance, cultural value and environmental importance. As the silent guardians of urban landscapes, they offer invaluable knowledge of the past, while playing a crucial role in the present and future urban environment. This monograph delves into the complex significance of urban ancient trees, exploring their historical and humanistic value, as well as assessing their environmental impact. By analysing these trees through different lenses - historical, cultural and ecological - the monograph aims to provide a comprehensive understanding of their significance and the need for their preservation.

The historical aspect of this study traces to the life of ancient trees alongside the development of cities. Many of these trees existed before the urban structures surrounding them, offering a living link to the history of the land before urbanisation. Dendrochronology and historical records were used to reconstruct narratives about urban growth, climate change and human interaction over the centuries. From a humanistic point of view, ancient urban trees often have deep cultural and spiritual significance. They are substantial in local legends, religious rituals and community identity. This monograph explores how ancient trees have inspired art, literature and folklore, becoming an integral part of cultural heritage. The monograph also explored their role in promoting community engagement, education and psychological well-being in urban settings.

The environmental assessment presented highlights the ecological importance of ancient trees in urban ecosystems. As biodiversity hotspots, these trees provide crucial habitats for various species in urban environments. Their contribution to air quality, climate regulation and carbon sequestration is significant, especially in the context of growing urban environmental problems. However, ancient urban trees face numerous threats in rapidly changing cities. This study also addresses the challenges of preserving natural monuments in the face of urban development, climate change and other anthropogenic stressors. By assessing current conservation strategies and policies, the monograph aims to offer best practices for protecting and managing these invaluable natural assets.

Many scholars addressed this topic, emphasising its importance. O. Rackham (1980) offered a thorough historical and ecological analysis of British lowland woodlands, incorporating a wide array of sources – including archaeological evidence, pollen studies, historical records, and toponymy – to contest established beliefs regarding their origins and evolution. The author illustrated that human impact, particularly via the coppice system, has influenced woodland composition and continuity since the Neolithic period. Through a critical reevaluation of the significance of diverse tree species and an examination of climate, seed dispersal, and opportunistic regeneration, the author provided essential insights into the evolution of these landscapes and the determinants that will affect their future conservation and management. Researcher C. Konijnendijk (2008) examined city woods as vibrant cultural landscapes intricately connected to the social, cultural, and ecological dimensions of urban existence. Analysing historical and modern instances – from Amsterdamse Bos to Epping Forest – illustrated how trees have shaped urban identities, sustained livelihoods, inspired recreation and education, and occasionally incited confrontations. The author highlighted the interdependent relationship between urban areas and adjacent woodlands, emphasising the

necessity of including city forests into comprehensive sustainability initiatives. It is an essential resource for students, academics, policy-makers, and urban planners aiming to cultivate healthier, more resilient, and culturally dynamic urban settings.

D.J. Nowak (2023) in his book evaluated the impact of urban trees and forests globally on environmental quality and human well-being. It shown that these green spaces regulated temperatures, decreased energy use in buildings, alleviated flooding, and enhanced air quality. The author presented data on the economic value of these benefits, highlighting national savings of billions of dollars per year in the United States and significant local advantages in New York City. The researcher elucidated the mechanisms via which trees improved the physical and social aspects of urban environments, emphasising prospects for more efficient environmental engineering and the development of healthier, more sustainable cities. The authors C. Aleixo *et al.* (2023) evaluated the influence of data sources on assessing connectedness in urban green spaces (UGAs) in seven European cities. Comparing land cover classification (Urban Atlas) with high-resolution spectral data demonstrated that spectral data yielded more precise and standardised evaluations of UGA connectivity. Conversely, Urban Atlas classifications exhibited occasional inconsistencies, especially at localised scales and inside northern European towns. The results advocated for the utilisation of spectral data to enhance the dependability and relevance of urban biodiversity and ecosystem services research, hence facilitating more efficient urban planning and management.

L. Teron and T. Endreny (2023) analysed how recent policy alignments in the United States—encompassing climate initiatives, social justice issues, and infrastructure improvements—presented a timely opportunity to enhance urban tree cover and alleviate high heat effects in historically marginalised communities. They emphasised that environmental justice communities faced disproportionate exposure to higher temperatures and outlined how inclusive urban forestry initiatives, highway renovation, and the implementation of novel modelling methods facilitated more equitable environmental results. Their article highlighted the necessity of long-term engagement, trust-building, and collaboration with communities to ensure equitable and sustainable urban forest management, by illustrating that increased tree canopy coverage could mitigate the urban heat island effect and enhance public health. In his work, I. Braverman (2009) analysed how the straightforward actions of planting, cultivating, and uprooting trees transformed into significant instruments in the Israeli-Palestinian conflict. Structured around the symbolism of pine woods linked to Zionist afforestation initiatives and olive trees representing Palestinian connections to the land, it illustrated how the landscape was contested, polarised, and metamorphosed into a kind of conflict. Ethnographic reports illuminated the complex interconnections among law, economics, culture, and identity within the physical environment, animating the silent landscape as both a medium and a reflection of persistent battles.

C. Barona *et al.* (2023) analysed the perceptions of actors engaged in urban forestry throughout many Latin American and Caribbean cities on their involvement in decision-making processes, the condition of urban forest management and governance, and their faith in local authorities. An online poll revealed that heightened interaction among stakeholders correlated with improved engagement in collective decision-making and more favourable perceptions of urban forest

governance. Furthermore, enhanced perceptions of governance were associated with increased trust in local authorities. Nevertheless, non-governmental participants exhibited a lower level of trust in local governments compared to their governmental counterparts. The article stated that the implementation of urban forest policy necessitates sufficient resources, inclusive decision-making, and enhanced institutional confidence.

C. Gallis and W.S. Shin (2020) examined how forests have long served human health needs, though only recently were these non-material benefits widely recognized. It highlighted the growing demand for forests' health functions in response to rising urbanization, stress, and environmental challenges. Drawing on scientific research, it demonstrated that exposure to forests and green spaces offered measurable psychological and physiological health advantages, making them increasingly relevant in modern, urban societies. W.Y. Chen and D.T. Wang (2013) conducted the evolution of urban green areas in Chinese cities during a decade of fast urbanisation and economic expansion from 2001 to 2010. Through econometric analysis, evidence was discovered of an N-shaped environmental Kuznets curve, indicating that urban green space originally expanded with economic development, subsequently decreased after reaching a specific income threshold, and ultimately climbed again at elevated GDP levels. By 2010, only a limited number of cities had transitioned into the advantageous phase, underscoring the difficulties policymakers encountered in reconciling ongoing economic growth with the availability of natural amenities.

These scientists and researchers significantly contributed to the understanding of urban ancient trees from different perspectives. Their work together highlights the multifaceted importance of these trees in urban ecosystems and human societies. Through a comprehensive study, we hope to shed light on the irreplaceable value of urban ancient trees and inspire a deeper understanding of their role in our urban fabric. This monograph seeks to contribute to the growing body of knowledge on urban ecology and heritage conservation, advocating for the integration of these living places into sustainable urban planning and development strategies.

Chapter 1.

The historical significance of urban ancient trees

Ancient trees in cities are of great historical and cultural significance. They perform various functions, both biological and cultural, for example, ancient trees can serve as living landmarks that have witnessed centuries of urban development. Ancient trees in cities are silent witnesses to the evolution of urban landscapes over time. These living landmarks offer a unique perspective on the city's growth and transformation. Many ancient trees appeared before the cities around them, remaining in place when rural areas were transformed into bustling metropolises. Their presence can mark the transition from agricultural land to urban centres, providing a tangible link to the area's pre-urban history. Moreover, these trees have "witnessed" the change of architectural styles over decades or centuries. They witnessed the change from wooden structures to stone, and then to steel and glass skyscrapers.

The ancient trees survived as roads, railways and other infrastructure were built around them. Some have become part of modern urban planning, with streets or buildings designed to accommodate them. They have been present as the demographics, cultural practices and social norms of their neighbourhoods have changed and have witnessed everything from horse-drawn carriages to passing electric vehicles. Ancient urban trees have survived despite changing pollution levels, climatic conditions and local environmental conditions. Their sustainability often makes them a subject of study for urban ecologists and environmental scientists. Some trees have survived significant historical events, from wars and natural disasters to celebrations and social movements, so they can serve as living memorials or markers of important local or national events.

Many ancient urban trees become the subject of local legends or folklore, adding to the cultural fabric of the city. There are many stories about famous people who could rest under their branches or about events that took place around them. The presence of these trees can influence urban planning decisions, sometimes becoming focal points for parks or protected areas. They serve as a reminder of the importance of green spaces in the urban environment. These living landmarks provide a sense of continuity and perspective in a rapidly changing urban environment. They remind city residents of the history of the area and the importance of preserving natural elements in the urban landscape. Their presence often sparks discussions about sustainable urban development and the balance between progress and preservation.

Ancient trees often have a deep connection to past events or prominent personalities, acting as living links to history. Many ancient trees have witnessed significant historical moments, from wars to peace treaties. For instance, the Emancipation Oak at Hampton University in Virginia is the site of the first southern reading of the Emancipation Proclamation in 1863. Some trees are associated with prominent historical figures who may have planted them, sat under them or made important decisions nearby. The Newton Apple Tree at Woolsthorpe Manor in England is believed to be a descendant of the tree that inspired Isaac Newton's theory of gravity. Some trees have spiritual or cultural significance, often associated with religious figures or cultural rituals. The Bodhi Tree in Bodhgaya, India, is a direct descendant of the tree under which Buddha attained enlightenment. Trees were prominent in several political movements and became symbols of resistance. The

Liberty Tree in Boston became a rallying point for American revolutionaries in the 18th century. Many ancient trees were planted in memory of specific events or people. The Tree of Survivors at the 9/11 Memorial in New York City survived the terrorist attacks and is now a symbol of resilience (Jones and Cloke, 2002).

Some trees have inspired or been mentioned in literature, linking them to cultural figures. A large oak tree in Sherwood Forest, England, is associated with the legend of Robin Hood. Some trees have played a role in scientific discoveries or achievements. The hickory tree at the Sully Historic Site in Virginia is where agricultural scientist George Washington Carver conducted some of his early experiments. Many ancient trees become central figures in local legends and stories, often associated with historical figures or events. It is said that the Charter Oak in Connecticut hid the state's charter in 1687, protecting it from the British authorities. Some ancient trees served as boundary markers between estates or territories, often mentioned in historical documents (Pakenham, 1996). The witness trees at Gettysburg National Military Park have been standing since the famous Civil War battle.

The annual rings and composition of ancient trees can provide valuable data on past climate and environmental conditions, for example, the Bristlecone Pines in California, some of which are more than 4,000 years old, assisted scientists in reconstructing climate models over thousands of years. These connections to past events and prominent figures often elevate ancient trees from mere botanical specimens to revered historical artefacts. They become centres of historical education, preservation of culture and community identity. Their presence provides a feeling of tangible connection to the past, making history more immediate and relatable. Many cities and institutions are making great efforts to preserve these living historical monuments, recognising their value not only as natural wonders but also as irreplaceable links to our collective past. These efforts often include specialised care, protection from development and educational programmes to ensure that the stories and significance of trees are passed on to future generations.

Ancient trees in urban environments often serve as powerful symbols of resilience and continuity in the face of change. They have survived numerous challenges over the centuries, including:

- Extreme weather events (storms, droughts, floods);
- Urban pollution and soil compaction;
- Diseases and pests;
- Damage caused by humans or attempted removal;
- Their ability to withstand these challenges makes them living examples of adaptability and endurance.

As cities grow and develop, these trees remain permanent features: they can precede surrounding buildings, roads and other infrastructure; their presence provides a sense of permanence in a rapidly changing urban environment. Ancient trees store genetic information from past centuries: they may represent older, more diverse gene pools; some may be the last examples of species that were once common in the area; this genetic continuity is valuable for biodiversity and scientific research. In a rapidly changing urban environment, these trees are a reminder of slower, more natural rhythms: their seasonal changes (e.g. flowering, leaf fall) mark the passage of time, and they often become centres of community traditions and gatherings. The resilience of ancient trees can inspire communities, as they symbolise the ability to overcome difficulties and emerge stronger, and their longevity provides a different perspective to consider any problems.

Ancient trees often support complex ecosystems: they provide habitat for a variety of species in urban areas and their presence can improve air quality and mitigate the effects of the urban heat island, an ecological role that demonstrates the resilience of nature in human-dominated landscapes. Many ancient trees have adapted to changing urban conditions, some have developed resistance to pollutants, and others have adjusted their growth patterns to fit in with nearby structures, this adaptability demonstrates the ability of nature to coexist with human development. Ancient urban trees that have survived disasters or development attempts often become symbols of hope, such as the Tree that survived 9/11 in New York or trees that have survived wars. Their ability to recover from damage inspires stories of renewal and resilience. In rapidly globalising cities, trees support a sense of local identity as they often feature in local legends, art and literature, and their unique shapes can become iconic symbols of place.

Enduring centuries of change, ancient trees embody sustainability in a tangible, living form. They bear the symbol of the enduring power of nature and the importance of preserving natural heritage in the context of urban development. Their presence propels an idea of long-term thinking and a legacy for future generations to be left. Another cultural function is that ancient trees connect several generations of people and often become important centres of social gatherings and traditions in urban areas. Great-grandparents and great-great-grandchildren may have experience with the same tree, and this continuity fosters a sense of shared history and responsibility. Large old trees provide natural meeting places. Their wide crowns provide shade and shelter, and the space around them often becomes an informal public square and can serve as a venue for fairs, markets, concerts, performances, public readings, etc. Many ancient trees are central in local cultural or religious ceremonies: some are used for traditional blessing or prayer ceremonies, while others may be decorated during festivals or holidays (Blicharska and Mikusiński, 2014).

Ancient trees serve as living classrooms. Schools often organise field trips to learn about local history and ecology, and naturalists may run tree tours or workshops. Trees associated with historical events sometimes become scenes for re-enactments, such as the events of the War of Independence around the Liberty Trees or medieval fairs around ancient oak trees in European cities. Ancient trees inspire and provide a venue for various forms of artistic expression, such as plenary painting sessions, poetry readings or writing workshops, and photography meetings. Significant trees often become rallying points for conservation efforts, such as protests against deforestation or urban development, or tree-planting ceremonies to complement an ancient tree. The space around the ancient trees is sometimes used for traditional games, such as a village green cricket match in England or traditional wrestling events in parts of Africa and Asia. Communities often use ancient trees as living memorials, including tying ribbons or leaving memorabilia in memory of loved ones, and holding candlelight vigils during times of grief or community celebration. These community gatherings and traditions centred around ancient trees help to strengthen community ties, preserve local culture and maintain a connection to nature in an urban environment.

Trees become living symbols of community identity and shared history, and their durability is in keeping with the enduring nature of human traditions. As focal points, ancient urban trees not only improve the physical landscape of a city but also enrich its social and cultural fabric. They provide a sense of place and continuity in an ever-changing urban environment, reminding residents of their common heritage and the importance of preserving both natural and cultural heritage.

Ancient trees in urban environments are highly valuable ecological resources, as they support a wide range of life forms:

- Insects, including rare and specialised species;
- Birds, both for nesting and foraging;
- Small mammals such as bats and squirrels;
- Fungi, lichens and mosses, often including rare species;
- They are micro-ecosystems, hosting more biodiversity than young trees.

Older, larger trees are particularly effective in storing carbon. They continue to absorb CO₂ throughout their lives, and their extensive root systems also store significant amounts of carbon in the soil. This mitigates the effects of climate change in urban areas. Ancient trees with wide crowns are excellent air filters as they remove pollutants such as particulate matter, ozone and nitrogen dioxide and produce oxygen, improving overall air quality, which is especially valuable in urban areas with high levels of pollution. Large old trees have a significant impact on the local climate. They create shade, reducing the urban heat island effect, and their transpiration cools the surrounding air, acting as a windbreak, and mitigating local wind conditions. Mature trees are significant in urban water cycles as their extensive root systems absorb and filter rainwater. This reduces runoff and the burden on urban drainage systems and helps prevent soil erosion and flooding. Ancient trees contribute to long-term soil quality. Leaf litter and root decomposition enrich the soil by feeding beneficial soil microorganisms, while roots help maintain soil structure and prevent compaction.

In fragmented urban landscapes, old trees can serve as stepping stones to provide temporary habitat for migratory species and connect larger green spaces, making it easier for wildlife to move around. Ancient urban trees provide numerous free environmental services, including:

- Natural pest control by supporting predator species;
- Supporting pollination by placing different populations of insects;
- Reducing noise in urban environments.

Ancient trees growing in cities offer unique opportunities for scientific research:

- Long-term monitoring of the urban environment;
- Climate change research using dendrochronology (annual ring analysis);
- Research on the adaptation of urban wildlife.

Ancient trees are often important sources of seeds. They provide locally adapted genetic material for urban forestry programmes, which is particularly valuable if they represent rare or endangered species. The health of ancient trees can indicate more general environmental conditions. Their sensitivity to pollution can alert people to problems with air or soil quality, and changes in their associated species can signal changes in local ecosystems. By providing these ecological services, ancient trees play an important role in maintaining the ecological balance in urban areas. They offer many benefits that go far beyond their aesthetic value, significantly contributing to the sustainability and resilience of cities. Their presence in cities underlines the importance of preserving mature trees and incorporating them into urban planning and development strategies. As cities face challenges such as climate change, pollution and biodiversity loss, these ancient ecological powerhouses are becoming increasingly valuable. Ancient trees often have protected status and inspire local conservation efforts. Their rings can provide data on historical climate patterns and environmental conditions.

1.1 Definition and classification of urban ancient trees

Urban ancient trees are old, large trees found in urban environments that have significant ecological, historical and cultural value. These trees are usually defined by their advanced age, impressive size and location in urban areas. The definition of an ancient urban tree is complex and context-specific. While age is a decisive factor, it is often combined with considerations of size, historical significance, ecological value and cultural importance. Urban planners, arborists and conservationists can use a combination of these factors to identify and classify ancient urban trees for protection and management purposes.

The classification of urban ancient trees often includes several criteria (Farina, 2010). First of all, the age – as a rule, it is more than 100-200 years old, although it depends on the species and region. The age of urban ancient trees is a decisive factor in their classification, but it is also one of the most difficult aspects to determine accurately. Age is determined by several factors, such as species characteristics or regional differences. Different types of trees have different life expectancies and growth rates. For instance, a 200-year-old oak tree can be considered ancient, while a 200-year-old birch tree will be exceptionally old. Therefore, the age threshold for the status of “ancient” varies depending on the species. The definition of an “ancient” tree may vary depending on the geographical location. In Europe, where the history of human settlement is longer, trees may be older to be considered ancient compared to newer urban areas in North America or Australia.

The age of a tree can be determined in a number of ways. Counting tree annual rings is the most accurate method, but it is invasive and is usually limited to fallen or dead trees. On the other hand, historical records maintained by city planners may provide documentation of the dates of planting of notable trees. Another approach involves comparing the size of a tree to the established growth rate of its species, which provides a rough estimate of its age, albeit with limited accuracy. Classification systems often divide trees into age categories, including veteran trees, which are old but not ancient; ancient trees, which have reached a significant age; and landmark trees, which have historical or cultural value regardless of their age. These classifications make it easier to study and preserve trees, especially those that have thrived in difficult urban environments.

In addition, there are defined minimum age criteria that are important when surveying older trees. Broadleaf trees are often considered ancient at 300-400 years of age, although conifers can be classified as ancient at 300 to 500 years of age. Species with a short life span can be considered ancient when they reach an age of 150 to 200 years. Trees that have reached old age in urban environments are particularly outstanding because they have withstood numerous challenges, such as pollution, soil compaction, and urban expansion. These resilient trees act as historical witnesses and greatly enhance the cultural and ecological environment of their communities. Some trees may be biologically “ancient” at a younger chronological age due to stress factors in the urban environment that accelerate their ageing process. In some cultures, trees may be considered ancient based on their association with historical events or personalities, regardless of their actual age. However, age alone does not always determine the value of a tree or its protection status. Some young trees may be protected due to their rarity, ecological importance or cultural significance. Conversely, very old trees may not receive special status if they are common species in good health.

Second criterion is a size – as a rule, a large trunk diameter, height and crown spread relative to its species. Size is a key factor in the identification and classification of urban ancient trees, as

it often correlates with age and environmental conditions. However, sizing considerations can be complex and vary depending on several factors. A specific measurement system is usually used, which includes:

- Barrel diameter: usually measured at chest height (DBH), typically 1.3-1.5 metres above ground level.
- Height: the total vertical distance from the ground to the top of the tree.
- Size of the crown: the width of the tree canopy, often measured as the average of the widest and narrowest points.

The size thresholds for ancient status vary between species. For instance: an oak tree that is 20 metres high can be considered large, while a sequoia that is 20 metres high is small for its species. Some species, such as yews, can grow very wide, but not particularly tall. Many regions have lists of “champion trees” - the largest known specimens of each species. Although not all champion trees are ancient, many urban ancient trees are champions for their species in their area. Urban trees often grow differently from their forest counterparts. Trees growing outdoors in parks form wider and more spreading crowns, while street trees can be restricted in growth by buildings and infrastructure. As a rule, size is not always an accurate indicator of age. Some fast-growing species can reach large sizes quickly, and slow-growing species or trees under stress can be very old, but not exceptionally large.

In urban environments, girth (trunk diameter) is often considered more important than height when classifying ancient trees. This is because height growth often slows down or stops in very old trees. Urban environments can limit height more than girth, which continues to increase throughout the tree’s life. Many ancient trees are hollow due to natural decay processes. These trees can have an impressive girth but a lower total wood volume than young, hardwood trees. What is considered a “big” tree can vary depending on the local flora and cultural characteristics. A tree that is impressively large in one city may be unremarkable in another. Many cities have certain threshold sizes in their tree protection ordinances. For example, the city can protect all trees over 75 cm DBH, regardless of species or age. It is worth noting that while size is an important factor, it is not the only determinant of a tree’s value or status as an urban ancient tree. Smaller trees of great age, historical significance or rare species can also be classified as urban ancient trees, even though they are not the largest specimens.

Third criterion is the location: in urban environments such as parks, streets, gardens or historical sites. Urban ancient trees are found in a variety of urban settings, including public parks and gardens; streets and sidewalks; historical sites and monuments; private gardens and estates; constitutional areas (universities, hospitals, etc.); cemeteries; former industrial sites; urban forests or remnant forests. Ancient urban trees face many urban challenges to which they must adapt, for example: soil compaction and limited root space; air pollution; altered water regimes (e.g. increased runoff, decreased groundwater); and physical damage from human activity. The location of urban ancient trees often reflects the development of the city. Trees in urban centres may predate urban expansion, while some may be remnants of former forests or gardens, and others may have been deliberately planted during urban planning. The specific location of a tree in an urban area can create unique microclimates. As such, trees near buildings can be protected from wind, and street trees can be exposed to higher temperatures due to heat reflected from pavements.

The distribution of urban ancient trees can vary considerably. In some cities, the distribution is even, while in others there may be clusters in certain neighbourhoods or historic districts. The distribution often reflects historical land use patterns and socio-economic factors and influences how the public interacts with these trees. For instance, trees in public spaces are often valued and protected, while trees on private property may be less visible but still contribute to the urban canopy. The presence of urban ancient trees can influence urban planning. For instance, protected trees can influence construction projects, cities can be designed around significant trees, and some places can be designated as cultural heritage sites because of their trees. Street trees often require special care to avoid conflicts with infrastructure. Park trees need to be protected from soil compaction due to foot traffic, while trees on private property are less controlled by city foresters.

The location of urban ancient trees can play a role in urban ecology as they sometimes serve as stepping stones in green corridors or free-standing trees can be important habitat islands for urban wildlife. Moreover, the location of trees in a city is often linked to their cultural significance, for example, trees in central squares are community focal points, and trees on historical sites are associated with significant events. Trees on public land may have different protection than trees on private land. In some cities, there are special designations for trees in certain locations (e.g. “Trees on Heritage Streets”). The context of the location of urban ancient trees significantly influences their proper management, and protection and maximising their benefits to the urban ecosystem and community.

The fourth criterion is the type. Urban ancient trees cover a wide range of species, including:

- Local species that existed before the development of the city;
- Non-native species introduced for decorative or practical purposes;
- Rare or unusual species that have been preserved over time.

There is certainly a wide variety of tree species in cities, but the most common ones are the following: oak (*Quercus sp.*), elm (*Ulmus sp.*), linden (*Tilia sp.*), plane (*Platanus sp.*), cedar (*Cedrus sp.*), yew (*Taxus sp.*) and ginkgo (*Ginkgo biloba*). Different species have different lifespans and growth rates, which affects their classification as “ancient”. Slow-growing, long-lived species, such as oaks, can be considered ancient at 300–400 years old. Fast-growing and short-lived species such as birches can be considered ancient at a younger age.

Some species are better suited to urban environments. Pollution-tolerant species such as the London plane tree (*Platanus acerifolia*), drought-tolerant species in arid urban areas, or species that are resistant to soil compaction and limited root space. Native species of urban trees provide important habitat for local wildlife, while non-native species may have historical or cultural significance, which is significant for the cultural life of the city. Some urban ancient trees become important due to their species, including rare native species that have declined in the wild; and unusual varieties or species or species that are common worldwide but rare in a particular urban context. Certain species have strong cultural or historical ties, for instance, freedom trees (often elm or oak) in the United States of America; bodhi trees (*Ficus religiosa*) in Buddhist cultures or royal oaks in the UK. The choice of species for urban trees is changing due to climate change. Some traditionally common species may become less suitable, and more heat- and drought-tolerant species are preferred.

Species that have survived and become ancient often demonstrate resilience, for example, survivors of diseases such as Dutch elm disease or trees that are resistant to common urban pests.

Urban trees have not only historical or cultural significance but also perform other functions. Some tree species are particularly good at removing air pollution, while others excel at sequestering carbon or providing food for wildlife. The types of trees affect the strategies for managing them. The need for pruning varies by species, with some species being more prone to shedding branches and requiring more frequent inspections, and the characteristics of the root system affect the interaction between the road surface and infrastructure. Ancient trees of certain species are valuable because of their genetic material. These can be sources of hardy genes for future urban tree breeding programmes or for preserving genetic diversity within species. Understanding the species of ancient urban trees is crucial for proper management, conservation efforts and recognition of their unique contribution to urban ecosystems and cultural heritage.

The fifth criterion is the historical significance: trees associated with important events, people or cultural practices. The city's ancient trees have survived important historical events and periods. Some of them may have preceded the founding of the cities, while others may have been planted to commemorate certain events. Many of the city's ancient trees have deep cultural or religious significance. For instance, sacred trees in different religions (e.g. Bodhi trees in Buddhism); trees associated with folklore or local legends or trees that have become symbols of community identity. Some trees gain significance because of their association with famous people, such as trees planted or named after famous historical figures or trees under which important historical figures are said to have rested or made decisions. Ancient trees provide insight into historical land use and urban development, including remnants of ancient forests or woodlands; indicators of former property boundaries or land divisions; and evidence of historical trends and landscape design practices.

Some ancient urban trees are important in the history of horticulture, they can be early examples of introduced species or trees that represent important milestones in plant breeding or cultivation and are valuable for scientific research in dendrochronology (analysis of annual tree rings) for climate studies or genetic studies of long-term adaptation to urban environments. Trees can be an integral part of historic architectural projects. They are part of designed landscapes in historic estates or parks and shape the growth and layout of urban areas. Some trees reflect the economic history of the region, such as the remains of historic orchards or timber production, or trees associated with traditional industries or crafts. In addition, trees were used as observation posts or markers in historical battles, which is also an important part of the city's history. Understanding the historical significance of ancient urban trees adds depth to their value that goes beyond mere age or size. It connects modern urban residents to their city's past and often plays a crucial role in decisions about urban planning, preservation and community identity.

The sixth criterion is the environmental value – provide habitat for wildlife and contribute to urban biodiversity. The ecological value of urban ancient trees is significant and multifaceted. These trees are significant in urban ecosystems, often acting as key species in urban environments. They are an important component in maintaining biodiversity. They provide habitats for a wide range of organisms, from microbes to mammals. Older trees tend to have a more complex structure, offering a variety of habitat niches and can support species that are rare or absent elsewhere in urban areas.

These trees offer different habitat features:

- Cavities and hollows for nesting birds and bat roosts;
- Bark crevices for insects and small reptiles;

- Branches for birds of prey and other large animals;
- Root systems that provide shelter for small mammals.

Ancient trees make a significant contribution to urban food webs. They produce large quantities of seeds, fruits or nuts, are home to numerous insect species that in turn support bird populations and fallen leaves and decaying wood support detritivores and fungi. Large old trees have a significant impact on the local microclimate by providing shade, reducing the urban heat island effect, increasing humidity through transpiration and creating windbreaks, mitigating local wind patterns, and they are also important carbon sinks. Large trees sequester carbon at a faster rate than younger trees and store significant amounts of carbon in their biomass and surrounding soil. In addition, ancient trees are central to air purification. They filter out particulate matter and absorb gaseous pollutants, and the large canopies provide a large leaf surface area for air purification. Urban trees also contribute to soil and water dynamics, as their extensive root systems prevent soil erosion, improve soil structure and nutrient cycling, and infiltrate water, reducing surface runoff.

Older trees often have well-established mycorrhizal associations and support complex underground fungal networks that can benefit younger trees and other plants in the vicinity. In addition, they influence ecological succession in urban areas, providing conditions for shade-tolerant species to establish, and their eventual death and decomposition create new ecological niches. Many ancient trees are important for urban pollinators, providing nectar and pollen over large surface areas and providing a stable resource year after year. The ecological value of urban ancient trees goes far beyond the trees themselves, affecting entire urban ecosystems. Their conservation and proper management are crucial for maintaining biodiversity and ecological function in cities.

Seventh criterion is the rarity – unusual species or varieties in the urban context. The aspect of the rarity of urban ancient trees is an important factor in their classification and preservation. Some ancient urban trees are rare because of their species, such as relict species that were once common but are now rare; non-native species that are rare in urban settings but common elsewhere; or species that are globally threatened or endangered. Age can also affect the rarity of a tree; thus very old specimens of even common species can be rare. Some ancient urban trees may have unique genetic characteristics, including trees with rare genetic variations or mutations, or trees representing now rare varieties or species. Trees associated with specific historical events or periods are also rare, they may be the last surviving trees from a particular historical plantation or trees that are the only remnants of former forests or estates.

Some trees are rare due to their ecological role, such as trees that support rare or endangered species, and trees with unique ecological interactions in urban environments. Rarity often depends on the context. Thus, a species common in one city may be rare in another. Trees that have survived major urban change or disasters are also considered rare, including trees that predate significant urban development or that have survived diseases that have wiped out most of their species (e.g. elm that survived Dutch elm disease). Trees with unusual growth forms or characteristics are also considered rare, for example, trees with unique branching patterns or growth habits or trees that have adapted to urban conditions in rare ways. The functionality of trees also determines their rarity. Some trees perform rare ecological functions in urban areas, such as supporting unique ecosystems in cities or having unusual beneficial interactions with urban infrastructure.

With climate change, some trees may become rare in their current locations, including species at the edge of their climatic tolerance and relict populations from previous climates. In addition,

some trees are rare due to management practices. These include trees maintained using traditional, now rare methods (e.g. pruning) and trees preserved through unusual conservation efforts. Some trees are rare due to a combination of factors, such as a very old, large specimen of an unusual species in an unusual location. The rarity of urban ancient trees often contributes significantly to their value and the level of protection they receive. Rare trees can be given special status in urban tree inventories and may be subject to stricter protection measures. Consideration of the different aspects of rarity prioritises conservation efforts, thus appreciating the unique contribution of these trees to urban biodiversity and cultural heritage.

The last criterion is the aesthetic qualities – distinctive shape, structure or visual appeal. The aesthetic qualities of urban centenary trees are an essential factor in their value to urban landscapes and communities. Ancient trees often dominate their surroundings. Their impressive size and scale create focal points in cityscapes, and their unique silhouettes can become iconic features of the cityscape. Many ancient trees provide year-round visual interest due to their spring blooms, summer foliage, autumn colours and winter branch architecture. Older trees often have distinctive textures, including knotty, furrowed bark, complex branch patterns and varied leaf textures. The large canopies of ancient trees create interesting lighting effects, such as patchy sunlight under the tree; dramatic shadows cast by low sun angles or seasonal changes in light penetration. These trees often have unique growth forms such as spreading canopies, twisted or curved trunks and asymmetrical shapes that tell the story of their growth.

Trees contribute to the colour composition of urban spaces. Their green tones vary depending on the species and season. The colour of the bark varies from pale grey to deep brown, as well as the seasonal colours of flowers or fruits. Large ancient trees create a sense of scale in the urban environment by contrasting with artificial structures and creating a vertical dimension in open spaces. In densely built-up areas, ancient trees offer a natural aesthetic due to their organic shapes, contrasting with geometric urban patterns and softening the appearance of harsh urban landscapes. They can shape views in urban spaces as they frame views or architectural features and provide privacy between areas. Ancient trees often serve as objects for various works of art and are the inspiration for paintings, photographs and sculptures, themes of poetry and literature, and the changing appearance of ancient trees marks the passage of time (Muir, 2000). Thus, bare branches in winter turn into lush leaves in summer, demonstrating the cycles of flowering and fruiting.

Moreover, urban trees can present a striking appearance when lit up at night, forming dramatic silhouettes against the night sky. They often enhance the overall aesthetics of their surroundings as they complement architectural styles and contribute to the character of parks and public spaces. Signs of age and weathering often add to the aesthetic appeal. Depressions, bumps and other “imperfections” demonstrate history, while moss, lichen and mushrooms add layers of visual interest. The appearance of ancient trees can evoke emotional responses, such as a sense of awe or wonder at their size and age, or a sense of calmness or connection to nature. Ancient trees change not only with the seasons but also over the decades, gradually changing shape as they age and adapt to the urban changes around them.

The aesthetic qualities of urban ancient trees make a significant contribution to the character and attractiveness of urban spaces. They provide a visual richness, a connection to nature and a sense of place that enhances the overall experience of the city. These qualities often play a decisive role in the community’s attachment to these trees and motivate conservation efforts. Urban

ancient trees are often classified based on their location (e.g. park trees, street trees, garden trees) and their level of protection or heritage status. In many cities, inventories of these trees are being kept ensuring their preservation and proper management.

1.2 Historical documentation and dendrochronology

Historical documentation, including a variety of sources such as municipal archives, city planning documents, park and garden design plans, and tree planting records, is important for determining and confirming the age and significance of ancient urban trees. Historic maps and surveys provide a comprehensive assessment of the area showing where trees were planted, and historic photographs such as early cityscapes and aerial photographs depict the evolution of urban landscapes over time. In addition, written documents such as diaries, personal narratives, and travel diaries provide direct insight into specific trees and urban environments. Newspaper archives include articles about notable trees or tree planting events, as well as reports of storms and other incidents that affected notable trees. Public records, such as land ownership deeds, protection orders, or lists of protected trees, confirm the historical presence and significance of certain trees. Cultural and religious texts may contain references to sacred or culturally significant trees, folklore and legends associated with specific trees, and artistic representations such as paintings, sketches of urban landscapes depicting trees, and literary works that mention notable urban trees reinforce the narrative and cultural context surrounding these ancient urban trees (Foley and Kistemann, 2015).

Dendrochronology, or annual ring dating, is a scientific dating method based on the analysis of the patterns of annual tree rings. It provides valuable data for ancient urban trees for several reasons. One of them is the determination of the age of a tree by counting the rings of the plant, which is an accurate method for most tree species and helps to confirm or refute historical records. The next reason is the analysis of the growth patterns of ancient trees. The study of changes in ring width identifies favourable or stressful times for plant growth and indicates certain historical events, such as drought or fire, in the life of a tree. Annual tree rings store information about past climatic conditions, which is useful for understanding long-term changes in urban climate. The rings of ancient trees can also serve as indicators of environmental pollution. Chemical analysis of rings can reveal historical levels of pollution and track the environmental history of urban areas.

Changes in growth patterns can indicate phases of urban development and show the impact of nearby construction or changes in groundwater levels. The combination of historical documentation and dendrochronology provides a highly relevant method for studying ancient urban trees. With dendrochronology, year-ring data can confirm or dispute age statements in historical documents; also, dendrochronology can provide information about periods for which there are no written records (Lewis, 1996). Combining the documented events with the data from the annual rings provides insight into past urban conditions. The historical significance, combined with the scientific verification of age, also informs efforts to protect the trees. The past life of plants from historical documents, supported by scientific data, increases public interest in urban trees, and the integration of cultural history with scientific dating enriches the historical value of ancient urban trees (Gill *et al.*, 2007). Both historical and scientific evidence can support the need to preserve

trees in urban planning decisions. By combining the rich context provided by historical documentation with the precise data provided by dendrochronology, researchers, urban planners and conservationists, a comprehensive image of ancient urban trees, their history and their importance to the urban landscape can be determined.

The integration of historical documentation and dendrochronology provides a reliable approach to studying and verifying the age and significance of ancient urban trees. This interdisciplinary approach demonstrates these trees and their role in the history and ecology of cities in detail. Historical documentation offers context and cultural significance, while dendrochronology provides scientific accuracy and ecological data. Together they are substantial for urban forest management, conservation and public education. Historical documentation can provide valuable information about the cultural and social significance of trees that may not be apparent from scientific research alone. Dendrochronology can provide precise dating and environmental data that can confirm or sometimes challenge historical accounts. The combination of these methods reveals fascinating stories about urban development, climate change and the interaction between humans and nature in cities over time. This integrated approach is particularly valuable for urban planning and conservation efforts, providing both a cultural and scientific rationale for preserving ancient trees.

1.3 Practical examples of famous urban ancient trees around the world

Many ancient urban trees in different countries attract attention for their size, history, cultural or ecological significance. We will dwell on some of the most famous ones (Table 1).

Table 1. Notable ancient urban trees worldwide

Title and location	Age	Type	Significance
Great Oak, Sherwood Forest, Nottingham, UK	Approximately 800-1000 years	English oak (<i>Quercus robur</i>)	Associated with the legend of Robin Hood; one of the oldest oaks in England. Supported by a complex scaffolding system since the 1900s, requires regular pruning and soil treatment.
A century-old tree in Buenos Aires, Argentina	More than 200 years	Homero (<i>Ficus elastica</i>)	Planted in 1791, before Argentina gained independence. It is a symbol of the city's history and resilience; declared a national historical monument in 1991, it needs regular maintenance by the city's arborists.
The Hippocratic Tree, Kos Island, Greece	Claimed to be 2500 years old (the actual age is disputed)	Eastern plane tree (<i>Platanus orientalis</i>)	Is said to be the place where Hippocrates taught his students. It is a major tourist attraction and cultural symbol; and is propagated by cuttings to preserve its heritage.
Large baobab, Sunland Farm, Limpopo, South Africa	Estimated at 1700 years (before its collapse in 2016-2017)	African baobab (<i>Adansonia digitata</i>)	Was the largest African baobab; and contained a wine cellar inside its hollow trunk. Despite efforts, it collapsed due to a split trunk, but its parts continued to grow, demonstrating the resilience of baobabs.
Ginkgo biloba, Hiroshima, Japan	More than 200 years	Ginkgo biloba	Survived the atomic bombing of Hiroshima in 1945 and is a symbol of resilience and peace. It is protected as a natural monument, thus requiring regular health checks and maintenance.

Table 1, Continued

Title and location	Age	Type	Significance
General Sherman, Sequoia National Park, California, USA	Approximately 2300-2700 years	Giant sequoia (<i>Sequoiadendron giganteum</i>)	The largest living single-trunked tree known by volume, is a major tourist attraction and is protected in the national park.
Oak Brimmon, Powys, Wales	Approximately 500-600 years old	Scrub oak (<i>Quercus robur</i>)	Winner of the 2016 UK Tree of the Year competition, the subject of a successful campaign to re-route a bypass road; it has protected site status, which was obtained as a result of a public campaign and requires regular monitoring and maintenance
Bodhi tree, Anuradhapura, Sri Lanka	Said to be more than 2000 years old (in fact, the tree is a sampling of the original)	Holy figs (<i>Ficus religiosa</i>)	Believed to be a descendant of the tree under which Buddha attained enlightenment, it is one of the oldest known planted trees in the world; it is protected as a UNESCO World Heritage Site and requires constant care by dedicated caretakers.
El Árbol del Tule, Oaxaca, Mexico	Approximately 1400–1600 years old	Montezuma cypress (<i>Taxodium mucronatum</i>)	Has the widest tree trunk in the world and is a centre of local culture and tourism for the Zapotecs; it is protected by the local community and requires efforts to reduce water use in the area to maintain groundwater levels.
Treaty Oak, Austin, Texas, USA	Approximately 500+ years old	Virginia oak (<i>Quercus virginiana</i>)	Survived attempted vandalism in 1989, is a symbol of Austin's commitment to preserving urban forests, and requires intensive care after a poisoning attempt, ongoing maintenance and monitoring by city arborists.

These cases demonstrate the diverse cultural, historical and ecological significance of ancient urban trees around the world. They also highlight various conservation issues and strategies used to protect these living monuments. Many of these trees are closely intertwined with local history, legends and cultural customs. They often serve as living links to the past and symbols of cultural identity. Some of these trees have survived extreme conditions, from nuclear bombs to deliberate vandalism, demonstrating the remarkable resilience of trees. Each tree presents a unique conservation challenge, often requiring innovative solutions and significant resources. Many of them were saved or protected thanks to public interest and involvement, which underscores the importance of community involvement in urban forest conservation. Such ancient trees provide valuable data for scientists studying climate change, urban ecology and tree biology.

These trees also often become centres of tourism and environmental education, raising awareness of the importance of urban forests. The stories of trees like the Brimmon Oak demonstrate how ancient trees can influence urban planning and political decisions. Symbolic value: many of these trees have become powerful symbols of sustainability, peace or environmental protection. These examples show that ancient urban trees are not just biological entities, but complex socio-ecological systems that interact with human society in many ways. Their conservation often requires a holistic approach that addresses both their biological needs and their cultural and social significance. A unique species of tree – *Ginkgo biloba* L., is especially noteworthy. This is a living fossil with a rich history and potential health benefits.

Ginkgo biloba L. boasts a remarkable origin dating back more than 200 million years. It is one of the oldest living tree species on Earth, as it has witnessed the rise and fall of dinosaurs and the

evolution of our planet. Today it thrives in East Asia, but its leaves have a special place in traditional Chinese medicine. One of the most striking features of *Ginkgo biloba* L. is its fan-shaped leaves (Jim and Chen, 2009). Unlike most trees, ginkgos are naked seeded, meaning they produce naked seeds rather than fruits. These unique leaves turn a brilliant golden yellow in autumn, creating a breathtaking view. The leaves of *Ginkgo biloba* L. are commonly used in herbal supplements. Although research is ongoing, some studies suggest that they can improve cognitive function and memory, especially when they deteriorate with age. However, it is important to consult a doctor before using any supplements.

Ginkgo biloba L. is more than just a potential reminder. It is a beautiful and resilient tree that is often planted as an ornamental plant in parks and gardens. Its resistance to pests and diseases renders it a valuable addition to urban landscapes. Traces of this ancient plant were found on stone impressions. These prints date back to the Jurassic and Cretaceous periods. There was a time when ginkgo was widespread everywhere, but 80 million years ago, a severe cooling on Earth significantly reduced the distribution of this plant. Currently, only one wild species of ginkgo is known to grow in the mountainous regions of China. Manuscripts written several thousand years ago describe the extraordinary healing properties of ginkgo. But until a certain time, the situation was the same: science is science, and manuscripts are manuscripts. Translated from Latin, *Ginkgo Biloba* is a “silver apricot”.

Ginkgo is as beautiful as it is unusual. A powerful trunk covered with thick brown bark is topped with a crown (it can be pyramidal or spreading). The ginkgo leaves have a delicate shade and are shaped like Japanese fans. The autumn tree is no less beautiful. In preparation for winter, *Ginkgo biloba* L. sheds its golden ornament on the ground. In Japan, ginkgo is considered a symbol of longevity and vitality and is an object of worship. And leaves are believed in Japan to be able to tell fortunes. Ginkgo remains a cult plant in Japan. It ends up in local churches. The Tokyo Botanical Garden is home to a magnificent specimen of a ginkgo tree, next to which is a plaque telling the story of a scientist who devoted most of the life to caring for this plant. *Ginkgo biloba* L. is a unique and ancient species that is of great importance in modern society. Its constant presence dates back more than 270 million years, making it one of the oldest surviving tree species on Earth. Today, its relevance covers many areas: from traditional medicine to modern scientific research, urban landscape design and environmental protection efforts.

One of the most remarkable properties of *Ginkgo biloba* is its medicinal value. Extracts of its leaves were used for centuries in traditional Chinese medicine to treat various diseases, especially those related to cognitive function and blood circulation. In recent decades, scientific research has explored its potential benefits in improving memory, and cognitive function and alleviating symptoms associated with conditions such as Alzheimer’s disease and dementia. Studies show that ginkgo can increase blood flow to the brain and act as an antioxidant, protecting nerve cells from damage caused by free radicals (Keniger *et al.*, 2013). In addition to its medicinal properties, *Ginkgo biloba* is increasingly recognised for its role in urban environments. Its hardiness and resistance to pollution make it a popular choice for urban planners looking to improve green spaces. Ginkgo trees grow well in a variety of climates and soil conditions, offering shade, and aesthetic beauty with their fan-shaped leaves and contributing to urban biodiversity. Their resistance to pests and diseases once again underlines their suitability for urban landscape design.

Ginkgo biloba L. also benefits environmental conservation efforts. As a living fossil, ginkgo is a preservative of genetic diversity and evolutionary history. Conservation initiatives aim to preserve

wild populations and genetic resources of ginkgo trees, ensuring their survival in the face of habitat loss and climate change. Efforts to propagate ginkgo through cultivation not only support its continued existence but also provide economic opportunities through the sale of ginkgo products and supplements. Moreover, the cultural and symbolic significance of ginkgo increases its relevance. Revered in many cultures for its durability and resilience, ginkgo is often planted near temples, shrines and historical sites as a symbol of hope, endurance and peace. Its presence in literature, art and architecture once again illustrates its enduring appeal and cultural significance around the world. In conclusion, *Ginkgo biloba* L. is a testament to sustainability, adaptability and longevity. Its relevance today is complex, as it covers health and well-being through medical applications, environmental benefits in urban environments, contribution to biodiversity conservation and cultural symbolism. As our understanding of its properties and potential continues to evolve through scientific research and cultural recognition, ginkgo remains a fascinating and invaluable part of our natural and cultural heritage.

1.4 The role of ancient trees in urban development and cultural heritage

Ancient trees are substantial in shaping urban landscapes and preserving cultural heritage. Their influence extends to various aspects of urban life and development. Urban planning and design depend on the presence and location of ancient trees, as they often serve as natural landmarks, influencing the layout of streets, buildings and public spaces. Moreover, these trees are key components of urban green infrastructure, providing ecosystem services on a large scale, and the presence of protected ancient trees can limit development, leading to creative urban design solutions.

Incorporating old trees into urban planning and design entails numerous critical elements that guarantee the preservation and appreciation of these historic natural features within the urban environment (Niemelä, 1999). Spatial design is essential, as ancient trees frequently act as natural monuments that order surrounding urban elements. Parks, squares, and roadway configurations can be meticulously built to highlight these trees as focal points, so augmenting the aesthetic and ecological value of urban environments. Furthermore, ancient trees can serve as nodes within extensive networks of green spaces, linking various segments of the urban ecology. Planners are progressively creating green corridors that connect these trees to enhance biodiversity and establish pathways for wildlife. Urban developments may integrate view corridors to emphasize notable ancient trees, maintaining sightlines from multiple perspectives across the city.

Infrastructure adaptation is a crucial factor, as the enormous root systems of ancient trees necessitate meticulous consideration in urban development. Infrastructure planning must accommodate the existence of these roots by altering subterranean utilities, roadway configurations, and building foundations to avert harm. Zones adjacent to old trees can be constructed using permeable materials to facilitate water absorption and root respiration, so safeguarding the vitality of these plants. Moreover, outdoor furnishings like seats and lights are frequently custom-designed to enhance the distinctive forms and requirements of ancient trees. Zoning regulations may enforce setbacks or height limitations around ancient trees during the design and construction of structures to save their crowns and root systems. Innovative architectural designs can include old trees by constructing around them or incorporating them into structures, employing specialized techniques such as air shoveling and directional drilling to mitigate detrimental effects.

Urban regeneration and reconstruction initiatives often prioritize existing ancient trees, integrating them into repurposed spaces and designating regions with notable trees as historic districts. This methodology impacts extensive urban revitalization plans, especially in the redevelopment of abandoned industrial sites where ancient trees can represent renewal and continuity in brownfield initiatives. The incorporation of smart city technologies improves the conservation of old trees through real-time monitoring of their health and structural integrity (Aronson *et al.*, 2017). Digital platforms and augmented reality applications furnish inhabitants and tourists with information regarding these trees, which simultaneously function as stations for gathering environmental data, including air quality and temperature, thereby advancing smart city projects.

Transport planning also takes into account the existence of ancient trees by integrating them into traffic calming strategies such as roundabouts and medians. Bicycle and pedestrian pathways are constructed to traverse places with notable trees, so enriching the experience of active transportation. Parking areas adjacent to old trees may incorporate suspended paving systems to safeguard root zones, so preserving the integrity of these trees from automotive disturbance. Moreover, strategizing for climate change resistance utilizes the expansive canopies of mature trees to alleviate the impacts of urban heat islands and shape the configuration of structures and public areas. The strategic positioning and conservation of these trees are essential to urban stormwater management methods and are prioritized as carbon sequestration zones in climate change action plans.

A comprehensive legislative and regulatory framework is crucial for the preservation of ancient trees, necessitating governments to establish specific restrictions that affect development trends and construction practices. Policies may mandate compensatory planting if development affects historic trees, with the objective of establishing future urban forests. Cities may provide zoning incentives, such as increased density allowances, for developments that effectively incorporate and safeguard historic trees. Public involvement in planning is essential, as community feedback influences the conservation and presentation of old trees in collaborative urban design initiatives. Urban initiatives frequently incorporate educational components concerning old trees, establishing open classrooms and interpretative areas that involve the public. Collaboration with cultural heritage specialists guarantees that trees of notable cultural significance are appropriately recognized and displayed, promoting a collective responsibility for these enduring components of the urban landscape.

Urban planning and design with ancient trees require a delicate balance between development needs and conservation imperatives. This requires creativity, interdisciplinary collaboration and a long-term vision to create an urban environment that honours these natural monuments while meeting the changing needs of urban residents. Integrating ancient trees into urban planning requires collaboration between urban planners, arborists, architects, engineers and community stakeholders (Beatley, 2011). Urban designers often need to create customised solutions to meet the unique needs and characteristics of ancient trees. Planning with ancient trees requires a long-term vision, given the longevity of these trees and their potential impact on future urban development. Modern urban planning is increasingly incorporating smart city technologies to monitor and display ancient trees. The presence of ancient trees can shape urban policies and regulations, affecting everything from zoning laws to construction methods.

The successful integration of ancient trees into urban design often requires significant community involvement and participatory planning processes. Ancient trees are significant in urban

climate resilience strategies, influencing how planners approach issues such as urban heat islands and stormwater management. Urban planning should address the cultural and historical significance of ancient trees, especially in areas where these trees are of particular importance to local communities. The presence of ancient trees often stimulates innovation in infrastructure design, from permeable paving systems to adaptive street furniture. Urban planners must constantly balance the needs of development with the need to preserve these natural heritage assets. As the cultural identity of a city, ancient trees can become symbols of neighbourhoods or entire cities, contributing to local identity. They provide a tangible link to the city's past, offering a sense of continuity in a rapidly changing urban environment. Many ancient trees are associated with local legends, folklore or historical events, enriching the cultural narrative of the place.

Old trees are central in shaping and maintaining cultural identity in both urban and rural settings. Their influence extends to various aspects of cultural expression and community identity. Ancient trees link the past with the present, having survived generations of human history, they provide a sense of continuity in a rapidly changing urban environment. Many ancient trees play a central role in local stories and legends passed down from generation to generation, acting as physical anchors for oral histories, and keeping cultural narratives alive. Trees often mark the sites of historical events, acting as natural monuments, commemorating everything from battles to peace treaties, and embedding local history in the landscape. In many cultures, groves of ancient trees are considered sacred places. These areas are often required in religious ceremonies and spiritual practices. Some ancient trees may be revered as incarnations of deities or spirits and become places of pilgrimage or regular worship. Furthermore, different types of trees have different symbolic meanings in cultures, influencing local beliefs and practices.

Ancient trees often serve as natural community gathering points. They are becoming places for social events, informal meetings and community rituals. Distinctive ancient trees act as landmarks, defining areas and aiding in navigation, they contribute to a sense of place and local identity, and the presence of notable ancient trees is a source of community pride and distinction, as they often feature in local branding and tourism promotion. Ancient trees often appear in local literature and poetry, inspiring writers of different generations. They often symbolise endurance, wisdom or the passage of time in literary works. Painters, photographers and sculptors draw inspiration from ancient trees and they become iconic objects in the local art scene. Some ancient trees inspire musical compositions or serve as unique performance venues, as well as appear in folk songs or local musical traditions. Old trees are often sources of traditional medicine, preserving ethnobotanical knowledge. The practices associated with these trees help maintain cultural continuity. Some ancient trees are used as material for traditional crafts, supporting the local craft identity. The skills associated with the use of these materials are often part of the intangible cultural heritage. Ancient fruit or nut trees preserve traditional varieties and cultivation methods, keeping a primary role in maintaining local food cultures and identities.

Trees that have survived natural disasters or human conflict often become significant symbols of societal resilience. Their stories of survival parallel and inspire human stories of resilience. Ancient trees that adapt to the changing urban environment symbolise the need for environmental stewardship, becoming centres of local environmental movements and identities. Many families have traditions associated with certain ancient trees that are passed down from generation to generation. Trees can mark important family events, becoming part of the family identity. In

addition, ancient trees serve as living classrooms where older generations share their knowledge with younger ones, and this transfer of experience helps to maintain cultural continuity and identity. The presence of ancient trees contributes to the unique character of cultural landscapes, as they distinguish one area from another, strengthening local identity. Ancient trees often become part of cultural heritage tourism routes, demonstrating local culture to visitors. Such tourism strengthens local cultural identity through interaction with outsiders.

Trees sometimes influence local names, incorporating them into linguistic identity. These names preserve historical and cultural information about the landscape. Local dialects have special terms for ancient trees or practices related to them. This specialised vocabulary becomes part of the local linguistic identity. Sometimes ancient trees become the focus of cultural or territorial conflicts. Resolving these conflicts can lead to new shared identities and understandings. In some cases, ancient trees serve as symbols of peace and reconciliation between different cultural groups, and they become powerful symbols of common heritage and identity. Longevity and presence deeply tie ancient trees into the cultural fabric of communities. They serve not only as biological objects but also as repositories of history, catalysts for social interaction and symbols of common identity (Mabey, 2007). Their role in shaping and maintaining cultural identity underlines the deep connection between natural heritage and human culture.

Ancient trees influence cultural identity through various channels - historical, spiritual, artistic and social. They provide a sense of continuity, connecting past, present and future generations and carry powerful symbolic meanings that resonate deeply with local cultures. At the same time, they serve as centres for community meetings and the exchange of experiences, fostering social connections. Ancient trees inspire creativity and are represented in various forms of cultural expression, from literature to the visual arts, and preserve traditional practices and knowledge, contributing to the maintenance of cultural heritage. Such trees often become distinctive markers of local identity, distinguishing one community from another. They symbolise the connection between human communities and the natural environment, often inspiring environmental stewardship. But in some cases, ancient trees become centres of cultural conflict, although they can also serve as symbols of reconciliation. Unlike static monuments, ancient trees are living, changing creatures that are actively involved in the ongoing formation of cultural identity. Ancient trees often serve as outdoor classrooms, offering unique opportunities to engage people of all ages in learning about ecology, history and conservation. They provide valuable data for the study of urban ecology, climate research and forestry sciences, and the presence of ancient trees raises public awareness of the importance of urban forests and long-term environmental management.

Ancient trees serve as essential living laboratories, providing opportunities to study complex ecosystems in their native habitats. Students can study the relationships between trees and various species of flora and fauna, gaining insight into biodiversity and ecosystem dynamics. By analyzing the annual rings of trees, teachers can elucidate historical climate patterns and current climate changes, emphasizing the longevity of these trees and their ability to tolerate long-term environmental changes. These trees often serve as habitat for multiple species, making them an exceptional topic for biodiversity research. In addition, students can explore concepts such as keystone species and habitat dependence, allowing them to better understand ecological interactions. In addition to their ecological importance, ancient trees are of great importance for historical and cultural education. They serve as an organic timeline that contextualizes historical events,

providing a concrete link to the past that can be used to study both local and global history. Many trees have cultural or religious significance, facilitating discussions about the merging of nature and culture. They serve as conduits for the transmission of traditional ecological knowledge and practices, allowing students to recognize the deep relationships between communities and their natural surroundings.

Preserving and caring for old trees poses special challenges that exemplify real-world issues in reasoning about environmental protection. Students can explore the subtleties of combining urban expansion with conservation initiatives. Mature trees often serve as an important element of citizen science initiatives, engaging the community in data collection and observation. Such initiatives teach scientific methodologies while emphasizing the importance of ongoing environmental monitoring, instilling a sense of duty and responsibility in students. Ancient trees provide interdisciplinary learning by creating art projects that combine environmental education with creative expression. This method engages children who do not have a natural aptitude for science, allowing them to explore environmental issues through a variety of artistic methods. In addition, models of the development and structure of ancient trees can be used to teach mathematical principles including geometry and exponential growth. Many historic trees are linked to fairy tales and literature, providing an opportunity to integrate environmental and literary lessons and thereby enhance students' integrated learning experiences.

The sensory and experiential learning provided by ancient trees is a notable addition to environmental education. The areas surrounding these trees can function as natural outdoor classrooms, providing immersive learning experiences that promote hands-on, experiential techniques. Students are exposed to a variety of sensory experiences with ancient trees, including bark texture and wildlife sounds, which enrich multimodal learning and nurture a deep relationship with nature. The use of modern technology enhances the educational value of old-growth trees. Virtual tours can offer accessible learning opportunities for trees that are far away or sensitive to foot traffic. Augmented reality applications can overlay information about tree species, thereby enriching experiential learning in the field. In addition, creating and maintaining online databases of ancient trees instills important data management and digital literacy skills in students, preparing them for the technological demands of modern ecological research.

Engaging with the local community is a critical element of how ancient trees contribute to environmental education. The trees enable intergenerational educational initiatives where older members of the community impart their wisdom to younger generations. Volunteer initiatives to preserve historic trees offer hands-on arboriculture and conservation training, fostering collaboration and community involvement in conservation efforts. In urban ecology, historic trees exemplify green infrastructure and ecosystem services, emphasizing the enduring benefits of urban forests. They illustrate the balance between urban expansion and environmental conservation, acting as a tangible reminder of the need to incorporate nature into urban planning. These urban environments allow students to understand the importance of trees in improving the urban environment and the vital functions they fulfill.

Ancient trees significantly contribute to the cultivation of scientific research skills in students. They provide possibilities to apply outdoor research methodologies, including arboreal measuring, soil collection, and wildlife observation. The extensive datasets linked to these trees can facilitate the instruction of data analysis and interpretation abilities, providing students with the essential

tools for performing significant scientific research. The existence of ancient trees enhances the field of environmental ethics. These trees stimulate discourse regarding the inherent and instrumental value of nature, enabling students to examine concepts of environmental ethics and intergenerational responsibility. Situations concerning the conservation or eradication of old trees can serve as case studies for environmental decision-making activities, assisting students in addressing intricate ethical challenges associated with conservation.

Educational initiatives emphasise the health and wellness advantages of engaging with nature, including ancient trees as central themes. These trees exemplify the principle of “One Health,” highlighting the interrelation of environmental, animal, and human health. By interacting with ancient trees, students may recognise the psychological advantages of immersing themselves in natural environments and comprehend the wider ramifications of ecological health on general well-being. Ultimately, engagement with ancient trees exposes students to diverse environmental careers, including arboriculture and environmental policy. The complex aspects of ancient tree protection highlight the necessity for interdisciplinary strategies in environmental disciplines, motivating students to investigate various career options and comprehend the joint endeavours essential for tackling environmental issues.

Ancient trees, with their complex ecosystems, rich history and conservation issues, provide invaluable resources for environmental education. They offer tangible, engaging ways for people to connect with nature, science and conservation, fostering a deeper understanding and commitment to the natural world. In the example of old trees, students have the opportunity to study various disciplines, from science and history to art and literature (Clay and Daniel, 2000). These trees provide concrete, observable examples of abstract environmental concepts, making learning more accessible and memorable. Their longevity allows for unique lessons on the time scales of nature and environmental change, and educational programmes focusing on ancient trees can promote community engagement and intergenerational learning. Ancient trees promote experiential learning by allowing students to interact directly with nature. Modern educational technologies can improve and extend the learning experience associated with ancient trees. Old trees stimulate important discussions about environmental values and decision-making, and learning about them and preserving them sparks interest in environmental professions.

Complex ecosystems associated with ancient trees demonstrate the interconnectedness of natural systems. Such trees are often locally significant, allowing for local education that resonates with the immediate environment of the students. This approach to environmental education, which uses ancient trees as focal points, promotes a deeper connection with nature, increases scientific literacy and contributes to environmental protection. It demonstrates how natural heritage can be a powerful tool for education, bridging the gap between scientific knowledge and personal experience. Ancient trees often become meeting places, promoting community interaction and social cohesion. Efforts to preserve these trees provide opportunities for community participation and volunteering. Threats to ancient trees often trigger grassroots movements, encouraging civic participation in urban planning processes.

Engagement with society is prominent in the conservation and appreciation of ancient trees. It fosters a sense of ownership, promotes conservation efforts and strengthens ties between people. Awareness-raising and education programmes can be used to improve communication. These can be guided tours dedicated to the ancient trees in the city or independent walking routes with

information boards or mobile apps. In addition to excursions, classes led by experts on tree biology, tree care and local history or practical workshops to teach basic arboriculture skills will be useful. Integrating education about ancient trees into local school curricula has had a positive impact on children's knowledge, especially with the addition of field trips to significant trees for hands-on learning.

There are also tree monitoring programmes, which are community-led programmes to monitor the health and growth of ancient trees. People can do this individually or in groups, using apps and online platforms to collect and share data. To unite residents, it is involve them in cataloguing the flora and fauna associated with ancient trees and organise annual bioblitz events dedicated to significant trees. In addition to these activities, there are community projects to uncover and document the history of local ancient trees, which include collecting oral histories related to significant trees. Conserving and sustaining mature urban trees while promoting community involvement necessitates a comprehensive strategy that unites city inhabitants through many efforts. Scheduled community clean-up initiatives surrounding old trees, along with fundamental maintenance tasks conducted by volunteers under expert supervision, provide residents with opportunity to engage in tree stewardship. Initiatives such as "Adopt a Tree" enable individuals or collectives to assume stewardship of certain old trees, guaranteeing their continued maintenance and cultivating a sense of personal accountability. Moreover, community fundraising activities and crowdfunding initiatives furnish critical financial assistance for tree conservation projects, facilitating the execution of crucial preservation strategies.

Cultural and artistic endeavours significantly enhance the community's bond with historic trees. Local art shows showcasing works inspired by these trees or photography contests focused on the city's trees promote creative expression and enhance awareness of their significance. Community forums in which inhabitants recount narratives and folklore regarding local trees, coupled with writing workshops inspired by ancient trees, facilitate the preservation and transmission of traditional knowledge. Annual or seasonal celebrations honouring notable trees in the city, incorporated into existing cultural activities, commemorate natural heritage and foster community spirit. Social media activities, including hashtag campaigns and online contests, enhance local engagement by prompting them to post photographs and narratives, thus augmenting visibility and admiration for ancient trees.

Technological improvements are utilised to aid in the maintenance of mature urban trees while enhancing their accessibility for the population. Virtual tours and augmented reality experiences facilitate educational access for individuals unable to see the trees physically, presenting historical and biological facts in an interactive manner. Online forums and social media groups focused on local old trees promote information sharing and event coordination, building a collaborative digital community. Citizen-driven initiatives that produce intricate 3D representations of ancient trees and employ drones to survey inaccessible areas of these trees exemplify novel methodologies in tree conservation. Public activities aimed at creating technological solutions for tree monitoring or education, like competitions for developing tree-related mobile applications, promote community engagement in enhancing tree preservation initiatives.

Initiatives targeting intergenerational engagement and youth involvement are crucial for the enduring conservation of ancient trees. Facilitating interactions between older community members and younger ones enables the exchange of knowledge regarding local trees and fosters intergenerational tree planting initiatives, thereby cultivating future ancient trees. Programs for

youth centred on the stewardship of ancient trees and the establishment of youth advisory councils enable young individuals to engage actively in public decision-making about tree protection. Inter-school competitions focused on the understanding and conservation of old trees, coupled with sustained school initiatives aimed at documenting and preserving local historic trees, cultivate a sense of responsibility and environmental stewardship in pupils.

Partnerships with local enterprises and healthcare practitioners augment community initiatives aimed at conserving historic trees. Collaborations with enterprises can result in the development of tree-related products or services, hence enhancing support for conservation efforts. Partnering with healthcare professionals to create natural therapy programs, including support group meetings amidst ancient trees, emphasises the psychological advantages of engaging with nature and advocates for the “One Health” principle, which illustrates the interdependence of environmental, animal, and human health. Furthermore, the creation of citizen advisory groups to deliberate on urban forestry, along with the organisation of frequent meetings at City Hall concerning tree-related matters, guarantees that community perspectives are acknowledged in the stewardship and conservation of historic trees.

Acknowledgement and rewards for community members who participate in tree protection are essential for maintaining involvement and motivation. Permitting community members to dedicate trees to cherished individuals and establish plaques or installations beside notable trees personalises their association with these natural symbols. Annual awards recognise and honour individuals who engage in tree conservation and certification initiatives for businesses or residences that safeguard ancient trees. These recognition initiatives not only acknowledge accomplishments but also motivate others to participate, cultivating a culture of conservation and reciprocal support within the community.

The interaction of people with ancient trees creates a link between environmental protection, cultural preservation and social cohesion (Neckar, 1996). By involving residents in various aspects of tree care and assessment, these initiatives foster a deep sense of connection to the natural heritage and promote long-term management of urban forests. Effective public engagement includes a wide range of activities, from education and citizen science to cultural events and policy advocacy. Programmes target different age groups, interests and abilities, ensuring broad community participation. These initiatives foster a sense of ownership and responsibility for ancient trees among community members. Many activities promote intergenerational knowledge transfer, preserving local history and traditions. Engagement programmes often combine science, history, art and technology, appealing to a variety of interests and through this, ancient trees are increasingly recognised for their potential to contribute to community health and well-being.

Some initiatives create economic benefits through ecotourism or local business partnerships. For this, modern technology is used to enhance engagement and promote efforts to preserve and promote ancient urban trees. The involvement of residents often leads to greater public participation in urban forestry policies and decisions. These programmes aim to build a strong commitment to tree conservation in the community, and many activities highlight and reinforce the cultural significance of ancient trees. This approach to engaging people demonstrates how ancient trees can serve as focal points for creating stronger, more environmentally conscious communities. It demonstrates the potential of natural heritage to be a catalyst for social cohesion, environmental stewardship and cultural heritage preservation.

Preserving ancient urban trees has significant economic implications, contributing to the local economy in various impactful ways. One of the primary avenues through which these trees generate economic benefits is tourism. Ancient trees often become renowned tourist attractions, drawing visitors from afar who are interested in ecotourism. This influx of tourists leads to the development of specialized tours and events centered around these majestic trees, further enhancing their appeal and economic value. Additionally, ancient trees boost local tourism by increasing pedestrian traffic in their vicinity, which benefits nearby businesses such as cafes, shops, and hotels. Integrating these trees into broader tourism strategies ensures that their presence is maximized for economic gain. Furthermore, parks and green spaces that feature ancient trees attract more visitors, providing opportunities for paid recreational activities such as guided walks, photography workshops, and nature-based events, thereby adding another layer of economic benefit to the community.

The presence of ancient trees also positively impacts the cost of real estate in surrounding areas. Properties located near these venerable trees often command higher prices, as the aesthetic and environmental benefits they provide are highly valued by potential buyers. This phenomenon, known as property premiums, means that areas with significant trees tend to exhibit higher property values compared to those without such natural landmarks. Commercial properties near ancient trees benefit as well, experiencing increased pedestrian traffic and enhanced visual appeal, which can lead to higher sales and customer engagement. Moreover, ancient trees influence urban planning and development patterns, often leading to increased land values in certain areas. Planners and developers recognize the desirability of these green spaces, which can drive investment and development in neighborhoods that boast these natural assets, further elevating the economic landscape of the city.

City branding is another crucial aspect where ancient urban trees play a vital role in stimulating economic activity. Iconic ancient trees are frequently incorporated into the branding and promotional efforts of cities, serving as symbols of natural heritage and cultural identity. By featuring these trees in marketing materials, cities can attract tourists and investors, indirectly stimulating economic growth. Local businesses also leverage the image and themes of well-known ancient trees in their product marketing, creating a unique and appealing brand that resonates with both residents and visitors. Additionally, companies that associate themselves with the preservation of ancient trees can enhance their corporate image, portraying themselves as environmentally responsible and community-oriented. This positive brand image not only attracts customers who value sustainability but also fosters goodwill and loyalty among consumers, further driving economic benefits for the city as a whole.

Ancient trees have a significant and complex economic impact on the communities around them, ranging from direct income generation to more subtle effects on the local economy (Costanza *et al.*, 1998). For example, it affects the development of ecosystem services, as large ancient trees reduce the need for artificial stormwater infrastructure, saving costs. There are also economic benefits from reduced healthcare costs due to improved air quality and the potential for carbon credits or offsets from large ancient trees that sequester carbon. In addition, trees providing shade and windbreaks reduce energy costs for nearby buildings. Older urban trees require special care and therefore generate employment and skills development by creating specialised jobs for the care and maintenance of ancient trees. This provides new employment opportunities in research, education and outreach related to ancient trees. There are also jobs created in the tourism and hospitality sectors, serving visitors interested in trees.

Ancient trees assist in the development of local businesses as there is a need for specialised products inspired by or derived from ancient trees (e.g. seeds, cuttings, crafts). New opportunities for cafes, souvenir shops or other specialised tree-related businesses are opening up, as well as economic opportunities for local artists and photographers focusing on ancient trees. Several factors will influence the healthcare economy, some of which are presented below:

- Mental health benefits. Potential reduction in mental health costs due to the stress-reducing effect of green spaces with ancient trees.
- Improving physical health. Reduced healthcare costs associated with respiratory diseases and obesity due to improved air quality and increased outdoor activity.

Undoubtedly, ancient urban trees are a cultural and historical asset to a city, nation or country, for example, ancient trees of cultural significance attract tourists interested in cultural heritage, and there is growing economic activity generated by festivals or events dedicated to significant trees. Old trees are one of the reasons for the development of education and new technologies, influencing the economy through grants and funding raised for research on ancient trees and their ecosystems, as well as generating income from educational programmes, seminars and courses related to ancient trees. In addition, such trees inspire the development of new technologies for plant care and monitoring and reap economic benefits from the integration of ancient trees into green infrastructure planning.

For several reasons, ancient trees can reduce or avoid the impact and cost of natural disasters such as flooding or soil erosion and reduce cooling costs and heat-related health problems due to the cooling effect of large trees (Sun *et al.*, 2012). Ancient trees are a source of non-timber forest products, with the potential for sustainable harvesting of seeds, fruits or other products, as well as the economic value of traditional medicines derived from them.

Several other factors can be considered as a source of income for the city, including:

- Film and media industry. Revenue from film and television production using ancient trees as filming locations.
- Media coverage. Economic benefits from media coverage of significant trees, raising the prestige of the region.
- Sponsorship of nature protection. Financial contributions from companies to preserve trees as part of corporate social responsibility initiatives.
- Adoption programmes. Revenue from corporate or individual tree adoption programmes.
- Design integration. Potential increase in property value with the successful integration of ancient trees into projects.
- Zoning and development rights. Economic impacts of zoning decisions and development rights affected by the presence of ancient trees.

The economic impacts of ancient trees are diverse and far-reaching, often going beyond easily quantifiable indicators. While some benefits are prominent and measurable, others are indirect and contribute to the overall economic well-being and attractiveness of a community. Recognising and harnessing these economic aspects can help justify and fund conservation efforts, creating a positive feedback loop between economic development and environmental conservation. The economic value of ancient trees goes far beyond the traditional value of timber, encompassing tourism, real estate values, ecosystem services and much more. While some of the economic impacts (e.g. tourism revenues) are direct, many others (e.g. improved health) are indirect but significant.

Ancient trees can shape long-term economic patterns of urban development and property values, and their presence can create specialised jobs in sectors ranging from forestry to tourism.

Ancient trees stimulate innovation in green technologies and sustainable urban planning, and important trees contribute to city branding and marketing efforts, indirectly stimulating economic activity. The health benefits provided by ancient trees can lead to significant savings in healthcare costs. In addition, ancient trees often play a role in cultural tourism and heritage-based economic activities. The economic value of the ecosystem services provided by ancient trees is substantial, although often underestimated in traditional economic assessments. Ancient trees provide opportunities for corporate engagement through corporate social responsibility initiatives and sponsorship. The presence of ancient trees can lead to significant cost reductions in areas such as storm-water management and disaster mitigation. Ancient trees can generate income in a variety of ways, from tourism to research grants to sustainable product development.

The economic view of ancient trees emphasises their value as natural assets that contribute significantly to local and regional economies. It demonstrates the importance of preserving these trees not only for environmental and cultural reasons but also for their tangible economic benefits. This understanding can help inform policy decisions, urban planning strategies and conservation efforts, contributing to a more holistic approach to urban forestry and development. As part of the flora, ancient urban trees have a positive impact on the physical and mental health of people. Access to ancient trees and green spaces around them can improve mental health and reduce stress in urban populations. They help improve air quality and provide places for physical activity. In addition, ancient trees support the principles of biophilic design in urban areas, fulfilling the human need to connect with nature.

Ancient trees significantly influence human well-being, providing multiple advantages that improve various facets of life. A major contribution is in the field of mental health care. Exposure to old trees and natural spaces has demonstrated a reduction in cortisol levels and perceived stress, fostering a sense of tranquility and perspective for individuals. Engaging with these magnificent trees can enhance mood and mitigate depressive symptoms, while the impressive presence of ancient trees cultivates pleasant feelings and a profound connection to nature. This natural serenity offers an essential sanctuary in our progressively urbanised and frenetic lifestyles, enhancing general mental health.

The cognitive advantages of being in proximity to ancient trees are similarly significant. Natural surroundings, especially those characterised by old-growth trees, have been associated with enhanced concentration and cognitive performance. Exposure to natural environments helps alleviate ADHD symptoms in youngsters, hence improving their focus and learning capabilities (Mitchell and Popham, 2008). Furthermore, ancient trees frequently operate as focal places for mindfulness and meditation, prompting folks to contemplate and cultivate a connection with nature. This mindfulness enhances mental clarity and resilience, promoting improved cognitive health and emotional stability. The presence of ancient trees also enhances physical health. Mature, ancient trees significantly enhance air quality by filtering pollutants, hence decreasing respiratory ailments and allergies in metropolitan populations. Furthermore, the shade and cooling offered by these trees alleviate the urban heat island effect, diminishing the prevalence of heat-related ailments and fostering more pleasant living conditions. The existence of old trees in parks and green spaces fosters outdoor activities, enhancing cardiovascular health and assisting in weight management

through elevated physical exertion. These advantages jointly foster a healthier populace and a more sustainable urban ecosystem.

Ancient trees positively impact social well-being. These trees frequently serve as focal gathering areas throughout communities, promoting social interaction and communal cohesion. Engagements with these trees, such as community events, picnics, and recreational pursuits, foster social cohesion and mitigate feelings of loneliness. Shared community experiences around ancient trees reinforce social bonds and foster a sense of belonging among people. Furthermore, the restorative settings created by these trees replenish diminished cognitive resources, so enhancing work performance and alleviating mental weariness, which subsequently improves social connections and general community well-being. The presence of ancient trees considerably supports children's health and development. Natural play areas including old trees foster the enhancement of motor skills and imaginative play, offering children chances for physical difficulties and creative discovery. Frequent exposure to natural spaces featuring ancient trees correlates with improved emotional control, facilitating children's development of empathy and environmental stewardship. These activities foster better physical and emotional development while cultivating a lasting appreciation for nature and environmental responsibility.

Engaging with old trees provides profound experiences that enhance sensory well-being, especially aiding those with sensory processing disorders. The aesthetic appeal, tactile surfaces, and organic aromas of ancient trees stimulate several senses, offering therapeutic sensory engagement. Moreover, old trees are crucial in environmental health education, fostering awareness and comprehension of ecosystem vitality. This education fosters mindful health practices and motivates individuals to choose healthier lifestyle choices, based on a profound understanding of the interrelation between human health and the environment. The therapeutic applications of old trees are gaining recognition in numerous rehabilitation programs. Horticultural treatment programs involve engagement with old trees to facilitate the physical and psychological rehabilitation of individuals with diverse health issues. These therapeutic settings utilise the soothing and rejuvenating qualities of ancient trees to facilitate healing and recuperation. Moreover, vistas of old trees from work environments have been associated with less stress and enhanced job satisfaction, offering restorative intermissions that elevate general workplace well-being. Exposure to natural settings featuring ancient trees promotes creativity and problem-solving skills, hence increasing productivity and enjoyment in work contexts.

Ancient trees enhance sleep quality and aid in the management of chronic disorders. The availability of natural light and the presence of ancient trees facilitate the regulation of sleep and wake cycles, enhancing sleep quality and general health. Enhanced sleep augments cognitive function and emotional stability, hence promoting general well-being. Furthermore, the air-purifying capabilities of substantial trees enhance cardiovascular health by diminishing toxins and fostering healthier air in metropolitan environments. Promoting outdoor activities amidst trees enhances cardiovascular health and aids in the management of chronic diseases, underscoring the essential contribution of ancient trees to a better and more balanced lifestyle. The health and well-being benefits of ancient trees are diverse and significant. From improving air quality and encouraging physical activity to providing places for mental recuperation and social interaction, these trees play a crucial role in promoting public health. Recognising and harnessing these benefits can help urban planning, health strategies and conservation efforts, ultimately contributing to healthier and more sustainable societies.

Ancient trees contribute to physical, mental and social aspects of health, demonstrating their comprehensive impact on human well-being, with one of the most significant benefits being stress reduction, which has far-reaching implications for a variety of health outcomes. The ecological benefits of ancient trees, such as air purification and temperature regulation, directly translate into health benefits for the urban population. The presence of ancient trees in a natural play environment can significantly improve the physical and emotional development of children. Today, there is a growing recognition of the therapeutic use of ancient trees in various medical interventions. The positive effects of ancient trees also extend to the workplace, potentially increasing job satisfaction and productivity. The multisensory experience provided by ancient trees also contributes to overall sensory health and well-being. This view of ancient trees as contributors to health and well-being emphasises their value beyond mere aesthetics or environmental protection. It suggests that preserving and integrating these trees into the urban environment can be a cost-effective public health strategy. The aforementioned information can be used in informed political decision-making, urban design and approaches to healthcare, promoting an integrated view of the environment and human health.

Ancient trees are substantial in environmental sustainability, contributing to the ability of ecosystems and urban environments to withstand and recover from disturbances. Their impact on environmental sustainability is complex and significant for several reasons, for instance, they are significant carbon sinks, storing large amounts of carbon in their biomass and surrounding soil, and continue to sequester carbon into old age, often at a faster rate than young trees. The large crowns of ancient trees create a microclimate that mitigates extreme temperatures, a buffering effect that helps to offset the effects of heat waves and cold snaps. In urban areas, they significantly reduce the effect of the urban heat island by providing shade and evapotranspiration, which increases the resilience of cities to rising temperatures. The longevity of ancient trees provides ecological continuity, which is crucial for species with low dispersal capacity, they act as reservoirs of biodiversity, helping to restore the ecosystem after disturbances. Moreover, ancient trees often represent important genetic resources with potentially resilient traits, their genetic diversity may be crucial for adaptation to changing environmental conditions.

Ancient large trees have a direct impact on soil health and resilience, they improve soil structure and stability, promote soil formation and nutrient cycling over long periods, and prevent soil erosion, especially in riparian zones and on slopes, their root systems help stabilise the soil during extreme weather events, the soil around ancient trees often has a high organic matter content and improved structure, which improves water infiltration, helping to recharge groundwater and mitigate flooding. Ancient trees intercept and absorb a large amount of precipitation, reducing stormwater runoff, and their extensive root systems increase soil water storage. In addition, they filter pollutants from the water as it moves through the soil, improving overall water quality, and ancient riparian trees help stabilise stream banks and regulate water temperature. Many ancient trees act as keystone species, disproportionately affecting ecosystem function, and their removal can lead to cascading effects throughout the ecosystem as they affect pollination support, nutrient cycling and wildlife habitat.

Large ancient trees are particularly effective in trapping air pollutants, improving urban air quality and can significantly reduce particulate matter, ozone and other pollutants. The complex structure of ancient trees and their surroundings helps to reduce urban noise, contributing to a more sustainable and liveable urban environment. The complex structure of ancient trees creates

micro-refugia, potentially protecting species from the effects of climate change, and these micro-habitats are crucial for species conservation in a changing environment. By providing a stable environment over long periods, ancient trees can support evolutionary adaptation processes in associated species. Ancient trees are essential components of sustainable ecosystems and urban environments. Their longevity, size and complex structure contribute significantly to ecological stability and adaptability. Facing increasing environmental challenges, especially climate change, the role of ancient trees in enhancing ecological resilience is becoming increasingly important. Preserving these trees and understanding their functions can both be used in overall ecosystem resilience strategy development and creation of more sustainable urban environments.

Ancient trees contribute to environmental sustainability through a variety of mechanisms, from climate regulation to biodiversity support, and play an important role in both mitigating and adapting to climate change. As keystone species, ancient trees are crucial for maintaining ecosystem stability and function. In urban areas, they make a significant contribution to environmental quality and resilience to various stressors. The diverse habitats provided by ancient trees are crucial for maintaining biodiversity, especially in fragmented landscapes, they play a vital role in regulating the water cycle, contributing to both water quality and quantity management, and the impact of ancient trees on soil structure and stability is a key factor in environmental sustainability. This view of ancient trees as pillars of environmental sustainability emphasises their importance beyond their aesthetic or cultural value. It suggests that the conservation and management of these trees should be a key component of strategies to enhance environmental sustainability, especially in the face of climate change and increasing urbanisation. This understanding can guide conservation policies, urban planning strategies and ecosystem management approaches.

The presence of ancient trees often leads to the development of special laws and policies to protect trees, for example, many ancient trees are included in heritage lists, combining the preservation of natural and cultural heritage, and therefore they often form the cornerstone of broader urban forest management strategies. The protection and management of ancient trees involves a complex network of legal and policy frameworks (Low and Altman, 1992). These can vary considerably from jurisdiction to jurisdiction but generally aim to conserve these valuable natural and cultural assets. Legal regulations are created by local governments to protect certain trees or groups of trees. Certain restrictions prohibit cutting, topping, pruning, trimming, or intentionally damaging protected trees without a permit, and they apply to both public and private lands. Violations of the rules can result in significant fines or criminal charges. Many countries maintain registers of trees of special cultural value, and inclusion in such a register provides legal protection and access to conservation resources. Criteria for listing include age, size, historical significance environmental value, and sometimes cultural or spiritual significance to local communities.

Many jurisdictions require ancient trees to be accounted for in planning new developments in the city and may require tree surveys and protection plans as part of the planning process. Legislative zones exist around trees where development is restricted, based on the size and species of the tree, and some regulations require developers to compensate for the loss of ancient trees, often at a high ratio. Moreover, jurisdictions require consideration of impacts on ancient trees in environmental assessments, which affects project approval and development. The policy requires compliance with the mitigation hierarchy: avoid, minimise, restore, compensate, as ancient trees are often a priority for avoidance due to their irreplaceability. Many cities have policies in place to

maintain or increase the overall tree canopy, with such trees receiving special attention due to their disproportionate contribution. Special regulations for the protection of street trees, focusing on ancient species, include maintenance requirements and restrictions on removal.

There are special protection zones with markings that protect areas of significant ecological value, including ancient trees, restricting activities that may harm the protected trees. The special protection of ancient forests, which often contain numerous ancient trees, usually involves strict controls on development and land use change. Laws protecting certain tree species were created, these provide indirect protection for ancient specimens and include restrictions on harvesting, transport and trade. In addition to the laws, there are separate provisions for invasive species, affecting the management practices of ancient trees of non-native species. Laws protecting cultural landscapes include provisions for ancient trees of cultural significance and imply restrictions on landscape alteration, including tree felling. Special protections for trees of cultural significance to indigenous peoples include access rights and management input from indigenous communities. Policies that balance the preservation of ancient trees with public safety concerns include risk assessment and management protocols. The legal framework that addresses liability issues related to damage caused by protected trees also affects management decisions and insurance requirements.

Government or non-government organisations grant programmes for the preservation and care of ancient trees to cover the costs of maintenance, surveys or educational programmes. Some jurisdictions offer tax breaks or other financial incentives for preserving ancient trees on private property. Local laws governing the protection, removal and replacement of trees within the city include special provisions for historic or significant trees. Local enforcement mechanisms impose fines and penalties for violations of tree protection laws. The legal and policy frameworks relating to ancient trees are diverse and continue to be modernised. They reflect the growing recognition of the ecological, cultural and economic value of these natural assets. Effective protection and management of ancient trees often requires a combination of strong legal protection, supportive policies and active public participation. As environmental issues continue to evolve, this framework may adapt, potentially offering even stronger protection for the oldest and most valuable trees. The protection of ancient trees includes a variety of legal and policy instruments, from specific tree preservation orders to broader environmental regulations. The exact nature of the protection can vary considerably from country to country, state to state, and even municipality to municipality. Many frameworks integrate tree protection into broader urban planning and development processes, and this protection often takes into account both the cultural heritage and ecological value of ancient trees.

Ancient trees have consistently served as a significant source of inspiration for artists, writers, and cultural practitioners globally. In visual arts, these magnificent trees frequently function as focal points or emblems in landscape paintings, embodying their grandeur and timelessness. Meticulous botanical images emphasise the distinctive species of ancient trees, whilst abstract representations leverage their forms and textures to produce captivating artworks. Artistic photography accentuates the character and grandeur of these trees, while documentary photography safeguards their historical and scientific importance. Frame-by-frame initiatives that chronicle seasonal transformations or prolonged development provide a dynamic viewpoint on the existence of old trees. Moreover, sculptures inspired by or including components of these trees, alongside environmental art works utilising living ancient trees as essential elements, exemplify the har-

monious fusion of nature and artistry. Wood carvings, tapestries, ceramics, and expansive murals collectively represent a diverse array of artistic forms that pay attention to the lasting significance of ancient trees.

In literature and the performing arts, ancient trees are crucial in constructing narratives and motivating creative endeavours. Poems, such as *hokku* and other concise forms, frequently employ ancient trees as metaphors for resilience and endurance, whilst novels may depict them as pivotal characters or symbolic components within their narratives. Children's literature often features ancient trees as enchanting or ornamental motifs, igniting imagination and evoking a sense of awe in youthful readers. Traditional narratives, myths, and urban tales concerning sacred or magical trees enhance cultural legacy and offer abundant material for authors and storytellers. Theatrical productions and ecological performances centred on or inspired by ancient trees vividly animate these natural marvels on stage, while choreography and dance sequences influenced by the forms and growth patterns of trees provide a distinctive mode of artistic expression. Compositions that replicate the sounds and rhythms of old woods, and melodies that celebrate particular tree species, further exemplify the profound relationship between ancient trees and the creative spirit.

Craftsmanship and product design are significantly influenced by the inspiration derived from ancient trees. Handcrafted items fashioned from the timber of ancient fallen trees uphold traditional carpentry techniques and honour the inherent beauty of these materials. Sustainable fashion collections influenced by ancient forest ecosystems integrate natural patterns and eco-friendly techniques, while jewellery made from materials derived from ancient trees imparts a sense of nature's elegance to wearable art. Products featuring designs that replicate the patterns and textures of arboreal materials are prevalent, encompassing both home décor and useful things, thereby connecting nature with quotidian existence. Moreover, natural dyeing techniques utilising components from ancient trees enhance sustainable textile manufacturing, while the manufacture of fabrics and tapestries illustrating old trees highlights their visual allure in a tangible format. Ceramics influenced by tree textures and glazes derived from the ash of specific ancient trees illustrate the incorporation of natural elements into creative handicraft.

Architectural and urban planning initiatives are also enhanced by the inspiration derived from historic trees. Opulent tree houses and eco-resorts constructed around these trees provide distinctive lodgings that highlight a symbiotic relationship with nature. Public parks and observation decks intended to highlight ancient trees foster welcoming settings for communal gatherings and the appreciation of natural beauty. Architectural and product designs that emulate the structures of ancient trees underscore the complex and durable forms of these natural giants, while urban planning efforts that emphasise the conservation of ancient trees guarantee that these significant ecological and cultural landmarks remain essential to urban landscapes. The conservation and reverence of ancient trees in religious contexts, together with rites and ceremonies conducted around notable trees, highlight their spiritual and cultural significance. Meditation practices and forest bathing centred on ancient trees provide environments for contemplation and well-being, fostering a profound connection between individuals and their natural environment.

Educational and community engagement activities underscore the diverse influence of old trees on human existence. Seminars and excursions centred on the artistic and cultural significance of old trees inform persons about their relevance and stimulate creative pursuits. Educational initiatives that integrate the study of ancient trees into art curricula cultivate environmental

stewardship and appreciation in young learners. Culinary traditions that incorporate products from ancient fruit or nut trees, as well as specialised cuisine and beverages inspired by tree species, honour the varied applications and advantages of these natural resources. Community events, including annual festivals celebrating notable trees or seasonal observances of ancient trees, unite locals to honour and appreciate their collective natural heritage. Tattoos and traditional inks sourced from ancient trees enable individuals to embody a fragment of this natural beauty, while performances and sustainable fashion lines inspired by these trees illustrate their enduring impact on modern culture and lifestyle. Ancient trees, with their deep cultural roots and powerful presence, continue to inspire diverse forms of artistic and cultural expression. They serve as bridges between past and present, nature and culture, offering rich material for creative exploration and cultural significance. This enduring influence underlines the importance of preserving these natural monuments not only for environmental reasons but also as vital sources of cultural and artistic inspiration.

Ancient trees inspire creativity in a wide range of artistic mediums, from traditional visual arts to contemporary digital media. They are substantial in spiritual practices, folklore and cultural traditions around the world, and provide a sense of connection to the past, often appearing in works that explore themes of time and heritage. Many artistic expressions related to ancient trees also serve to raise awareness of environmental issues and conservation. The influence of ancient trees crosses the boundaries between art, science and technology, inspiring innovative and interdisciplinary work, these trees often serve as powerful symbols in literature, visual arts and cultural narratives, representing concepts such as wisdom, sustainability and the cycle of life. Artists explore not only the visual aspects of ancient trees, but also their textures, sounds and even smells, creating rich, multisensory works, and artistic representations of ancient trees often serve educational purposes, helping to convey scientific and historical information in engaging ways.

This perspective on the artistic and cultural expression inspired by ancient trees highlights their importance beyond their ecological value. It demonstrates how these natural monuments contribute to our cultural heritage, artistic innovation and collective imagination. This can be useful in the development of conservation measures, urban planning and cultural policies, emphasising the need to preserve ancient trees not only as natural resources but also as irreplaceable sources of cultural and artistic inspiration. Ancient trees are a central correlation point in intergenerational connections, bridging gaps between age groups and strengthening a sense of continuity in society. By their very nature, they span generations and centuries and serve as living links between the past, present and future, providing unique opportunities for meaningful intergenerational interaction. These links not only enrich the lives of individuals but also strengthen the fabric of communities by ensuring that knowledge, values and a sense of shared heritage are passed on across age groups. In an era of rapidly changing and sometimes fragmented communities, ancient trees offer stable focal points for creating and maintaining these important intergenerational connections.

Old urban trees represent tangible links to the past, connecting older generations to share historical context with younger ones and becoming centres of intergenerational transmission of ecological, cultural and practical knowledge (Neckar, 1996). Activities centred around ancient trees create opportunities for interaction and connection between different age groups, and trees often play a central role in cultural practices and traditions, helping to maintain cultural identity across generations. The long-term nature of tree conservation encourages intergenerational cooperation and reasoning. Interactions around ancient trees foster both traditional skill sharing and mutual

learning of new technologies. These trees often serve as community landmarks, evoking a sense of shared identity among age groups and often become important in family traditions and genealogical interests. This perspective on ancient trees as intergenerational mediators highlights their importance not only as ecological entities but also as social catalysts. It demonstrates how these natural monuments can play a critical role in strengthening community ties, preserving cultural heritage, and fostering a sense of continuity in rapidly changing times. This understanding can inform public planning, educational initiatives and conservation efforts, highlighting the social value of preserving and honouring ancient trees.

The role of ancient trees in urban development and cultural heritage is dynamic and evolving. As cities grow and change, these trees become witnesses to history, custodians of ecosystem services and centres of community identity and interaction. Their conservation and integration into urban life represent a bridge between natural and cultural heritage, making a significant contribution to sustainable and liveable cities. This review shows the multifaceted role that ancient trees play in urban environments. They are not just biological entities but are also closely intertwined with the social, cultural and economic fabric of cities. The conservation and management of ancient urban trees requires an integrated approach that addresses their ecological, cultural and social value, as they contribute significantly to the unique character and identity of urban areas, often becoming iconic symbols of their cities.

While ancient trees can pose challenges to urban development, they also create opportunities for innovative design and community engagement, and the presence of ancient trees often stimulates the development of more comprehensive urban forest policies and heritage conservation strategies. The long lifespan of these trees encourages long-term thinking in urban planning, promoting sustainability and intergenerational equity. Ancient trees provide a wide range of benefits, from ecosystem services to social and cultural value, demonstrating the importance of urban conservation, and acting as catalysts for community action and engagement, promoting a sense of shared responsibility for the urban environment. The role of ancient trees in urban development and cultural heritage highlights the need for interdisciplinary approaches in urban planning and management. This demonstrates the potential for synergy between the preservation of natural and cultural heritage and the importance of including living natural monuments in the structure of sustainable cities.

Chapter 2.

Humanistic values of urban ancient trees

Urban ancient trees embody and promote numerous humanitarian values, making a substantial contribution to the well-being, social equality and cultural wealth of urban communities. Ancient trees in public places provide all urban residents with a free and accessible natural experience, they offer an element of equalisation in cities where nature can be enjoyed regardless of socio-economic status. The health benefits of ancient trees (air purification, stress reduction) are available to all nearby residents, they contribute to reducing health inequalities in urban areas by improving the quality of the environment. These trees represent a common historical and cultural legacy that can unite different urban populations (Perini and Sabbion, 2017). The presence of ancient trees in different areas can be an indicator of environmental justice, efforts to preserve these trees often coincide with broader environmental justice initiatives. They become unifying points to protect the interests of the community, giving residents the opportunity to participate in urban planning and environmental decision-making.

The presence of ancient trees in an urban environment provides stress-reducing green areas and offers contemplative spaces that support mental well-being, which is especially important in densely populated areas. Such trees are an integral part of nature therapy programmes, providing healing spaces accessible to urban residents and supporting community mental health initiatives by offering a cost-effective, natural therapeutic environment. The preservation of ancient trees ensures that future generations will be able to enjoy their benefits, they embody the principle of intergenerational responsibility in urban planning and conservation. Many ancient trees are important to various cultural groups, promoting cultural diversity and mutual understanding. They serve as symbols of inclusivity and represent the diverse legacy of the urban population. In some cases, ancient trees are linked to the history of indigenous peoples, supporting recognition and respect for indigenous cultures in urban settings.

Ancient urban trees can contribute to the local economy through tourism or cultural activities, potentially benefiting surrounding communities, increasing the value of real estate in areas, contributing to more equitable urban development, and the care and promotion of ancient trees creates local employment opportunities in horticulture, tourism and education. Ancient trees are often seen as symbols of peace and continuity, promoting nonviolent values in urban communities, they are used in peace education programmes, especially for young people in urban areas, and the serene environment around ancient trees can serve as a space for meditation and peaceful reflection. Some ancient fruit or nut trees contribute to urban food security, which is especially important for low-income communities; they are integrated into urban forestry initiatives, contributing to sustainable local food systems; in addition, old trees often store traditional knowledge about local food sources and cooking methods.

Ancient urban trees, due to their constant presence and multifaceted roles in urban life, embody and promote numerous humanitarian values. They contribute to the creation of a more equitable, healthy and socially cohesive urban environment. By providing freely accessible natural spaces, supporting the well-being of the community and symbolising common legacy and

sustainability, these trees play a crucial role in improving the quality of life of all urban residents. Their preservation and integration into urban planning represent a commitment to humanitarian values in the development of the city, ensuring that the benefits of nature will be available to all, regardless of social or economic status.

In this chapter devoted to the humanitarian values of ancient urban trees, several key points are highlighted, which will be considered, the main ones are outlined below:

- Ancient trees provide equal access to natural benefits in an urban environment, promoting equality in health and social integration, they serve as a gathering place and a common legacy, promoting social ties between different groups.
- The spread and preservation of ancient trees can be an indicator and catalyst for environmental justice in urban areas.
- Ancient urban trees offer accessible learning opportunities in the real world, which is especially valuable in areas with limited resources.
- The presence of these trees makes a substantial contribution to the mental health of society through stress reduction and natural therapy.
- The preservation of ancient trees embodies the principle of intergenerational justice in urban planning.
- Many ancient trees have multicultural importance, contributing to cultural diversity and mutual understanding in urban settings.
- These trees can become a neutral platform for conflict resolution and reconciliation in the community.
- Ancient trees can contribute to the local economy and create jobs, potentially benefiting others.
- Large ancient trees play a role in the resilience of cities to natural disasters, offering both physical protection and symbolic hope.
- The sensual experiences that ancient trees provide offer inclusive natural experiences for people with disabilities.
- Ancient trees often symbolise peace and continuity, supporting nonviolent values in urban communities.
- Some ancient trees contribute to urban food security and preserve traditional food knowledge.
- These trees often become powerful symbols of sustainability, hope, and interconnectedness for urban communities.

This view of urban ancient trees as carriers of humanitarian values highlights their importance beyond their ecological or aesthetic contribution. It demonstrates how these natural monuments can play a crucial role in creating a more equitable, healthy, and socially cohesive urban environment. This understanding can inform urban planning, social policy, and conservation efforts, emphasising the need to preserve and integrate ancient trees as part of broader humanitarian goals in urban development.

2.1 Cultural and spiritual importance in different societies

Ancient urban trees have deep cultural and spiritual importance in various societies around the world. These trees, often ancient and towering, are not only natural landmarks but also symbols of cultural legacy, spiritual beliefs, and social identity. Their roles and meanings vary greatly, reflecting the different beliefs, histories, and traditions of different cultures (Bowler *et al.*, 2010). It seems necessary to consider the cultural importance of ancient trees around the world. In various cultures of West Africa, sacred groves containing ancient trees serve as places of worship and are believed to be inhabited by spirits or ancestors. For example, the baobab is often seen as a symbol of life and fertility, playing a central role in rituals and traditional medicine. In turn, iroko trees are believed to house spirits in the Yoruba tradition. Ancient trees in West Africa are revered as living repositories of history, culture, and spirituality. They are closely intertwined with the life of local communities, acting as both practical and symbolic pillars. Many ancient trees are found in sacred groves, which are considered to be the abode of deities or spirits. These places are used for rituals, prayers, and offerings. Old trees are often seen as connecting links between the living and their ancestors, and they are even considered elders or guardians of the family. Certain types of trees have unique symbolic meanings.

Ancient trees serve as centres for public gatherings, decision-making, and dispute resolution, and they are also used as geographical markers and help with orientation. Trees provide important services such as shade, oxygen, and soil conservation, and many of them have medicinal properties and edible fruits, supporting livelihoods. Despite their enormous cultural and ecological value, ancient trees in West Africa face numerous threats, including deforestation, urbanisation, and climate change. Efforts to preserve these priceless natural and cultural legacy sites are crucial to preserving the region's rich heritage. In Europe, ancient trees such as the oak (*Quercus spp.*) were closely intertwined with cultural identity. In Celtic traditions, the oak was considered sacred and symbolised strength and endurance. It was often the centre of druid worship, and rituals and gatherings were held under its branches. In England, a large oak tree in Sherwood Forest is associated with the legend of Robin Hood, embodying resistance and community spirit.

In Celtic traditions, oaks act as symbols of strength and endurance in city parks, and yew trees in churchyards represent immortality and rebirth. In German culture, lime trees are symbols of justice and are often planted in city squares. In the historic city of Neustadt, Germany, a 700-year-old lime tree is a loved attraction. This majestic tree has been a gathering place for local residents for centuries, where town meetings, festivals, and other social events were held. The tree is closely connected with the history and identity of the city. In the Mediterranean, olive trees symbolise peace and prosperity in urban landscapes. Located on the Greek island of Kos in Greece, the ancient Hippocratic plane tree is believed to have been planted in the 4th century BC and is associated with the famous ancient Greek physician Hippocrates. The tree is revered as a symbol of the origins of Western medicine and is the centre of attention for visitors to the island. The Guernica oak in the Basque region of Spain is a revered symbol of Basque autonomy and self-government. For centuries, this ancient oak tree has been a meeting place where Guernica residents gathered to discuss and make decisions about their collective future.

In the small French village of Alluville-Belfosse, a 1,000-year-old sycamore tree has been transformed into a chapel with a small wooden structure built inside its hollow trunk. This unique and

awe-inspiring tree has become a place of pilgrimage for visitors who come to admire its spiritual and historical importance. In the culture of East Asia, of course, residents pay a lot of attention to ancient trees, which are also attractive to tourists, along with museums and other historically important monuments. In Japan, ancient sakura (cherry blossom) trees are revered for their beauty and symbolism of the transience of life. These trees, especially in historic urban areas such as Kyoto, are the centres of festivals such as Hanami, where people gather to admire the blossoms, strengthening community ties and cultural traditions. The famous sakura trees are perhaps the most widely recognised symbols of Japanese culture. These delicate, short-lived flowers have inspired countless works of art, poetry, and cultural traditions. The fleeting beauty of cherry blossoms has become a metaphor for the transience of life and understanding of the present moment in Japanese philosophy.

The Hiroshima Ginkgo, which survived the atomic bombing of Hiroshima in 1945, has become a symbol of resilience and hope, inspiring visitors from all over the world. In the heart of Tokyo, in the Meiji Temple, there is a grove of ancient ginkgo trees, some of which are more than 300 years old. These towering trees are revered for their longevity and resilience and are closely linked to Japan's cultural and spiritual legacy. On Yakushima Island, a grove of ancient Japanese cedars grows in the Osugi Sanctuary, some of which are estimated to be more than 7,000 years old. These tall, moss-covered giants are revered as sacred and are closely intertwined with the indigenous culture of the Ainu Island and the beliefs of Shintoism. The cedars of the Osugi Shrine are a testament to the enduring connection between the Japanese people and the natural world. In addition, on Yakushima Island, the Dsemon-sugi is considered one of the oldest living trees in the world, its age is estimated at more than 7,000 years. This ancient Japanese cedar is a symbol of the island's rich natural legacy and the deep-rooted connection between the Ainu people and their environment. Jōmon Sugi is a UNESCO World Heritage Site and a source of great cultural pride for the Japanese.

The art of bonsai, growing miniature trees in small containers, is a typical Japanese cultural practice. Bonsai trees are not just decorative; they are filled with deep symbolism, embodying harmony between nature and humanity, as well as an understanding of beauty in small and simple. In China, ginkgo trees are of great importance in culture and are symbols of longevity and sustainability. The Temple of Heaven in Beijing is home to a magnificent grove of ancient ginkgo trees, some of which are more than 500 years old. These towering trees are revered for their longevity and connection to Chinese philosophical and spiritual traditions. Ginkgo is considered a sacred tree in China, symbolising wisdom, resilience, and harmonious relations between humanity and nature. The Ming Tombs, the final resting place of the Ming Dynasty emperors, are surrounded by a stunning array of ancient ginkgo trees. These trees are not only beautiful but also have deep symbolic meaning, representing the enduring legacy of the Ming Dynasty and the cycle of life, death and rebirth.

In Guangzhou City, the historic Liuzhong Temple is surrounded by a sprawling network of ancient banyan trees. These massive, intertwined trees are closely linked to Chinese folk beliefs and Taoist traditions, serving as gathering places for social rituals and celebrations. The banyan tree is considered as a symbol of strength, longevity and cyclicity of life. In the coastal city of Quanzhou, there is a wonderful grove of ancient camphor trees, some of which are more than 1000 years old. These towering, fragrant trees are honoured for their connection to the city's rich maritime history and cultural legacy. The camphor tree is considered a symbol of resilience, prosperity, and the steadfast spirit of the Chinese people. The venerated Bodhi tree grows in the Linin Temple in

Hangzhou, which is considered a direct descendant of the tree under which the Buddha achieved enlightenment. This sacred tree is the centre of attention of Buddhist pilgrims and a symbol of the enduring presence of faith in Chinese culture. Changdeokgung Palace in Seoul is home to an amazing grove of ancient ginkgo trees, some of which are more than 300 years old. These towering, fan-shaped trees are revered for their longevity and connection to the royal history of Korea. Ginkgo is considered a sacred tree in Korean culture, symbolising wisdom, resilience, and harmonious relations between humanity and nature.

Gyeongbokgung Palace in Seoul is surrounded by a magnificent grove of ancient Zelkova trees. These majestic, broad-leaved trees are closely connected with Korean cultural and political history, serving as a symbol of the indestructible spirit of the nation and the continuity of its traditions. The rugged peaks of Soraksan National Park are home to a stunning array of ancient Korean pine trees. They are revered for their ability to thrive in harsh mountain environments and are considered a symbol of Korea's indomitable spirit and connection to the natural world. The city of Andon is popular due to the centuries-old persimmon trees, which are deeply woven into the local culture and traditions. They are famous for their abundant harvests and their role in traditional Korean cuisine and folk customs, such as making vinegar from persimmons. Every spring, Genhe City is transformed by the stunning blossoming of its cherry blossoms. The trees have delicate, short-lived flowers that have become a symbol of Korean culture, a source of inspiration for art, poetry, and the beloved cherry blossom festival in Jinhae, which attracts tourists from all over the world.

In the Middle East, trees are symbols of paradise in the gardens of urban mosques, and the olive tree (*Olea europaea*) is both a symbol of peace and an important source of sustenance due to its mention in the Quran. Ancient olive trees, some of which date back thousands of years, are considered living monuments of cultural and agricultural legacy. They are often found in urban areas, where they serve as a reminder of the enduring connection between people and the earth. Lebanon, with its rich history and diverse landscape, has a deep connection with its native trees, which often acquire important cultural, religious, and historical importance. For example, the Lebanese cedar (*Cedrus libani*) is the national emblem of Lebanon, often appearing on flags, coins, and stamps. Cedars were known in ancient times for their strength and durability and were used in the construction of temples, ships, and palaces. The cedar of Lebanon is often mentioned in the Bible, associated with strength, beauty, and longevity.

The olive tree (*Olea europaea*) has been an important part of Lebanon's agriculture for centuries, providing oil, food, and timber. Olive branches are often associated with peace and reconciliation, a symbol that has been adopted by various cultures around the world, and olive trees can live for thousands of years, representing endurance and resilience. Sycamore (*Ficus sycomorus*) is mentioned in the Bible and is associated with various religious stories and figures, and this tree has been used to create shade, food, and medicine throughout history. The carob tree (*Ceratonia siliqua*) is grown for its pods, which are used as a natural sweetener and food source. The abundance of carob pods has made it a symbol of prosperity and abundance. In Iran, cypress (*Cupressus sempervirens*) is often planted in cemeteries as a symbol of eternal life and mourning. Cypress trees have been used in Iranian architecture for centuries, especially in gardens and courtyards. The pomegranate tree (*Punica granatum*), with its numerous seeds, is associated with fertility and abundance in Iranian culture; pomegranates are mentioned in the Quran and are considered a symbol of paradise.

Plane trees (*Platanus orientalis*) are known for their longevity and are often associated with strength and resilience, they have been planted in Iranian gardens and parks for centuries, providing shade and beauty. The Pistachio tree (*Pistacia vera*) has been grown in Iran for thousands of years and is a substantial part of the country's economy. Pistachios are a popular snack in Iran and are often associated with holidays and celebrations. Willow (*Salix babylonica*) is often associated with sadness and mourning in Iranian poetry and literature. Willows are a common sight in Iranian gardens and parks. In Central America, the Ceiba pentandra tree, also known as the kapok tree, revered by the Maya civilisation, is considered the World Tree or Tree of Life. In ancient urban centres such as Tikal, ceiba was believed to connect heaven, earth and the underworld, embodying Mayan cosmological beliefs. This veneration continues today, with ceiba serving as a symbol of sustainability and cultural continuity. This tree is often found in urban parks and squares in Guatemala, symbolising the country's Mayan legacy.

The mahogany tree (*Swietenia mahagoni*) is the national tree of Belize and is closely linked to the history of logging in the country, it has played a substantial role in the country's economy. Mahogany trees can be found in parks and along the streets of Belize city, they serve as a reminder of the country's natural legacy. The guanacaste tree (*Enterolobium cyclocarpum*) is the national tree of Costa Rica and is often found in parks and squares throughout the country. The city of Liberia, Costa Rica, is named after the guanacaste tree, which highlights its importance in the region. The mango tree (*Mangifera indica*) is a popular fruit tree in El Salvador and is often associated with the tropical climate of the country, it can be found in gardens and parks throughout San Salvador, complementing the tropical atmosphere of the city.

The coconut palm (*Cocos nucifera*) is the backbone of life in Honduras, providing food, drink, and building materials. The coastal town of Tela in Honduras is known for its coconut plantations and is a popular destination for tourists looking for a tropical vacation. In the United States, the Liberty Oak (*Quercus virginiana*) is a historic living tree growing in Philadelphia. It is believed that he was present at the signing of the Declaration of Independence, the tree became a symbol of American freedom and independence. The Washington Elm (*Ulmus americana*) is a historic American tree growing in Cambridge. It is believed that George Washington took command of the Continental Army under its branches in 1775, it became a symbol of American history and the War of Independence. The Angel Oak (*Quercus virginiana*) is a massive living tree growing on Jones Island. It is one of the oldest trees in the United States, estimated to be 400-500 years old, and the size and beauty of the tree have made it a popular tourist destination.

Miami is home to several large banyan trees (*Ficus benghalensis*) imported from India. These trees have become a distinctive feature of the urban landscape, they complement the tropical atmosphere of Miami and are often used as shade trees in parks and public places. In California, the evergreen sequoia (*Sequoia sempervirens*) is an iconic symbol of the city. It is known for its enormous size and longevity, and Redwood National and State Parks in California are popular tourist destinations for visitors who want to see these magnificent trees. In the indigenous culture of Australia, ancient trees such as eucalyptus or "scarred trees" have deep spiritual importance. These trees bear marks or scars inflicted by the aborigines for cultural purposes, such as the creation of canoes or shelters. They are seen as living evidence of the history of indigenous peoples, their survival and connection to the land. Papuan eucalyptus (*Eucalyptus papuana*) is an outstanding tree in Darwin, often found in parks and on city streets. Its white bark and twisted branches create a

striking silhouette against the sky, it is associated with Aboriginal stories about dreams and is believed to have spiritual importance. *Eucalyptus camaldulensis* (*Eucalyptus camaldulensis*) is a common tree along the Yarra River in Melbourne. It is known for its resilience and ability to thrive in flood-prone areas, it was used by aborigines for a variety of purposes, including food, shelter, and tools.

Kurrajong (*Brachychiton populneus*) is a versatile tree found throughout Australia, including Sydney. It is known for its distinctive bottle-shaped trunk, which was used by aborigines for food, making tools, and as medicine. It is also associated with stories and ceremonies about dreams. The similar bottle tree (*Brachychiton rupestris*) is a striking plant native to various parts of Queensland. It is known for its swollen trunk, which can store water during dry periods, and was used by aborigines for food, water, and shelter. The baobab (*Adansonia gregorii*), also known as the Boab, is a unique and iconic tree native to the Kimberley region of Western Australia, it has great cultural importance to the aborigines of the region and is often associated with stories about the time of dreams and is used for food, shelter, and ceremonies. In addition to the above, there are still many ancient trees in Asia that have cultural importance for cities and countries. For example, in the ancient city of Angkor, huge trees such as the silk cotton tree (*Ceiba pentandra*) have grown around the ruins of temples such as Ta Prom. These trees have become an integral part of the historical landscape, symbolising the passage of time and the enduring connection between nature and human civilisation.

In many parts of India, ancient trees are considered sacred and are often found in sacred groves or near temples. Trees such as banyan (*Ficus benghalensis*) and pipal (*Ficus religiosa*) are revered as the abodes of deities. The pipal tree, for example, is associated with the god Vishnu and is considered the gateway between heaven and earth. People perform rituals and offer prayers under these trees, considering them places of spiritual enlightenment. In the world of ancient legends and myths of India, trees are not just plants, but symbols that hold deep meanings and mystical powers. Another of these trees, which is of key importance in Buddhism, is Bodhi, the sacred fig tree under which Siddhartha Gautama, the future Buddha, stopped to rest after long wanderings. It was here, in meditative contemplation, that he achieved enlightenment, rethought his existence and became who we know as the Buddha, the enlightened teacher.

The Bodhi tree, which still stands in Bodhi Gaya in India, has become sacred to Buddhists, a place of pilgrimage and a symbol of enlightenment, wisdom and liberation. In Hindu mythology, there is also an important tree, nyagrodha (Skt. nyag – rodha – “growing down”), which is the equivalent of the “World tree” connecting heaven and earth. In the Mahabharata, nyagrodha is described as a tree the branches-roots of which go deep into the ground, embodying the cyclicity of life, constant movement, and rebirth. In Vedic legends, the mythical Parijata tree (or har singhar) is mentioned, the beauty and fragrance of which are second to none. This tree was extracted and planted in his garden of Eden by the king of the gods Indra, lord of Indraloka. Parijata is a symbol of heavenly beauty, well-being, and abundance. These trees are not just plants but important symbols in various religions and mythologies. They embody enlightenment, the cyclical nature of life, heavenly bliss, and the connection with ancient knowledge and mystical ideas about the world.

The Dragon Tree (*Dracaena cinnabari*) is a unique and iconic tree native to Socotra Island, Yemen. It is known for its unusual umbrella-shaped crown and red juice, is a symbol of Socotra and is under the protection of the Yemeni government. Separately, highlighting ancient important trees growing on the Pacific Islands are notable, for example, the breadfruit tree (*Artocarpus altilis*),

which is a staple food in many Polynesian cultures, providing a nutritious and versatile food source and is also often used in traditional ceremonies and celebrations. The coconut palm (*Cocos nucifera*) is an important part of life on many Pacific islands, providing food, drink, shelter, and other materials, it is often depicted in traditional carvings and art in the Solomon Islands. The kava tree (*Piper methysticum*) is a sacred plant in many Melanesian cultures and is used in traditional ceremonies and social events; eating kava is a popular social activity in Fiji and is often associated with hospitality and friendship. The banyan tree (*Ficus benghalensis*) is a symbol of strength and longevity in many Micronesian cultures. It is often planted near villages and sacred sites. The Chamorro people of Guam have a deep connection with the banyan tree and use it in traditional ceremonies and celebrations.

The pandanus tree (*Pandanus spp.*) is a versatile plant that provides food, drink, and materials for clothing and shelter, pandanus leaves are used to make traditional Tahitian skirts known as pareos. In modern urban culture, ancient urban trees are perceived as symbols of environmental protection and resistance to urbanisation and are often used during tree planting protests to protect old trees from urban development. In many countries, large fir trees grow in city squares, which are used as Christmas trees of cultural and religious importance. In the scientific world, ancient urban trees are valued as living laboratories and repositories of environmental data, there are civilian scientific projects focused on monitoring and examining old trees in cities, and they are used as living classrooms for environmental and cultural education. In addition, ancient trees are a source of inspiration in poetry, literature, and visual arts in different cultures and are used as metaphors for human life and society in various cultural narratives.

The cultural and spiritual importance of ancient urban trees is as diverse as people (Blicharska and Mikusiński, 2014). These trees serve as living links with cultural legacy, spiritual beliefs, and social values. They often transcend their biological roles, becoming powerful symbols of continuity, wisdom, and the interconnectedness of nature and human society. In many urban contexts, they represent a bridge between the natural world and the built environment, embodying the complex relationship between human culture and the natural systems that support us. As cities continue to develop, preserving and honouring these culturally and spiritually substantial trees is becoming increasingly important. They not only support biodiversity in urban ecosystems but also preserve cultural diversity and spiritual legacy. In rapidly changing urban landscapes, ancient trees are evidence of the enduring power of nature to inspire, unite, and give meaning to human groupings in different societies and belief systems.

Ancient urban trees are more than just elements of the natural environment; they are embodiments of cultural narratives, spiritual beliefs, and historical continuity. In different societies, these trees serve as sacred symbols, public anchors, and living monuments, illustrating the deep connection between humans and the natural world. Their preservation is not only a concern for the environment but also a cultural imperative, as they carry the legacy of the past into the present and the future. This view of the cultural and spiritual importance of ancient urban trees highlights their importance beyond mere biological or aesthetic value. It shows how these trees can serve as powerful symbols of cultural legacy, spiritual beliefs, and social values in urban settings. This understanding can be useful in urban planning, conservation activities and cultural policy, emphasising the need to preserve these trees not only because of their environmental benefits but also because of their deep cultural and spiritual importance in various societies.

2.2 Ancient trees in literature, art, and folklore

Ancient trees occupy an important place in literature, art, and folklore, embodying vital ideas, wisdom, and the connection between generations. They often become symbols that give deep meaning to cultural works. For example, the “Tree of life” in Christian art emphasises the importance of the tree as a source of growth and life. In Slavic culture, the apple tree, as a mythological element, is used in rituals and beliefs, which indicates the strong connection of the people with nature. In this section, we explore how different cultures embody ancient trees, their symbolism and influence on art and folklore. Ancient trees occupy a special place in human culture, serving not only as physical objects but also as powerful symbols that permeate the literature, art, and folklore of various peoples. These majestic creatures of nature, which have survived the centuries, become the personification of vitality, wisdom, and communication between generations. In the modern world, where ecology and nature conservation are becoming more and more important issues, the symbolism of ancient trees acquires a new meaning. They not only represent physical objects but also serve as metaphors for discussing deeper topics such as sustainability, continuity, and connection to nature. In this context, ancient trees become symbols of hope and rebirth, which makes them relevant for discussion within the framework of cultural and environmental studies.

Different peoples perceive and interpret ancient trees in many ways; various legends and myths are associated with them, and they reflect cultural values and worldviews (Jones and Cloke, 2002). Artists of different eras and styles depicted ancient trees and used many artistic techniques to convey their greatness and symbolism. There are a large number of fairy tales and myths about ancient trees based on folklore traditions and used in rituals, festivals, and beliefs, which emphasises their importance in the life of the people. Ancient trees are also an object of modern art. Modern artists and sculptors use images of ancient trees to create new works reflecting current social and environmental issues. Below, we will explain in more detail the mentions and importance of ancient urban trees in literature, art, and folklore. Ancient urban trees often served as powerful symbols and metaphors in literature, reflecting the relationship between people and nature, as well as the passage of time and the enduring nature of certain places. They usually play several key roles, for example, trees are symbols of time and endurance. Ancient trees that have stood for centuries often serve as witnesses to historical events, symbolising the continuity of life in an ever-changing world. They are often used as metaphors for longevity and the enduring nature of certain things and represent the passage of time and the cyclical nature of life.

Trees often symbolise a connection with the earth and the natural world. They represent harmony between people and nature or the destructive forces of nature and are associated with growth, renewal, and the cycle of life, symbolising hope, rebirth, and the possibility of change. In many cultures, trees are considered sacred and are often associated with gods or spirits, alluding to spiritual power, knowledge, or wisdom. The roots and branches of a tree are often used as metaphors for human life, representing family, connections and growth, and the fruits and leaves appear as rewards and consequences of human actions. Another role of ancient urban trees in literature is that they serve as a picturesque backdrop for literary works, adding depth and atmosphere to the story. Further examples from the literature will be presented, demonstrating the importance of ancient trees in the works:

- In Homer's *Odyssey*, Odysseus' bed is made of ancient olive wood, which symbolises the permanence of his marriage.
- In Ovid's *Metamorphoses*, there are several stories about how people turn into trees, like Daphne into a laurel.
- The Green Knight in *Sir Gawain and the Green Knight* is often interpreted as a depiction of the Green Man, a figure associated with ancient trees and nature.
- In Dante's *Divine Comedy*, there is a Suicide forest in Hell where souls are trapped in gnarled trees.
- In William Wordsworth's poem "Yew-Trees", the author reflects on the ancient yew trees in English churches.
- In George Eliot's work *Middlemarch*, the metaphor of a spreading tree is used to represent the interconnectedness of provincial life.
- Virginia Woolf in "Orlando" showed the main character's connection with an ancient oak tree, spanning centuries and symbolising continuity and change.
- Richard Powers's work "Overstory" intertwines numerous narratives about the life of trees, including ancient redwoods and chestnuts.
- Shel Silverstein's book *The Generous Tree* tells the story of a lifelong relationship between a tree and a boy.
- In the Harry Potter book series, the Rattlesnake Willow is an ancient sentient tree on Hogwarts grounds.
- Baobabs, in Antoine de Saint-Exupery's "The Little Prince", represent both danger and miracle.
- In Gabriel Garcia Marquez's novel *One Hundred Years of Solitude*, the chestnut tree in the courtyard of the Buendia family has been a central symbol for generations.
- In the Anglo-Saxon poem "Beowulf", the funeral pyre of a warrior is made of ancient trees.
- The sacred groves in Lucan's *Pharsalia* depict ancient trees as guides to the divine.
- In the work "The Old Man and his Grandson" by the brothers Grimm, an old pear tree is depicted.
- In J.R.R. Tolkien's works, including *The Lord of the Rings*, ancient trees such as the Ents and the White Tree of Gondor occupy a special place.
- The ancient Bodhi tree has a central place in Buddhist literature about the enlightenment of the Buddha.

These examples show how ancient trees in literature often symbolise constancy, wisdom, the cycle of life and the connections between the human and natural worlds. They can serve as silent witnesses to history, magical portals, or embodiments of natural forces. Artists often depict ancient urban trees as observers of urban history. These plants, which have stood for centuries, embody continuity among the changes. For example, Camille Pissarro's paintings of Paris often include old trees lining boulevards, contrasting natural permanence with urban development. In urban landscapes, ancient trees symbolise nature's ability to thrive despite human intervention. Modern photographers such as Beth Moon have taken stunning pictures of ancient trees surviving in modern urban landscapes, highlighting this juxtaposition. Artists use ancient urban trees as central elements to structure their compositions. The sprawling branches and distinctive shapes of old trees provide natural framing techniques. This is evident in works such as William Glackens' *Washington Square*, where an old elm tree dominates the stage.

Certain ancient trees in cities often become cultural landmarks, repeatedly represented in art. The large oak tree in Sherwood Forest, associated with the legends of Robin Hood, has been

depicted in countless paintings and illustrations over the centuries. Modern artists often use ancient urban trees in their works to comment on environmental issues. These trees are becoming powerful symbols of conservation efforts and the need to preserve nature in urban spaces. In paintings and photographs of urban parks, ancient trees often represent peaceful shelters from the hustle and bustle of the city. Artists such as George Bellows have captured this in paintings of New York's Central Park, where old trees create islands of serenity. Artists use ancient urban trees to tell stories about seasonal changes in the urban environment. Monet's series of paintings depicting London's Waterloo Bridge, with glimpses of old trees on the embankment, shows how these natural elements transform the appearance of the city throughout the year.

In both traditional and modern art, ancient trees are often juxtaposed with architecture to highlight the contrast between natural and man-made forms (Mabey, 2007). This is especially noticeable in modern urban landscapes, where glass and steel buildings stand next to century-old trees. Images of ancient urban trees often evoke a sense of nostalgia, representing unchanging elements in ever-changing urban landscapes. This theme is common in the works of urban sketchers and watercolourists who capture the character of urban neighbourhoods. Even in urban environments, ancient trees can retain their mythological or spiritual importance in art. For example, bodhi trees in images of Asian cities often carry Buddhist symbols.

We want to present how trees were reflected in paintings in different eras and what importance they had:

- Renaissance and Baroque. Leonardo da Vinci's drawings of trees, especially his examinations of olive trees, demonstrate a deep understanding of their ancient forms, and Albrecht Durer's watercolour "A Large Piece of Turf" (1503) includes detailed images of old, gnarled tree roots.

- Romantic period. Caspar David Friedrich often included ancient, twisted trees in his landscapes, symbolising resistance to time and nature; John Constable's "Study of the Trunk of an Elm Tree" (1821) demonstrates the texture and character of an old tree.

- Impressionism and post-Impressionism. A series of paintings by Claude Monet with poplars along the Epte River captured the changing light on these tall ancient guardians; Vincent Van Gogh's Olive Trees series (1889) depicts the intertwined ancient olive groves of Provence with emotional intensity.

- Contemporary art. Gustav Klimt's "Tree of Life" (1909) uses the shape of an ancient tree to create a symbolic decorative masterpiece, and David Hockney's recent iPad drawings of ancient trees in Yorkshire show how technology can convey the essence of these natural wonders.

In addition to painting, ancient urban trees appear in other forms of art, sometimes even unpredictable, among them:

- Sculpture. The bronze sculpture "Capitoline Wolf" depicts Romulus and Remus under ficus Ruminalis, a sacred fig tree in Roman mythology; Chinese penjing and Japanese bonsai are living sculptures that often depict miniature versions of ancient trees; "12 Meter Tree" by Giuseppe Penone (1980-82) is the carved shape of a young tree from a mature wooden beam, revealing "memory" of the tree's youth; Andy Goldsworthy often works with fallen ancient trees, creating ephemeral sculptures that emphasise their shapes and textures.

- Photography. Ansel Adams captured majestic images of ancient redwoods and bristlecone pines in the American West; Beth Moon's Ancient Trees: Portraits of Time series documents ancient trees around the world in stunning black and white photographs.

- Engraving. Japanese ukiyo-e prints often depict ancient pines, symbolising longevity and endurance; the series “Pines” (*Matsu no Uchi*) by Katsushiki Hokusai demonstrates various images of old, characteristic pines.

- Ceramics and pottery. The “Tree of Life” motif, often depicting an ancient, sprawling tree, is common in Mexican Talavera ceramics; Chinese Yixing clay teapots sometimes have a shape resembling gnarled, ancient tree trunks or roots.

- Textile. The Bayeux tapestry includes stylised depictions of old trees in its narrative scenes; William Morris’s textile drawings often featured intricate patterns of intertwining branches and leaves inspired by ancient forests.

- Digital art. Modern digital artists create fantastic landscapes with incredibly ancient and huge trees, often in the context of science fiction or fantasy.

These diverse artistic depictions of ancient trees reflect humanity’s enduring admiration for these natural monuments, exploring the themes of time, sustainability, wisdom and the interconnectedness of nature, we cited as an example the small number of mentions of ancient urban trees in art, so this subject requires more detailed consideration in the future. Ancient urban trees are of great importance in folklore and mythology, acting as living bridges between the urban landscape and the realm of legends. These plants have witnessed centuries of human drama and have become an integral part of the cultural life of any nation. In many urban myths, they act as silent guardians, their sprawling canopies sheltering not only the population but also spirits and supernatural beings. The legends surrounding these trees often paint them as conduits between worlds – portals through which fairies can enter our kingdom or gates to the afterlife. In some traditions, they are considered ancestral homes; their gnarled bark and rustling leaves whisper wisdom from past centuries. This connection with history and memory gives them an almost prophetic status; many believe that these trees absorb the secrets and stories of the city, becoming living repositories of urban memory.

Folklore often attributes magical properties to ancient urban trees. They become centres of desires and prayers, their branches are decorated with ribbons and symbols of hope. In many cultures, these trees are believed to have healing properties. Their leaves and bark are used in traditional remedies that blur the line between medicine and magic. Some are even considered capable of blessing or cursing, their favours are sought, and their anger is feared by the locals. The spiritual importance of these trees often goes beyond individual beliefs, many of them become synonymous with deities or serve as earthly incarnations of heavenly powers. In myths about the creation of the world in urban areas, they sometimes appear as the axis of the world, the central pillar connecting the skies, earth, and the underworld. This cosmological role highlights their importance in maintaining the spiritual balance of the city.

Seasonal changes in ancient trees often mark important cultural events and the passage of time in urban folklore. Their flowering or defoliation can signal the beginning of festivals or the time for certain rituals, intertwining natural cycles with human traditions. Thus, they serve as living calendars, their rhythms dictate the pulse of urban life. These mythological roles reflect humanity’s constant need to find meaning and continuity in an ever-changing urban environment. Ancient urban trees, with their longevity and sustainability, become powerful symbols of constancy among the flow of urban life, embody the union of nature and culture, their roots penetrate deeply into both the earth and the collective imagination of urban residents. Due to folklore and myths, these

trees go beyond their physical form, becoming storytellers, wish-fulfillers, protectors, and timekeepers – living monuments that connect the modern city with its legendary past and desired future.

Next, we want to present exactly where you can find ancient urban trees and what they symbolised in these cases:

- Scandinavian mythology. Yggdrasil: The world tree, a huge ash tree connecting the nine worlds of Scandinavian cosmology; its branches extend to the heavens, and three roots reach different spheres; it is home to various creatures, including the dragon Nidhegg and the Ratatoska squirrel. Mimamaid: The Tree of Knowledge, the cosmic tree mentioned in the Elder Edda, is said to hold secret wisdom and is difficult for people to comprehend.

- Greek and Roman mythology. Golden apples of the Hesperides – a sacred apple tree in the garden of Hera, guarded by nymphs and a dragon, the eleventh feat of Hercules was to get these apples. The Olive Tree of Athens, in competition with Poseidon for the patronage of Athens, Athena created the first olive tree, which symbolises peace, wisdom, and prosperity.

- Celtic folklore. Goronwy Oak is a magical oak in Welsh folklore, where Llew Llaw Giffes turned into an eagle, it personifies the cycle of death and rebirth. It is a bad omen to cut down some fairy-tale trees, such as single hawthorn trees, which are considered portals to the fairy kingdom.

- Asian traditions. The Bodhi Tree (Buddhism) is a sacred fig tree under which the Buddha achieved enlightenment, it symbolises spiritual awakening and wisdom. The peach tree of immortality (Chinese mythology) in the garden of Xi Wangmu, the Queen Mother of the West, its fruits grant immortality to those who eat them. The banyan tree (Hinduism) is associated with longevity and immortality, and the God Shiva is often depicted as meditating under a Banyan tree.

- Middle Eastern and Islamic traditions. The Tree of Life in Eden is the central place in the history of the Garden of Eden in the Abrahamic religions, which embodies immortality and divine knowledge. Sidrat al-Muntaha is a sacred lotus tree in the Islamic tradition, marking the border of the seventh heaven, mentioned in the Quran in connection with the night journey of Muhammad.

- African folklore. Baobab tree – In many African cultures, baobabs are considered a home for spirits; in some traditions, it is said that the baobab was planted upside down by the gods. The iroko (Yoruba) tree is considered sacred and is home to spirits, people believe that cutting it down without proper rituals brings misfortune.

- Native American traditions. World trees in Mesoamerican cultures occupy a central place in cosmology, often representing the axis of the world, and the ceiba tree is especially substantial in Maya culture. The Great Tree of Peace (Iroquois), a white pine tree under which the Iroquois Confederation was formed, symbolises unity and the burial of weapons of war.

- Polynesian mythology. The koa tree (Hawaiian) is associated with the god Ku and is considered the father of the canoe, symbolising the strength and spirit of a warrior.

These examples illustrate how ancient trees were woven into the spiritual and cultural fabric of societies around the world, often representing cosmic order, wisdom, immortality, and the connection between the earthly and divine realms. Ancient urban trees have played a key role in shaping literature, art, and folklore in different cultures and time periods. These towering guardians, often rooted in the very heart of history, served as symbols of nature, resilience, and the indomitable human spirit. In literature, they have been used as metaphors for time, growth, and the interconnectedness of life. In art, they were depicted in various forms, from paintings and sculptures to architecture, symbolising both the beauty of nature and the cultural importance of trees. Folklore

has also woven stories around ancient trees, linking them to myths, legends and spiritual beliefs. These eternal companions have witnessed the rise and fall of civilisations, acting as silent witnesses to human history. Their presence inspired artists, writers, and storytellers, leaving an indelible mark on the cultural landscape.

2.3 Opportunities for education and public engagement

Ancient urban trees represent valuable evidence of history, culture, and ecology. Their importance goes far beyond their natural appearance: they serve as unique educational resources for schools, universities, and public organisations. We have already reviewed how ancient trees can be used for education and public engagement, but in this sub-section, we want to explore in more detail the various ways in which ancient trees can be integrated into educational programmes, including excursions, workshops, and community events. The focus is on interpreting their ecological importance, their impact on the urban landscape, and ways to raise public awareness of the importance of environmental protection. Ancient trees not only enrich the natural diversity of cities but also help to build a sustainable society, connecting the past and the present through learning and interaction with people.

Ancient urban trees are unique and multifaceted objects that serve not only as natural monuments but also as important elements of the cultural and educational landscape. These trees, which have survived the centuries, are witnesses to historical events, changes in the urban environment, and the evolution of human society. Their roots, which go into the ground, seem to connect the past with the present, creating a bridge between nature and education. In the modern world, where environmental problems are becoming more and more urgent, ancient trees can play a critical role in shaping public consciousness and increasing the level of environmental literacy. We are convinced of the need to realise the importance of ancient trees as an integral part of the urban ecosystem. In the context of rapid urbanisation and climate change, the preservation and integration of these natural sites into educational programmes is becoming an important task. Ancient trees not only enrich the biological diversity of cities but also serve as living laboratories for examining ecology, history, and culture. They can become the basis for the creation of educational initiatives aimed at forming a sustainable society capable of being aware of the environment (Zhang *et al.*, 2022).

We want to demonstrate the historical importance of ancient urban trees, which includes not only biological value but also cultural legacy associated with specific places and events. Ancient trees can tell about the traditions, beliefs, and lifestyle of the people who lived next to them and thus serve as an important source of knowledge for future generations. It is also important to note education through interaction with ancient trees. We will review various approaches to integrating these facilities into educational programmes, including excursions, workshops, and community events. Such initiatives can deepen students' knowledge of nature and contribute to the development of critical thinking skills and environmental responsibility. Another important aspect is the ecological role of ancient urban trees. They not only improve air quality and create shade but also contribute to the maintenance of biodiversity, serving as a home for many species of animals and plants.

In addition, public awareness of the importance of ancient trees will also be considered. It is important to understand how public initiatives and educational programmes can raise public

awareness of the value of these natural sites and the need to protect them. Examples of successful educational programmes that are already being implemented in various cities will be examined, and their impact on public opinion and behaviour will be analysed. Finally, we will discuss the future of interaction with ancient urban trees and consider what steps can be taken to further integrate these sites into educational and environmental initiatives, as well as how modern technologies can be used to increase interest in ancient trees and their protection.

Ancient city trees, as mute witnesses to millennia of human history, are a valuable repository of historical information that can be revealed via careful analysis. The species of trees found in an urban environment can offer significant insights into the past landscape, revealing whether the region was formerly marshes, woods, or utilised for various land purposes. The existence of specific tree species may indicate that the area was formerly utilised for agricultural or industrial purposes. Moreover, the growth patterns of these ancient trees can provide insights into historical urban development. Discrepancies in their crowns may signify the sites of erstwhile edifices, thoroughfares, or other infrastructure that have subsequently been dismantled or altered. Through the analysis of these growth models, historians and students can rebuild the changing urban landscape and gain a deeper understanding of the historical context of their environment.

Climate change is a significant domain in which ancient urban trees yield essential data. Scientists can reconstruct past climate trends, including temperature changes and precipitation variations throughout the millennia, by analysing the annual rings of these trees. This dendrochronological data provides insight into historical climatic conditions, aiding in the contextualisation of present developments from a long-term viewpoint. Furthermore, the health and vigour of ancient trees can act as markers of climate change impacts. Growth anomalies generated by stress, such as uneven ring patterns or indications of disease outbreaks, may signify altering environmental conditions and the escalating stresses imposed by a changing climate. These insights not only deepen our comprehension of historical climate dynamics but also guide efforts for reducing future effects.

In addition to their ecological importance, ancient trees are profoundly connected to cultural traditions and social history. Numerous trees possess religious or spiritual importance, offering insights into the cultural and spiritual existence of historical communities. Examining these trees can illustrate how various cultures engaged with their natural surroundings, highlighting actions such as utilising trees for shelter during conflicts or as focal points for social gatherings. Historical linkages can be included into educational curricula, enabling students to investigate the diverse roles that ancient trees have had in influencing human experiences and society progress. Examining the narratives and myths associated with these trees enhances learners' understanding of their cultural history and the persistent connection between humanity and nature.

The social and economic history associated with old tree locations enhances our comprehension of historical human activity. Trees located near water sources signify the significance of these regions for access to potable water or irrigation, underscoring their contribution to early settlements and agricultural activities. The existence of fruit-bearing trees may indicate past economic activities associated with agriculture and trade, implying that specific regions were formerly centres of profitable farming or orchards. Mapping the distribution of old trees enables historians to reconstruct the socioeconomic landscape of previous eras, providing pupils with a concrete link to the daily lives of historical populations. This holistic approach provides a more intricate and thorough understanding of historical development, connecting natural and human history.

Beyond their historical significance, ancient urban trees are essential for environmental study, offering insights into biodiversity and ecosystem vitality (Low and Altman, 1992). These trees frequently function as crucial habitats for diverse creatures, encompassing insects, birds, and mammals. Ecologists can enhance their comprehension of the complex ecosystem sustained by ancient trees by examining the species that rely on them for nourishment, habitat, or reproduction. The distinctive microenvironments formed by the fissures, bark, and foliage of ancient trees promote different ecosystems, rendering them exemplary subjects for examining ecological functions and species interactions. This biodiversity study enriches our understanding of urban ecosystems and informs conservation efforts to preserve these essential natural resources.

Ancient trees have a crucial role in the nitrogen cycle, considerably impacting environmental research. Trees accumulate vital nutrients in their tissues, which are progressively released into the soil by processes including leaf abscission and root decomposition. Through the analysis of nutrient dynamics, researchers can gain a deeper insight into the function of trees in preserving soil health and fertility. Moreover, ancient trees are crucial for carbon sequestration, taking carbon dioxide from the atmosphere and storing it in their biomass. The capacity to alleviate climate change highlights the significance of conserving ancient trees within wider environmental sustainability initiatives. Comprehending the nutrient cycles and carbon sequestration potential of these trees yields essential information for formulating strategies to address climate change and enhance ecological resilience.

Ancient urban trees provide significant insights into ecosystem services, which are the advantages humans obtain from natural surroundings. These trees enhance air quality by sequestering pollutants, consequently diminishing the prevalence of respiratory ailments and allergies in urban populations. Furthermore, they improve water quality by removing contaminants from precipitation, serving a vital function in stormwater management and alleviating the impacts of urban runoff. By quantifying these advantages, researchers can illustrate the significance of urban green spaces in preserving public health and environmental quality. Furthermore, ancient trees alleviate the urban heat island effect by offering shade and cooling via transpiration, so enhancing urban climate comfort and sustainability. These ecosystem services underscore the diverse contributions of old trees to urban environments, emphasising their significance beyond simply visual attractiveness.

Urban ecology, which examines ecological processes inside urban settings, is significantly influenced by the existence of ancient trees. These trees serve as sanctuaries for biodiversity in heavily populated regions, providing refuges for many species inside the urban environment. Investigating the relationships between ancient trees and their habitats enables academics to formulate methods for conserving biodiversity and improving urban green infrastructure. This research is crucial for developing sustainable cities that harmonise growth with environmental preservation, guaranteeing that urban regions stay habitable and environmentally robust. Ancient trees, characterised by their enormous root systems and intricate ecosystems, offer essential insights into the coexistence of natural components and urban development, promoting resilience and flexibility amid environmental problems. By conducting ecological studies on ancient urban trees, biologists and other scientists involved in the study of plants and ecology can better understand the environmental processes taking place in the urban environment and develop strategies for sustainable urban development.

Ancient urban trees offer a unique opportunity for STEM education (science, technology, engineering, and mathematics). These plants can be used to teach students various scientific concepts and develop critical thinking, problem-solving, and creativity (Rousell and Tran, 2024). In botany and ecology, students can learn to identify different tree species, their characteristics and ecological role, study the anatomy of leaves, including their structure, functions, and adaptations, and explore the interactions between trees and other organisms such as insects, birds, and fungi. By studying environmental sciences, students have the opportunity to learn about the impact of climate change on trees, for example, changes in growth rates, susceptibility to diseases and shifts in habitats; about the impact of air and water pollution on trees and develop strategies to mitigate this impact; about the importance of tree conservation, and create plans to preserve ancient trees in the city. In math lessons, students can collect data on tree characteristics such as height, diameter, and leaf area and then analyse this data using mathematical tools to identify patterns and trends and create mathematical models to simulate the growth and development of trees, helping them understand the factors affecting their survival and health.

In engineering, students learn about engineering principles related to tree care, such as pruning, cabling, and soil management, and explore the role of trees in urban planning, including their use for stormwater management, air pollution control, and energy conservation. In addition, surely, the investigation of ancient trees develops critical thinking and problem-solving ability by analysing case studies of ancient urban trees that have encountered problems such as diseases, pests, or development pressures and then developing solutions to these problems. Students can work on project-based learning activities that include exploring ancient urban trees and developing critical thinking, problem-solving, and creative skills. By incorporating ancient urban trees into STEM education, we provide students with a hands-on and engaging learning experience that is relevant to their lives and society. Ancient urban trees, with their majestic presence and deep roots in local history, can serve as powerful catalysts for creating community. These plants offer a large number of opportunities to strengthen social ties, promote environmental protection, and celebrate a common cultural legacy.

They can act as a common meeting space, for example, ancient urban trees often grow in parks or public places, these areas provide a welcoming environment for public gatherings such as picnics, festivals, or just enjoying nature, in addition to parks, trees are sometimes landmarks of the area, serving as familiar and comfortable meeting places for residents. Trees can be planted together in honour of ancient trees to create a sense of community ownership and governance, involving people of different ages and social statuses, attracting residents in tree care activities such as pruning, mulching, or watering; this contributes to a sense of responsibility for the environment. From the standpoint of cultural legacy preservation, ancient urban trees often have a rich history associated with them, the dissemination of these stories helps to preserve cultural legacy and connect people with the past of their people. Trees can be included in public celebrations such as festivals or historical reenactments, strengthening the bond between residents and their local legacy.

Within a family or clan, ancient trees can be part of family traditions passed down from generation to generation. These traditions help to connect older and younger generations and foster a sense of continuity, and involving older residents who have personal ties to ancient urban trees can help bridge the generation gap and foster intergenerational understanding. Ancient urban trees can become a common ground for people from different walks of life to come together and build

relationships, by participating in activities related to ancient urban trees, people develop a stronger sense of belonging to their place of residence. By promoting social ties, encouraging environmental care, and glorifying cultural legacy, ancient trees have a beneficial effect on creating vibrant and sustainable relationships between people. Old trees have a profound impact on environmental awareness, connecting people to the natural world in a modern urban context. These trees, which are often hundreds of years old, serve as symbols of sustainability and continuity, reminding urban residents of the long-term relationship between nature and human development. They are not just aesthetic landmarks; they are vital components of urban ecosystems that are of great importance to the ecological health and well-being of people.

Such trees have deep roots, both literally and figuratively. From an environmental standpoint, they offer substantial benefits such as improved air quality, reduced urban heat islands, and providing habitat for various species. Their presence helps people understand the importance of biodiversity in cities, emphasising the need to preserve green spaces in areas with growing development. By observing the direct effects of these trees on their surroundings, such as lower temperatures in their shade or the cleaner air they help produce, urban residents become more susceptible to environmental problems such as climate change and pollution. These trees also have cultural and historical importance, often associated with local traditions, stories, and legends. They serve as natural monuments, linking the past with the present and the future. This connection fosters a sense of responsibility among the urban population, encouraging them to protect and preserve trees as part of their legacy. Respect for these trees can lead to a broader awareness of environmental issues as people realise the value of preserving not only individual trees but also the wider natural world that supports them.

Ancient urban trees are invaluable educational tools. Schools, community groups, and environmental organisations often use them as focal points for teaching ecology, conservation, and sustainable development. By interacting with them, people, especially the younger generation, develop a deeper appreciation for the environment. They will learn about the interconnectedness of all living beings and the importance of long-term thinking in environmental management. The presence of ancient trees in urban areas can also influence urban planning and policy. Urban planners and policymakers, inspired by the longevity and benefits of these trees, may be more likely to incorporate green spaces into urban projects. They can also promote policies that protect existing trees and encourage the planting of new ones. This leads to more sustainable urban development in which cities will be better equipped to address environmental issues. Ancient urban trees play a crucial role in promoting environmental awareness by providing illustrative examples of nature's sustainability, cultural continuity, and environmental importance. They serve as a reminder of the long-term human impact on the environment and inspire actions that contribute to a more sustainable future.

These trees often serve as physical anchors in the landscape, providing continuity in environments that are constantly changing due to urban development. They have experienced wars, social changes, and the evolution of cities, which makes them witnesses to the passage of time. They are often associated with historical events or personalities, choosing symbols of endurance and perseverance. For example, a tree under which important meetings or ceremonies were held can become a symbol of the common history and values of the community. By preserving these trees, society maintains a tangible connection with its past, ensuring that the memories and stories associated

with them will not be lost. Ancient trees in urban settings are also the centres of society's identity. They can be landmarks that help define the character of a neighbourhood or city, offering a sense of place and continuity. In many cases, these trees are deeply rooted in local culture, mentioned in folklore, songs, and literature. People gather around them for celebrations, ceremonies, or just as a meeting place, strengthening social bonds and a collective sense of belonging. The presence of such trees can contribute to pride in the local legacy, encouraging residents to take an active part in preserving their cultural and natural environment.

Throughout history, trees have had deep spiritual and symbolic importance in many cultures. Ancient urban trees are often revered as sacred or mystical, associated with deities, spirits, or religious rituals (Cheng and Monroe, 2012). For example, in many cultures, certain trees are believed to represent the presence of gods or ancestors, and people may leave offerings or perform rituals at their feet. The spiritual reverence for these trees emphasises their role as guardians of cultural legacy, embodying the intangible aspects of cultural identity that are passed down from generation to generation. Their preservation is often seen as a moral and spiritual duty, reflecting the cultural values and beliefs of society. Ancient trees are repositories of traditional ecological knowledge. They are related to practices and customs that have been passed down orally from generation to generation, such as medicinal plant use, seasonal cycles, or agricultural practices. These trees can play a central role in traditional ceremonies, narratives, or educational practices, serving as a means of transmitting knowledge and cultural practices to younger generations. Thus, the trees themselves become symbols of cultural continuity, embodying the wisdom and traditions of the past. Their preservation ensures that this knowledge remains a living part of the culture and does not disappear into obscurity.

The cultural importance of ancient urban trees extends to the fields of art and literature, often inspiring poets, writers, and artists who rely on their symbolism and historical associations to create works that echo cultural legacy. Depicted in paintings, mentioned in poems or represented in local legends, these trees contribute to the cultural narrative of the place and enrich the artistic and literary legacy of the society, acting as constant sources of inspiration that connect the creative manifestations of the present with the traditions of the past. Nowadays, the preservation of ancient urban trees has become a major challenge in the face of urban expansion and development. They are increasingly recognised as integral components of cultural legacy that deserve protection and preservation. Conservation efforts often involve collaboration between local communities, historians, environmentalists, and urban planners, reflecting a broader understanding of legacy that includes both the human environment and the natural world. Protecting these plants ensures that future generations will be able to continue to get to know and communicate with the cultural legacy they represent.

Incorporating ancient trees into educational and environmental programs, alongside the use of contemporary technology, can substantially elevate public awareness and promote impactful conservation efforts. A fundamental step in attaining these objectives is the creation of comprehensive teaching programs that address the ecological, cultural, and historical importance of ancient trees. These programs must incorporate lessons that emphasise the essential roles of these trees in urban ecosystems, their historical significance in the environment, and their cultural relevance to local populations. Incorporating this knowledge into the curriculum fosters a profound appreciation for ancient trees and underscores the importance of their conservation.

Promoting school-organized field trips to see local ancient trees provides kids with direct insight into their significance. These tours offer an immersive educational experience, allowing students to appreciate the trees' magnificence and ecological significance, thereby cultivating a personal bond with nature. Furthermore, developing interdisciplinary initiatives that connect disciplines such as biology, history, geography, and art through the fundamental concept of ancient trees might enhance students' educational experiences. A project may encompass the examination of the scientific characteristics of tree species, the investigation of their historical significance in the city, the mapping of their geographical distribution, and the creation of creative representations influenced by their forms and textures.

Conducting workshops for all age demographics focused on the care, preservation, and history of historic trees enhances the scope of conservation initiatives. These workshops offer essential insights into optimal tree preservation procedures, the need of conserving these natural monuments, and the historical events they have experienced. Community events like tree planting days, storytelling sessions, and cultural festivals honouring historic trees foster active engagement and celebrate the shared heritage linked to these trees. These assemblies cultivate a feeling of community and collective accountability, motivating locals to engage actively in conservation efforts.

Initiating citizen science projects enables community people to actively participate in the monitoring and conservation of historic trees. These projects cultivate a stronger relationship with the natural environment by engaging the public in the collecting of data regarding tree growth, health, and local biodiversity. Citizen scientists can monitor alterations in tree health, detect potential hazards, and provide significant data that might guide conservation measures. Partnering with cultural institutions to include ancient trees in legacy conservation initiatives enriches the connection of these trees to the overarching narrative of cultural identity and local history. This cooperation can promote discourse on the significance of environmental conservation and the function of historic trees in preserving cultural continuity.

Incorporating old trees into urban development is essential for their sustained preservation. Classifying these trees as protected landmarks in urban green spaces safeguards them against development encroachments. Establishing green corridors that link old trees fosters biodiversity networks, enhances ecological resilience, and elevates awareness regarding nature conservation. Offering incentives to landowners and municipalities, such tax reductions or subsidies for conservation initiatives, promotes the preservation of historic trees. Advocating for the establishment of tree protection legislation that imposes fines for unwarranted removal or damage enhances the safeguarding of these essential natural resources.

Public awareness efforts are essential in emphasising the environmental advantages of old trees, including their contributions to carbon sequestration, air purification, and biodiversity preservation. Utilising old trees as symbols in extensive environmental campaigns associates their preservation with overarching concerns such as climate change and habitat destruction, so enhancing the message and fostering mass advocacy. Developing interactive digital maps that display ancient trees in urban environments enables users to identify, acknowledge, and explore these trees, enhancing engagement and appreciation. Creating smartphone applications that offer comprehensive information regarding the history, species, and ecological significance of each tree, augmented by augmented reality (AR) capabilities, can render the learning experience more interactive and engaging.

Contemporary technologies like virtual reality (VR) and augmented reality (AR) facilitate immersive experiences that enable anyone to investigate old trees and their ecosystems, regardless of their ability to visit them physically. Educational VR modules that replicate the life cycle of ancient trees, their ecological significance, and the challenges they encounter can offer an in-depth comprehension of their relevance. Leveraging social media tools to disseminate narratives, photographs, and videos of old trees promotes public visitation and engagement. Developing viral challenges or hashtags that encourage individuals to share their encounters with ancient trees can enhance awareness and fortify community connections. Promoting the utilisation of applications for uploading photographs and information regarding ancient trees aids in the establishment of a global database that monitors their health and status, thereby enabling informed conservation initiatives. Drones can be utilised to assess the health of ancient trees, particularly in inaccessible locations, offering comprehensive data on their status. Drones capture aerial imagery that produces captivating visual content, which may be disseminated online to increase interest and support for conservation initiatives. Utilising blockchain technology to uphold transparent and verifiable records of conservation initiatives, contributions, and the protected status of ancient trees guarantees accountability and ongoing engagement. Blockchain can facilitate community-initiated conservation projects, ensuring efficient resource utilisation and promoting trust among stakeholders.

Partnering with technology firms to create novel tools and platforms can enhance public accessibility and engagement with old trees. Collaborations with environmental NGOs, educational institutions, and local governments can enhance the reach of these technologies and projects, ensuring a unified and thorough approach to conservation. Collaborating with museums, historical societies, and cultural organisations to incorporate old trees into exhibitions, field trips, and public lectures incorporates these natural icons into the community's cultural and educational framework. Incorporating ancient trees into local tourist initiatives establishes them as significant attractions that connect natural and cultural history, fostering economic advantages while encouraging conservation. By combining educational efforts with modern technology, ancient trees can be brought to the forefront of public consciousness. This approach not only raises awareness but also empowers people to play an active role in the preservation and appreciation of these vital components of our natural and cultural legacy.

Concluding this subparagraph, it is important to recognise the profound impact of ancient urban trees on education, culture, and environmental awareness. These trees are not just remnants of the past; they are living archives that connect us with the history, ecology and culture of the urban environment. Integrating them into educational and environmental initiatives is not only a way to preserve nature but also to enrich people's cultural legacy and promote a deeper understanding of their environmental responsibilities. Modern technology offers exciting opportunities to increase public engagement in the life of ancient trees. Digital platforms, virtual reality, and mobile applications can bring the stories of these trees to a wider audience, making their preservation relevant for today's technologically advanced generation. Using these tools can ensure that the knowledge, beauty, and importance of ancient trees will be passed on to future generations, which will enhance their role as vital components of both our natural and cultural landscapes.

Ancient urban trees, as living monuments of the past, offer a wealth of opportunities for education, public participation, and environmental protection. They serve as catalysts to create community, inspire environmental awareness, and provide valuable knowledge about history,

ecology, and cultural legacy. Summarising, ancient urban trees are invaluable resources that connect the past and the present, acting as educational tools, cultural symbols, and environmental pillars. Their preservation and integration into modern initiatives are crucial to creating a sustainable and culturally rich future.

2.4 The psychological and social benefits of preserving urban ancient trees

In recent decades, considerable attention has been paid to the issues of sustainable urban development and the preservation of their natural legacy. One of the most striking and substantial elements of the urban ecosystem are ancient trees, which represent living monuments of nature and play an important role in the life of urban communities. These trees, with their impressive size and age, become symbols of sustainability and continuity, as well as a source of many psychological, social, environmental, and economic benefits. In conditions of rapid urbanisation and climate change, the preservation of ancient trees is becoming not only an urgent, but also a necessary task that requires an integrated approach and attention from both local authorities and residents themselves.

Ancient trees growing in cities represent an important element of the urban ecosystem, affecting the psychological and social well-being of residents. Their impact on human health is multifaceted: they reduce stress levels, create cozy relaxation areas, and help improve mood. In addition, such trees serve as natural filters, purifying the air, and provide habitat for various species of animals, including beneficial pollinators, which enhances biological diversity in the urban environment. The advantages of ancient trees also lie in their ability to enhance the attractiveness of the city, which can contribute to the development of tourism and local business. The conservation and care of such plants is not only of ecological but also of social importance, affecting the quality of life of residents and forming a harmonious living environment.

Ancient trees in cities have a multifaceted impact on the psychological and social well-being of their inhabitants. Research shows that the presence of green spaces, especially such as ancient trees, helps to reduce stress levels, improve mood, and create a comfortable urban environment (O'Brien *et al.*, 2024). In the conditions of a modern megalopolis, where residents face constant noise, pollution and stress, the presence of such natural objects becomes especially important. Ancient trees create cozy recreation areas, promote social integration and the formation of public spaces where people can interact with each other, which, in turn, strengthens social ties and promotes the development of local community groups. This subparagraph is aimed at a comprehensive examination of the psychological and social benefits of preserving urban ancient trees, as well as their ecological and economic functions. In the context of modern challenges faced by cities, it is important to realise the value of these natural sites and develop strategies for their conservation and protection. The preservation of ancient trees is not only an environmental issue but also a matter of social responsibility, health, and well-being of citizens, which makes this subject especially relevant and important for research.

First, we want to demonstrate the psychological benefits of preserving ancient urban trees. One of the top priorities is stress reduction and mental health. This is due to the fact that ancient trees in urban environments provide natural spaces for relaxation and reflection, their presence

improves mood and overall mental well-being due to the aesthetic pleasure received from plants, serotonin levels increase. Simply observing or being near these trees can reduce cortisol levels and promote a sense of calm. Watching or being near trees can have a calming effect on the cardiovascular system and reduce heart rate and blood pressure. Staying under ancient trees or walking among them can induce a meditative state that promotes awareness of the present moment, which is a powerful antidote to anxiety and reflection.

In an increasingly artificial urban environment, ancient trees satisfy an innate human need for connection with nature, known as biophilia. This connection can contribute to a sense of belonging to the natural world, to a larger natural system, by combating the sense of isolation prevalent in urban settings, which is crucial for psychological health. The impressive size and age of these trees evoke a sense of awe, which is associated with increased life satisfaction and stress reduction, and the multisensory experience of interacting with trees (touch, smell, sight) helps people to feel a connection with the earth and nature directly. In rapidly changing cities, ancient trees provide a sense of stability and continuity. Their longevity gives confidence and can help people contextualise their lives over a wider time frame, potentially reducing anxiety about change, and the unchanging nature of these plants amid the urban flow can give a sense of emotional grounding. Thinking about the age and endurance of these trees helps people rethink personal problems, and trees become silent witnesses, allowing them to emotionally release and process feelings in an unbiased space.

Exposure to natural elements such as ancient trees is associated with improved cognitive functions, including better concentration, creativity, and problem-solving skills. This is especially valuable in conditions of high stress levels in an urban environment. According to the theory of attention restoration, a natural environment similar to that provided by ancient trees helps to restore depleted cognitive resources, research shows that even short-term exposure to natural elements can improve concentration and attention span; complex patterns and shapes of ancient trees stimulate creative thinking and the ability to solve problems, and the unique and often striking appearance of ancient trees serve as anchors of memory, potentially helping to remember and learn. Interacting with nature, especially with prominent elements such as ancient trees, can boost self-esteem and overall life satisfaction. These plants act as objects of pride for local residents, enhancing their sense of place and belonging, as trees often become landmarks that people use to orient themselves, both physically and psychologically, in their surroundings, and the unchanging nature of trees provides a sense of personal continuity, linking the past, present, and future. Interaction with ancient trees strengthens a person's identity as an environmentally conscious person.

Interacting with and preserving ancient urban trees can contribute to the development of social and emotional intelligence, such as empathy, as caring for trees can extend to an increased interest in other living beings and the environment in general; observing the slow growth and changes of trees develops patience and long-term thinking, and participation in tree conservation efforts enhances a sense of social responsibility and effectiveness. For many, ancient urban trees provide a connection to something greater than themselves, they evoke a sense of transcendence, connecting people with a sense of something sublime or divine, the unchanging nature of trees helps people find meaning and purpose, especially when faced with existential questions, and also create natural shelters for reflection and spiritual practices. The psychological benefits of preserving urban ancient trees are extensive and interrelated. By providing natural spaces for relaxation, contemplation, and participation in society, they play a vital role in maintaining and strengthening

the mental health of the urban population. Their preservation is not only an ecological but also a psychological imperative, making a substantial contribution to the well-being and sustainability of urban residents.

The social benefits of preserving ancient trees in the city are also multifaceted and affect every resident, for example, ancient trees often become natural meeting places, promoting social interaction and cohesion of people, they serve as venues for social events or just common spaces for casual meetings, trees create a sense of place, strengthening social ties and social cohesion. They provide a neutral territory where people from different walks of life can come together, promoting social integration and reducing isolation. These plants often have substantial cultural or historical value, acting as living links to the city's past, they become sources of local identity and pride, strengthening the cohesion of residents and a sense of common legacy. In addition, ancient trees are important characters in local legends and folklore, enriching the cultural narrative of the area, as well as landmarks that define the identity and character of the area. Ancient urban trees provide clear and accessible examples of environmental education. They can be used to teach ecology, history, and the importance of preserving the environment, contributing to increasing environmental awareness of the urban population. They are tangible examples of the importance of long-term conservation efforts and catalysts for discussions about climate change and urban sustainability. By raising environmental awareness, they can inspire society to participate in conservation efforts.

Preserved ancient trees in public places provide all residents of the city, regardless of socio-economic status, with a free and accessible natural experience, this contributes to social justice in terms of access to nature and its benefits. Trees provide free and accessible natural experiences to all residents, regardless of socio-economic status, creating shared spaces that transcend social differences and offering health benefits (such as clean air and shade) equally to all members of society. This equal access to nature helps mitigate some of the effects of urban inequality. Efforts to preserve ancient trees often stimulate the involvement of residents and civic engagement, which leads to greater participation in local decision-making and a stronger sense of belonging and responsibility of society through active participation of people in local decision-making processes, the formation of local conservation groups, and joint projects between residents, local authorities, and environmental organisations. Such participation can strengthen local democracy and empower residents to shape their urban environment. Ancient trees can foster intergenerational connections as older residents share tree-related stories and experiences with younger members of the community, fostering a sense of continuity and shared history, the younger generation has the opportunity to learn about local history and develop a sense of continuity and tree planting and care initiatives can bring together different age groups. This intergenerational interaction promotes social cohesion and the transfer of local knowledge and values.

The presence of ancient trees enhances the aesthetic appeal of urban areas, potentially increasing the value of the real estate and contributing to the overall attractiveness of the areas, as well as attracting tourists interested in notable or historic trees. In addition, the presence of ancient trees reduces energy costs due to natural cooling and windproof effect. These economic benefits contribute to the general prosperity of the population. The presence of ancient trees contributes to public health by providing places for physical activity such as walking or running, improves air quality and provides shade, which is especially important in urban heat islands, and offers public spaces for relaxation and stress relief, these health benefits can reduce healthcare

costs and improve people's overall well-being. Research shows that urban green areas, including areas with ancient trees, contribute to reducing crime. There are several theories, for example, well-groomed green areas increase public supervision (the "eyes on the street" effect); the natural environment reduces aggression and aggressive behaviour; green areas contribute to the formation of a sense of territoriality among residents, increasing their investment in the security of the area.

Ancient trees play a role in shaping urban development by influencing the design and layout of urban spaces, promoting green infrastructure and sustainable urban planning, and serving as models for long-term thinking in urban development strategies, their presence directs cities towards more sustainable, livable projects (Townsend and Barton, 2018). As cultural and artistic inspiration, trees often serve as objects for local artists, photographers, and writers; community art projects and cultural events; a backdrop for performances and cultural events, such a cultural role enriches the artistic life and creative expression of the community. In conclusion, it should be noted that the social benefits of preserving urban ancient trees are far-reaching and multifaceted. These trees are not just passive natural elements of the urban landscape but also active participants in the social fabric of cities. Their preservation is an investment in the well-being of the community, social justice and the long-term liveability of the urban environment. By taking care of these living landmarks, we take care of the very essence of vibrant, connected, and sustainable urban communities.

The preservation of ancient city trees provides a wide range of psychological and social benefits; they serve not only as natural landmarks but also as essential elements of mental health, social structure and cultural identity of urban communities. Their presence substantially contributes to making cities more livable and to a sense of connection with both nature and public legacy. The preservation of such trees provides urban residents with substantial psychological and social benefits, creating a unique intersection of nature, history, and community well-being. This subject deserves a thoughtful exploration of how these venerable natural landmarks contribute to urban life beyond their ecological value. The preservation of ancient urban trees provides many psychological and social benefits that substantially improve the quality of life in cities. From a psychological point of view, these trees play a crucial role in promoting mental well-being, they serve as natural stress relievers, providing places for relaxation and contemplation in an otherwise bustling urban environment. The mere presence of these ancient living beings can reduce stress levels, improve mood, and promote overall mental health.

The psychological benefits are profound and diverse, affecting many aspects of mental well-being. In the foreground is their remarkable ability to reduce stress and ease anxiety. In an often-chaotic urban environment, these trees serve as natural oases capable of lowering cortisol levels, reducing heart rate and blood pressure, and improving overall mood. Simply spending time with these ancient living beings can induce a meditative state, promoting awareness of the present moment. Ancient trees also play an important role in improving cognitive functions. According to the theory of attention restoration, a natural environment, such as that provided by ancient trees, helps to restore depleted cognitive resources. This leads to improved concentration, increased creativity, and improved problem-solving ability. The unique and often striking appearance of these trees can even serve as anchors of memory, potentially helping in the processes of memorisation and learning. In addition, ancient urban trees contribute to emotional regulation and psychological stability. Their unchanging nature amid the urban flow gives a sense of emotional grounding while thinking about their age and stamina can help people rethink personal issues. These trees often

become silent witnesses of human experience, allowing you to experience emotional catharsis and recycle in an unbiased space.

The presence of these trees also satisfies our innate need for connection with nature, known as biophilia. This connection promotes a sense of belonging to a larger natural system, fighting the sense of isolation prevalent in urban environments. The impressive size and age of these trees can evoke a sense of awe, which is associated with increased life satisfaction and reduced stress. Interestingly, ancient urban trees can influence how people perceive themselves and their place in the world. They often become landmarks that people use to orient themselves, both physically and psychologically, in their environment. The unchanging nature of these trees can give a sense of personal continuity, linking the past, present, and future and strengthening ecological identity. Moreover, interacting with these trees and preserving them can contribute to the development of social and emotional intelligence. It can enhance empathy, develop patience, and enhance feelings of social responsibility and effectiveness. Finally, for many, these trees provide a connection to something bigger than themselves. They can evoke feelings of transcendence, help people find meaning and purpose, especially when faced with existential questions, and create natural retreats for reflection and spiritual practices.

In fact, the preservation of urban ancient trees is not only an ecological but also a psychological imperative. These living monuments make a substantial contribution to the mental health, sustainability, and overall well-being of urban residents, making their preservation an essential aspect of creating a livable and psychologically healthy urban environment. The social benefits of preserving urban ancient trees have far-reaching implications, affecting aspects of community life ranging from social cohesion and public health to civic engagement and cultural identity. These trees are not just natural elements of the urban landscape, they are also active participants in the social fabric of cities. Their preservation is an investment in the well-being of the community, social equality and the long-term liveability of the urban environment. The social benefits of preserving urban ancient trees are extensive and have a profound impact on community life. These venerable natural attractions serve as powerful catalysts for social cohesion and community engagement, offering many benefits that enhance urban life.

First of all, ancient urban trees often become natural centres for people to meet, they create attractive public spaces where people gather naturally, promoting social interaction and strengthening the bonds of society. These trees provide a neutral area where people from different walks of life can come together, promoting social integration and reducing isolation in an often-fragmented urban environment. The cultural and historical importance of these trees cannot be overestimated; they serve as living links with the city's past and often become the subject of local legends and folklore. This common legacy strengthens the ties of the people and instils a sense of pride and belonging among the residents. The trees become part of the identity of the area, contributing to its unique character and sense of place. From an educational standpoint, ancient urban trees are invaluable resources; they serve as living classrooms for environmental education, offering illustrative examples of ecology and biology and highlighting the importance of long-term conservation efforts. This raises environmental awareness and can inspire the participation of all people in broader sustainable development initiatives.

Importantly, these trees play a crucial role in promoting social equality. By providing a free, accessible natural experience to all residents regardless of socioeconomic status, they help bridge

social differences and offer health benefits equally to all members of society. This equal access to nature can help mitigate some of the effects of urban inequality. Conservation efforts for these trees often trigger increased civic engagement. People often unite around the protection of these natural attractions, which leads to more active participation in local decision-making processes. This can strengthen local democracy and enable residents to shape their urban environment actively. Ancient trees also contribute to valuable intergenerational connections. Older residents can share stories and memories related to the trees, while the younger generation learns about the local history and develops a sense of continuity. Tree planting and care initiatives can bring together different age groups, promoting understanding and respect between generations.

From a public health perspective, the presence of these trees makes a substantial contribution to the well-being of society. They provide places for physical activity, improve air quality, provide shade in urban heat islands, and create areas for relaxation and stress relief. Some studies even suggest that urban green areas, including areas with ancient trees, can help reduce crime by increasing public oversight and strengthening a sense of territoriality among residents. From an economic standpoint, the preservation of these trees can have a positive impact on the value of real estate, tourism, and energy costs due to the natural cooling effect. They also play a role in shaping sustainable urban development by influencing the design and layout of urban spaces and promoting green infrastructure. Finally, these trees often serve as sources of cultural and artistic inspiration, enriching the creative life of the community. They become objects for local artists, backgrounds for performances, and inspiration for community art projects.

In conclusion, the preservation of urban ancient trees provides a wide range of psychological and social benefits. They serve not only as natural attractions but also as essential elements of mental health, social structure and cultural identity of urban communities. Their presence makes a substantial contribution to making cities more livable, strengthening a sense of connection with both nature and public legacy, and ultimately enhancing the overall well-being of urban residents. The examination of the humanistic values embodied in ancient urban trees identifies their profound importance, going beyond a simple ecological or aesthetic contribution. These venerable living monuments play a crucial role in promoting social equality, community well-being, and cultural wealth in an urban environment. By providing a freely accessible natural experience, ancient trees offer an element of equalisation in cities, allowing people to enjoy nature regardless of socio-economic status. Their health benefits, from air purification to stress reduction, are available to all nearby residents, helping to alleviate health inequalities in urban areas. Moreover, these trees represent a common historical and cultural legacy that can unite a diverse urban population. Their presence in different areas can be an indicator of environmental justice, and conservation efforts often coincide with broader environmental justice initiatives.

Ancient urban trees are becoming centres of public protection, giving residents the opportunity to participate in urban planning and environmental decision-making. They offer contemplative spaces that support mental well-being, which is especially valuable in densely populated areas, and play an integral role in nature therapy programmes. The preservation of these trees ensures that future generations can benefit from their presence, embodying the principle of intergenerational responsibility in urban planning and conservation. Many ancient trees are important to various cultural groups, contributing to cultural diversity and mutual understanding. In some cases, they are linked to the history of indigenous peoples, supporting recognition and respect for

indigenous cultures in urban settings. Economically, they can contribute to the local economy through tourism or cultural activities, potentially benefiting the surrounding communities. The care and promotion of ancient trees also create local employment opportunities in horticulture, tourism, and education. By embodying and promoting these many humanistic values, ancient urban trees make a substantial contribution to creating a more equitable, healthy, and socially cohesive urban environment. Their preservation and integration into urban planning represent a commitment to humanistic values in the development of the city, ensuring that the benefits of nature will be available to all, regardless of social or economic status.

Chapter 3.

Environmental impact assessment and conservation strategies

Ancient trees are unique and complex ecosystems, central to maintaining biodiversity and forest function. These organisms, many of which have survived for centuries and sometimes millennia, are not only home to a variety of flora and fauna, but also perform important ecological functions such as carbon sequestration, water balance regulation and soil fertility maintenance. In the context of global climate change and anthropogenic impact on nature, the protection of ancient trees is becoming a particularly urgent task that requires an integrated approach and a deep understanding of their role in ecosystems. The relevance of this section is determined by not only the importance of ancient trees for ecosystems but also the threats they face in the modern world. Deforestation, urbanisation, climate change, diseases and pests are all factors that can lead to the extinction of these unique organisms. Importantly, the loss of ancient trees can have catastrophic consequences for the ecosystems in which they live, as well as for biodiversity in general. Therefore, research into the ecosystem benefits of ancient trees, their role in species conservation and the development of conservation strategies are essential to ensure the sustainability of natural systems.

We believe it is necessary to consider several key topics related to ancient trees. First, the ecosystem benefits they provide. Ancient trees are important sources of food and shelter for many species of animals, as well as contributing to the microclimate and improving soil quality. Their root system helps prevent erosion, and their crown helps regulate the moisture level in the forest and the city. Another important aspect is the role of ancient trees in species conservation. These organisms are home to many rare and threatened species that depend on them for survival. Researching the relationship between ancient trees and biodiversity will determine how their loss can affect the ecosystem as a whole in more detail. It is equally necessary to analyse the threats faced by ancient trees. It is worth demonstrating how anthropogenic factors such as deforestation and climate change, as well as natural threats (diseases and pests), can endanger these plants. Determination of these threats is a necessary step in developing effective strategies to protect them. Existing approaches to protection, including the creation of nature reserves, reforestation programmes and legislative measures to protect ancient trees, will be analysed. Attention will also be devoted to international experience in this area, which will help identify best practices and adapt them to local conditions.

The impact of ancient trees on the climate is also an important topic. Their contribution to carbon sequestration and how their conservation can help fight climate change will be addressed. Ancient trees as indicators of ecosystem health is another noteworthy topic. Their condition can serve as an indicator of the overall health of the forest and urban green spaces, and the ecosystem as a whole, making them important targets for monitoring. Methods of researching ancient trees, including modern technologies such as remote sensing and genetic research, will also be discussed. This will determine how modern scientific approaches can help protect and study these organisms. Comparative analysis of ancient tree protection in different countries will identify successful practices and approaches that can be applied in other regions. It will also determine how cultural and economic factors influence security strategies. Lastly, future of ancient trees in the face of climate change will be discussed. How they will be able to adapt to the new conditions and what measures

should be taken to protect them in the face of global change. Answers to these questions will help to form a more complete picture of the importance of ancient trees and the need for their protection. Thus, this section aims to provide an in-depth study of the ecosystem consequences of ancient trees and strategies for their protection, which is an important step towards the conservation of biodiversity and ecosystem resilience in the face of modern challenges.

3.1 Ecological importance of ancient trees in urban ecosystems

Ancient trees play a huge ecological role in urban ecosystems, acting as cornerstones of biodiversity and ecological stability. These trees, often several centuries old, provide critical habitats for a wide variety of species, including birds, insects, fungi and small mammals. Their large hollow trunks and extensive crowns create unique microhabitats that are indispensable for certain organisms (Niemelä, 1999). The presence of such biodiversity increases the sustainability of urban ecosystems by promoting ecological balance, maintaining food chains and regulating populations of different species. In addition to their role in maintaining biodiversity, ancient trees make a significant contribution to the health of urban environments by improving air quality and mitigating climate change. They absorb large amounts of carbon over their long lifespan, helping to reduce CO₂ levels in the atmosphere. Their extensive crowns provide shade, and cool urban areas and reduce the heat island effect, which is a common problem in cities. This cooling effect not only softens the temperature but also reduces the energy required for cooling, contributing to the overall sustainability of the city.

Ancient trees are also significant in maintaining soil quality and hydrological balance. Their deep root systems stabilise the soil, preventing erosion and facilitating water infiltration. By capturing rainwater, they reduce surface runoff and reduce the risk of flooding, which is becoming an increasingly serious problem in urban areas due to the increase in impervious surfaces. In addition, these trees enrich the soil with organic matter by shedding their leaves and branches, which contributes to a more fertile environment for other plants and trees to thrive. In addition to their environmental benefits, ancient trees are cultural and historical landmarks that enrich urban green spaces. They connect people with nature, offering psychological and recreational benefits to city dwellers. The presence of such venerable trees in urban landscapes can inspire conservation efforts, highlighting the importance of integrating natural heritage into urban planning and environmental management. In general, ancient trees are important components of urban ecosystems. They enhance biodiversity, improve air and soil quality, regulate urban climate and provide cultural and recreational value, making their conservation essential for the sustainability and resilience of cities. Below we will elaborate on each of these points, demonstrating the main ecological functions that trees perform.

Ancient trees serve as critical biodiversity hotspots in urban ecosystems, hosting a multitude of life forms and playing a key role in maintaining urban biodiversity. Their complex structures and long-life cycles create unique microhabitats that support a wide variety of species, many of which are specialised to these particular environments. Ancient trees provide a variety of microhabitats within a single organism, for example, the deeply grooved bark of ancient trees offers numerous niches for epiphytic plants (e.g. mosses, ferns), invertebrates (e.g. beetles, spiders) and microorganisms (e.g. bacteria, fungi). Cavities and hollows form natural shelters for nesting birds (e.g. owls, woodpeckers), mammals (e.g. bats, squirrels), amphibians and reptiles. Decaying parts of

the tree support provide habitat for saproxylic insects (those that depend on dead wood), wood-decomposing fungi and slime moulds. The vast canopy provides shelter for arboreal mammals, various species of birds, insects and arachnids living in the forest canopy. And the extensive root network supports mycorrhizal fungi, soil fauna (e.g. earthworms, nematodes) and root-related bacteria.

Thanks to ancient trees, there is an exceptionally large number of species of flora and fauna. An ancient oak tree can contain up to 2,300 species; invertebrate diversity is particularly high, with hundreds of insect species found on a single tree; fungi are abundant, both with visible fruiting bodies and microscopic mycelia; and lichen communities on ancient trees can be incredibly diverse, with some trees supporting more than 100 species. Many species are specially adapted to the conditions provided by ancient trees, as saproxylic insects and many rare species of beetles depend on the dead wood of ancient trees. Epiphytic lichens are found only on the bark of very old trees. Some species of mushrooms only bear fruit on mature trees. Several species of bats depend on the special conditions provided by hollows in ancient trees. The longevity of ancient trees provides temporal continuity in the ecosystem. They act as reservoirs of biodiversity over time, sustaining populations through urban development and change. Old trees carry the “ecological memory” of a place, preserving genetic diversity and the interaction of species over the centuries.

As biodiversity hotspots, ancient trees are important for the connectivity of urban ecosystems, as they are used to traverse across fragmented urban landscapes and act as source populations for the repopulation of restored or newly created urban habitats. The great biodiversity associated with ancient trees contributes to the sustainability of the ecosystem. This is because a greater diversity of species can increase the ability of an ecosystem to withstand and recover from disturbances, and the genetic diversity preserved in these pockets can be crucial for adaptation to urban change and climate change. The recognition of ancient trees as biodiversity hotspots has important conservation implications for several reasons. It emphasises the need to preserve individual ancient trees, not just forests, and demonstrates the importance of maintaining the continuity of tree ages in urban forests to ensure future ancient trees and the value of dead and decaying wood as important elements of biodiversity. Ancient trees in urban environments are much more than just impressive natural monuments; they are complex, living ecosystems in themselves.

As biodiversity hotspots, they are crucial in maintaining the ecological health and sustainability of urban areas. Their conservation is vital not only for the preservation of individual species but also for the complex network of life that supports the functions of the urban ecosystem. In the context of rapid urbanisation and biodiversity loss, the protection and recognition of these tree elders is becoming increasingly important for a sustainable urban ecology. The recognition of ancient trees as biodiversity hotspots has important conservation implications. It emphasises the need to conserve individual ancient trees, not just woodlands, and the importance of maintaining continuity of tree ages in urban woodlands to ensure future ancient trees and notes the value of dead and decaying wood as important elements of biodiversity.

Ecosystem connectivity. Ecosystem connectivity refers to the extent to which landscapes facilitate or impede the movement of organisms and matter between different habitat areas. In urban environments, where natural habitats are often fragmented and isolated, ancient trees play a crucial role in maintaining this connectivity. They serve as ecological bridges, facilitating the flow of species, genes and ecological processes through the urban matrix. Ancient trees contribute to two main types of connectivity:

1. Structural coherence: the physical connection between habitat areas.
2. Functional coherence: the extent to which landscapes facilitate the movement of organisms and ecological processes.

One of the main ways that ancient trees improve ecosystem connectivity is by acting as stepping stones. They provide temporary habitats for mobile species moving across the urban landscape, allowing species to move into inhospitable urban areas and create a network of connected habitats across the city. Ancient trees contribute to the genetic flow between populations. This means that they support pollinator species that transfer genetic material between plant populations, provide habitat for seed-dispersing animals, facilitate the flow of plant genes, and maintain genetic diversity in urban wildlife populations by allowing exchange between isolated groups. Older trees can create microclimatic corridors in urban areas, as their canopies regulate temperature and humidity, create more hospitable pathways for temperature-sensitive species, and facilitate the movement of species that might otherwise be restricted to urban heat islands. Ancient trees keep nutrients and energy flowing in the city – their leaf litter provides nutrients to surrounding areas, supports insect populations that provide food for birds and bats, facilitates energy transfer between trophic levels, and their extensive root systems can connect underground food networks in urban spaces.

The longevity of ancient trees provides temporal connectivity by acting as living links between past and present ecosystems and ensuring habitat continuity over time, which is crucial for species with long life cycles or special habitat requirements. Ancient trees are particularly important for connecting specialised species. This is because many saproxylic insects that depend on dead wood use networks of ancient trees to maintain their populations, and certain types of lichens and fungi spread between ancient trees, relying on the special conditions of their bark. In urban planning, ancient trees are recognised as key elements of green infrastructure, often included in urban wildlife corridors, forming key components of ecological networks in urban biodiversity plans, and influencing the design of new green spaces to improve overall urban connectivity. Several factors can affect the connectivity provided by ancient trees, among them: urban development, leading to the removal or isolation of trees; air pollution, affecting the health of trees and related species; climate change, changing the suitability of trees for certain species.

Conservation efforts can enhance the connectivity of ancient trees. The main methods include the protection of individual ancient trees and their surrounding areas; the creation of buffer zones around ancient trees to extend their influence; the planting of future ancient trees to ensure long-term connectivity; creation of green corridors linking ancient trees in urban landscapes. Determination of the connecting role of ancient trees requires constant research. This could be using GPS and radio-tracking to study animal movements between trees; genetic studies to measure gene flow between populations; or long-term ecological studies to track correlated changes over time. Ancient trees are essential components in maintaining ecosystem connectivity in urban environments. They serve as living bridges across fragmented urban landscapes, facilitating the movement of species, genes and ecological processes.

By maintaining biodiversity, softening the microclimate and providing temporal continuity, these trees play an indispensable role in the urban ecology. As cities continue to grow and face environmental challenges, the role of ancient trees in ecosystem connectivity is becoming increasingly important for creating sustainable and resilient urban ecosystems. Ecosystem connectivity

is a fundamental concept in ecology, and ancient trees play a key role in maintaining this connectivity in urban environments. In cities, where natural habitats are often fragmented and isolated, these venerable trees serve as essential ecological bridges, facilitating the flow of species, genes and ecological processes across the urban matrix. Ancient trees contribute to both structural and functional connectivity in urban ecosystems. Structural connectivity refers to the physical relationship between habitat patches, while functional connectivity refers to how landscapes facilitate the movement of organisms and ecological processes. In both aspects, ancient trees are priceless.

Carbon sequestration and storage. Ancient trees are significant in the global carbon cycle, especially in urban areas where green space is limited. These trees act as significant carbon sinks, continuously consuming carbon dioxide from the atmosphere and storing it in their biomass and the surrounding soil. Determination of this process is crucial for urban planning and climate change mitigation strategies. The carbon sequestration process involves several aspects: photosynthesis, biomass accumulation and soil carbon. Ancient trees, like all plants, use photosynthesis to convert atmospheric CO₂ into organic compounds. As trees grow, they store carbon in their trunks, branches, leaves and roots, and contribute to soil carbon through root growth, fallen leaves and other organic matter. Ancient trees have several characteristics that make them particularly effective in sequestering and storing carbon. For instance, their sheer size means they contain much more stored carbon than younger trees, contrary to previous perceptions, ancient trees continue to absorb carbon at high rates, their extensive root networks contribute significantly to underground carbon storage, and their long-life spans ensure that carbon is stored for long periods.

The amount of carbon stored in ancient trees can be significant, for instance, a single large old tree can store as much carbon as an entire young forest. Recent studies challenged the notion that old trees are carbon neutral, ancient trees can sequester up to 10-15% of the total carbon stored each year, and it has been found that the rate of carbon sequestration by some ancient trees increases with age (Coutts *et al.*, 2016). Ancient trees contribute significantly to soil carbon because they develop extensive mycorrhizal networks that store carbon in the soil, their deep roots can store carbon deep below the surface where it is less likely to be released, and the leaf litter and other organic matter of ancient trees contribute to the long-term storage of carbon in the soil. In an urban environment, ancient trees are crucial for several reasons: they often represent a significant portion of the total carbon storage in urban forests; they can be more effective at storing carbon than planting new trees in the short to medium term; and they provide this carbon storage service in areas where space for new planting is limited.

The role of ancient trees in mitigating climate change is significant because they provide immediate and permanent carbon sequestration, their preservation prevents the release of stored carbon that would occur if they were removed, and trees offer a nature-based solution to carbon management in urban areas. Several factors can affect the ability of ancient trees to store carbon, including urban development and tree removal; stress and mortality caused by climate change; pests and diseases; and air pollution. Recognition of the carbon storage value of ancient trees has important conservation implications, as it provides an additional argument for their preservation in urban planning, highlights the need for proper care and management to maximise their carbon storage potential, and demonstrates the importance of planning for the future of ancient trees by protecting and caring for young specimens. An accurate assessment of carbon sequestration and storage is crucial. Advanced techniques such as LiDAR and allometric equations are used to

estimate biomass and carbon content, and long-term monitoring programmes are needed to understand changes in carbon storage over time.

Ancient trees should be integrated into broader urban carbon management strategies, for example, they can be included in urban carbon offsetting programmes, their carbon storage value can be factored into urban development decisions, and the plants can be part of educational initiatives on urban carbon cycles. Ancient trees in urban environments are not only historical or aesthetic assets; they are essential components of urban carbon management. Their ability to sequester and store large amounts of carbon over long periods renders them invaluable in the fight against climate change. As cities seek to reduce their carbon footprints, the conservation and proper management of ancient trees should be a key factor in urban forests and climate action plans. By recognising and maximising the carbon storage potential of these woody elders, cities can make significant strides in sustainability efforts while maintaining a connection to their natural heritage.

Ancient trees are key in maintaining and improving soil health and contributing to nutrient cycling in urban ecosystems. Their extensive root systems, long-term interaction with soil microorganisms and constant supply of organic matter make a significant contribution to soil structure, fertility and biodiversity. Older trees develop extensive, deep root systems over centuries, and these roots improve soil structure by creating channels for water and air to move through and prevent soil compaction, a common problem in urban areas. Root secretions and associated microorganisms contribute to the formation of soil aggregates, and improved soil structure increases water retention and erosion resistance. Plants contribute organic matter to the soil in several ways, for instance, ancient trees produce significant amounts of leaf litter each year, which is crucial for soil fertility and structure, as the decomposition of leaf litter slowly releases nutrients, ensuring a steady supply to the ecosystem. The death and decomposition of small roots also make a significant contribution to soil organic matter. This process goes deeper than leaf litter, affecting different soil layers. As the branches die and fall, they contribute to the organic matter content of the soil, while rotting wood provides a habitat for various organisms involved in the nutrient cycle.

Old trees are an important part of the nutrient cycle in the ecosystem. Their ability to absorb carbon and store it in biomass and soil was discussed, and additionally, some ancient trees (e.g. legumes) fix atmospheric nitrogen through symbiotic relationships, and the decomposition of leaf litter slowly releases nitrogen into the soil. Deep roots take nutrients from the lower soil layers and bring them to the surface, this “nutrient pumping” enriches the upper soil layer and makes nutrients available to other plants. Ancient trees develop extensive mycorrhizal associations over time, and such fungal networks improve nutrient uptake and transfer between plants, as well as contribute to soil carbon storage and improve soil structure. The area around the roots of trees (the rhizosphere) contains diverse microbial communities and root secretions feed these microbes, which in turn increases the availability of nutrients. In addition, ancient trees can influence the pH of the soil over time through their fallen leaves and root excretions, and this pH regulation can create microhabitats suitable for various soil organisms.

Another function performed by ancient trees is to influence the water cycle in nature. They help to retain water in the soil due to their improved structure under the influence of trees, which is especially relevant in urban areas prone to water runoff and flooding. Moreover, the deep roots of ancient trees can transfer water from the lower layers of the soil to the upper layers, a process that benefits the surrounding vegetation and soil organisms. Urban soils often contain pollutants

that can affect tree health and soil processes, but some ancient trees can play a role in phytoremediation by removing or stabilising certain pollutants, which is also one of the important functions performed by these plants. Unfortunately, the limited amount of soil in urban areas can limit the full potential of ancient trees to improve the soil, so understanding the soil benefits of these plants should be considered in urban planning and green space management. Ancient trees can be used as research objects for long-term monitoring of soil health and can be used to track parameters such as organic matter content, microbial diversity and nutrient levels. In addition, research is needed to quantify the economic value of soil improvement services provided by ancient trees.

Ancient trees are essential components of urban soil ecosystems. Their role in maintaining soil health and facilitating nutrient cycling is complex and significant. From improving soil structure and water retention to increasing nutrient availability and supporting diverse soil communities, these trees provide invaluable ecosystem services. In urban environments, where soil health is often at risk, the preservation and proper management of ancient trees are even more important. By recognising and protecting these living ecosystem engineers, it is possible to ensure healthier, more resilient urban soils for future generations. Ancient trees are key in maintaining and improving soil health and contributing to nutrient cycling in urban ecosystems. Their impact on soil processes is profound and multifaceted, stemming from their extensive root systems, long-term interaction with soil microorganisms and constant supply of organic matter.

Ancient trees are significant in urban hydrology, influencing water cycles, reducing flood risks and improving water quality. Their extensive root systems, large crowns and long-term interaction with the urban environment make them essential components of sustainable urban water management. The influence of ancient trees on the water cycle in nature was already mentioned, and it is now worth addressing the process in more detail. The large crowns of ancient trees intercept a significant amount of precipitation, reducing the volume and speed of water reaching the ground; some studies show that mature trees can intercept up to 30% of precipitation in their crowns. The water that reaches the ground is distributed more evenly through the trunk flow and throughflow, which helps prevent soil erosion and promotes gradual water percolation. The extensive root systems of ancient trees create channels in the soil, improving water infiltration, and the improved soil structure around these trees increases the water-holding capacity of the soil.

Ancient trees with their large root systems can absorb huge amounts of water, and this absorption capacity helps to reduce surface runoff during heavy rains. In urban floodplains, ancient trees are critical in slowing down floodwaters and reducing flood peaks. The deep root systems of ancient trees also help stabilise the soil, reducing erosion during floods. The influence of ancient trees improves water quality. This is done in several ways: filtration, nutrient uptake and sludge capture, each of which is noteworthy. As water percolates through the soil around ancient trees, it undergoes natural filtration, where the tree roots and associated microorganisms help remove pollutants from the water. Ancient trees absorb excess nutrients that could otherwise pollute water bodies, which is especially important in urban areas with high levels of nutrient runoff. The complex root system and associated vegetation around ancient trees trap sediment, which reduces sedimentation in urban water bodies and improves water clarity.

By improving soil structure and creating channels, ancient trees improve groundwater recharge, which is crucial in urban areas where impermeable surfaces often prevail. Deep roots of ancient trees can access and use groundwater, potentially regulating the water level. Heat islands

in the city were already mentioned, and ancient trees have a significant impact on mitigating the effects of such islands, for instance through evapotranspiration and shading. Therefore, trees emit a significant amount of water vapour, which helps to cool the urban environment, indirectly affecting the urban water cycle. The large canopies provide extensive shade, reducing evaporation from the soil and water bodies.

There are several current problems in the urban environment, among them is:

- Limited soil volume in urban areas, limiting the hydrological benefits of ancient trees.
- Compaction of urban soil, reducing the benefits of water infiltration by trees.
- Pollutants in urban runoff put stress on ancient trees, potentially reducing their hydrological functions over time.

However, ancient trees, with their extensive root systems, can help urban areas become more resilient to both droughts and heavy rainfall, and the role of ancient trees in both carbon sequestration and water management makes them valuable in climate change adaptation strategies, which once again points to the need to study and conserve these plants. Ancient trees are invaluable assets in urban hydrology. Their role in stormwater management, flood mitigation, water quality improvement and groundwater recharge render them essential components of sustainable urban water management systems. As cities face growing challenges from urbanisation and climate change, the conservation and integration of ancient trees into urban planning is becoming increasingly important. By recognising and maximising the hydrological benefits of these tree elders, cities can increase their resilience to water-related challenges while preserving their natural heritage. The role of ancient trees in urban hydrology is multifaceted and crucial, especially in the context of growing urbanisation and climate change. These plants have a significant impact on water cycles, reduce flood risks and improve water quality in urban areas.

Ancient trees play a pivotal role in regulating the microclimate within urban environments, significantly enhancing the livability of cities and mitigating the adverse effects of climate change. Their immense size, complex structure, and dynamic physiological processes collectively influence local temperature, humidity, wind patterns, and air quality. One of the primary ways these trees exert their influence is through their large crowns, which provide extensive shade and can reduce surface and air temperatures by up to 15°C compared to unshaded areas. This shading effect not only cools the immediate environment but also lessens the overall urban heat island effect, making areas with ancient trees several degrees cooler than their surroundings. Transpiration is another critical process by which ancient trees contribute to climate regulation. By emitting significant amounts of water vapor, these trees absorb heat from the air, thereby cooling the environment. This process also increases local humidity levels, creating more comfortable conditions in typically dry urban settings. Additionally, the large leaf surfaces of ancient trees facilitate dew formation, which supports the local water cycle and benefits surrounding vegetation. The substantial canopy of these trees also alters the albedo of urban surfaces, affecting how much solar radiation is absorbed or reflected by the landscape.

Ancient trees serve as natural windbreaks, effectively reducing wind speeds in urban areas. This reduction not only creates more comfortable open spaces but also minimizes heat loss from buildings during winter months. By decreasing overall wind speed, trees enhance air circulation, which helps disperse pollutants and moderate extreme temperatures. The expansive leaf surfaces of these trees are adept at trapping particulate matter, with studies indicating that trees can

remove up to 50-60% of airborne particulates. Moreover, trees absorb various gaseous pollutants such as ozone, nitrogen oxides, and sulfur dioxide, further improving air quality. Through the process of photosynthesis, ancient trees produce substantial amounts of oxygen, with a single mature tree capable of supplying enough oxygen for two to four people daily. The combined effects of shading and evaporative cooling not only reduce urban temperatures but also lower the need for artificial cooling in buildings. This reduction in energy consumption leads to decreased carbon emissions, contributing to a more sustainable urban environment. Furthermore, ancient trees help stabilize the microclimate by buffering sudden temperature changes, which benefits both human comfort and urban ecosystems.

Deciduous ancient trees offer the added advantage of seasonal regulation, providing shade during the summer months and allowing sunlight to penetrate in the winter. This natural adjustment enhances year-round comfort in urban spaces, making them more adaptable to varying climatic conditions. Overall, the presence of ancient trees is indispensable for creating resilient and comfortable urban environments, underscoring the importance of preserving these natural giants in our cities. Urban environmental issues can limit the full potential of trees in regulating the microclimate, for instance, urban development often reduces the space available for large trees, and air pollution and other urban stressors affect the health of trees, reducing their ability to do so. It is necessary to monitor the condition of plants in the city, as they not only improve the ecosystem but also have a beneficial effect on humans. For instance, microclimate regulation by ancient trees significantly improves thermal comfort in the open air, which contributes to active recreation and improves public health, and the presence of large old trees is associated with reduced stress and improved mental well-being.

Ancient trees are powerful sources of climate control in urban environments. Their ability to moderate temperature and humidity, change wind patterns and improve air quality make them invaluable assets in creating better urban spaces. As cities grapple with the challenges of urbanisation and climate change, the role of ancient trees in regulating the microclimate is becoming increasingly important. Preserving existing ancient trees and planning for future ones should be a priority in urban development strategies. By harnessing the natural climate control capabilities of such plants, cities can create a more comfortable, healthy and sustainable urban environment for their residents. The role of ancient trees in regulating the microclimate in urban environments is profound and multifaceted, significantly affecting local temperature, humidity, wind patterns and air quality, creating more better urban spaces and helping to mitigate the effects of climate change in cities.

Ancient trees serve as repositories of ecological memory and play a crucial role in increasing the resilience of ecosystems, especially in urban areas. Their longevity, genetic diversity and complex interactions with the environment make them key components in maintaining ecosystem stability and adaptability over time. Scientists believe that ancient trees have ecological, genetic and soil memory. Ecological memory refers to the way ecosystems store past events and conditions, influencing their present and future responses to environmental change. Their long-life span can carry information about past environmental conditions. Indicators such as annual rings, genetic adaptation and symbiotic relationships reflect historical ecological data. Ancient trees often have unique genetic variations that have been adapted to local conditions over centuries, which is crucial for species to adapt to a changing environment. The root systems of ancient trees influence soil

structure and composition over long periods, and the mycorrhizal networks associated with these trees store information about soil conditions and species interactions.

Ancient trees provide complex physical structures that increase ecosystem resilience. Ecosystem resilience is the ability of an ecosystem to respond to disturbances by resisting damage and recovering quickly. Multiple habitats within a single tree support different species, increasing the overall sustainability of the ecosystem. Older plants often support several species that perform similar ecological functions, and this redundancy ensures that ecosystem processes continue even if some species become extinct. The genetic diversity of ancient trees enhances the ecosystem's ability to adapt to environmental changes, and their long-term presence allows it to gradually adapt to changing conditions. Ancient trees provide constant ecosystem services over long periods, and their presence ensures the continuity of services such as air purification, water regulation and habitat provision. As many ancient trees are keystone species, disproportionately affecting ecosystem functioning, their removal can lead to cascading effects throughout the ecosystem. Urban development often leads to fragmentation of the ecosystem, which hinders the connectivity needed for sustainability. Urban pollution, soil compaction and altered hydrology can put stress on ancient trees, and these stressors can compromise their ability to maintain ecological memory and resilience.

Ancient trees are not just passive elements of urban landscapes, but also active participants in ecological memory and ecosystem resilience. Their ability to store and transmit environmental information over long periods, combined with their structural and functional role in ecosystems, makes them invaluable assets in maintaining a stable and adaptive urban environment. As cities face growing environmental challenges, the conservation and study of ancient trees are becoming critical to creating sustainable urban ecosystems. By recognising and protecting these living repositories of environmental memory, it is possible to improve sustainable urban environment creation strategies, thus better prepared for future environmental change. From the perspective of urban ecosystem services, ancient trees provide ongoing benefits over time. Their presence ensures the continuity of services such as air purification, water regulation and habitat provision. In addition, in urban environments, these trees often have cultural and historical significance, enhancing community participation in ecosystem conservation.

However, ancient trees face several problems in the urban environment. Fragmentation of the ecosystem due to urban development can compromise the connectivity needed for sustainability, although ancient trees can serve as critical nodes in fragmented landscapes. Environmental stressors such as urban pollution, soil compaction and altered hydrology can put pressure on ancient trees, potentially jeopardising their ability to maintain ecological memory and resilience. The implications of these results for conservation are significant. The role of ancient trees in ecological memory and sustainability provides good reasons for their preservation. Protecting these trees means preserving invaluable ecological information and functions. Urban planning should include ancient trees in green infrastructure plans to increase the overall sustainability of the ecosystem and consider their long-term preservation and continuity.

Ancient trees are central in supporting wildlife in urban ecosystems. Their complex structure, durability and diverse microhabitats make them invaluable resources for a wide range of animal species, from microscopic organisms to large mammals. In urban environments, where natural habitats are often scarce and fragmented, these trees serve as vital oases of biodiversity. What parts

of trees play a role in creating habitat for animals, birds, and insects will be discussed next. The canopy provides nesting sites for birds, supports arboreal mammals such as squirrels and opossums and hosts many insects and other invertebrates. The trunk and branches provide perching and sleeping places for birds and reptiles, and support climbing species such as some snakes and lizards. Cavities and hollows are necessary for nesting birds (e.g. owls, woodpeckers), provide shelter for bats and small mammals, and are nesting places for bees and other insects. The bark provides habitat for insects, spiders and other invertebrates; foraging ground for birds that pick-up bark; and support for epiphytic plants, which in turn attracts more wildlife. The root system provides shelter for terrestrial animals, supports burrowing species and creates microhabitats for soil organisms.

In addition to the above-mentioned benefits of ancient trees, which have a favourable impact on biodiversity, they are also food resources, even if they do not bear fruit. For instance, fruits and seeds are an important source of food for birds and mammals, and they support species that spread seeds, helping to restore the ecosystem. The leaves provide food for herbivorous insects, indirectly supporting insectivorous bird and animal species. Nectar and pollen are crucial for pollinators such as bees, butterflies and nectar-feeding birds. Deadwood and decay attract saproxylic insects (those that depend on dead wood) and provide food for woodpeckers and other insectivorous species. The effects of ancient urban trees on ecosystem interactions are important; for instance, they form the basis of complex food chains in urban ecosystems and support several trophic levels, from primary consumers to top predators. Old trees often act as keystone species, disproportionately influencing ecosystem function, and their presence can determine the emergence of many other species. By promoting ecological connectivity, they serve as a springboard for wildlife movement in fragmented urban landscapes and help maintain the genetic diversity of urban wildlife populations.

It is possible to argue that ancient trees in the city are a specialised habitat for other representatives of flora and fauna, they have something that cannot be found in young trees or bushes. Characteristics such as split trunks, loose bark and exposed dead wood support specialised species that depend on these conditions; ancient root systems contain complex fungal networks that preserve various soil organisms and indirectly benefit other wildlife. In addition, old trees provide constant shelter throughout the year, which is crucial in urban environments, and offer different food resources depending on the season (e.g. spring flowers, summer fruits, autumn seeds). They create a stable microclimate that protects wildlife from extreme weather conditions and provides resources for adapting urban wildlife (e.g. pigeons, raccoons), offering a familiar habitat structure for native species in a changed urban environment.

Ancient trees in urban environments are complex living ecosystems that provide critical support for a wide range of wildlife. From providing a variety of structural habitats to essential food resources, these plants are critical in maintaining urban biodiversity. Their ability to conserve specialised species, facilitate ecosystem interactions and provide year-round resources makes them indispensable components of urban ecosystems. As cities continue to expand and natural habitats shrink, the conservation and proper management of ancient trees is becoming increasingly relevant for wildlife conservation. By recognising and protecting these tree refuges, it is possible to ensure that urban environments continue to support diverse and thriving wildlife populations, enriching both the ecological health and quality of life in our cities.

Ancient trees are critical in soil stabilisation, especially in urban areas. Their extensive root systems, long-term interaction with soil microorganisms and constant supply of organic matter

make a significant contribution to soil structure, stability and overall health. This function is particularly important in urban areas where soil is often degraded, compacted or at risk of erosion. Ancient trees are the most important agents of soil stabilisation in urban ecosystems. Their extensive root systems, long-term interaction with soil biota and constant supply of organic matter significantly improve soil structure, stability and overall condition. In urban areas, where soils are often degraded and at risk of erosion, the soil stabilisation function of ancient trees becomes even more important. By mechanically strengthening the soil, improving water infiltration, enhancing biological activity and promoting chemical stabilisation, these plants perform a multifaceted role in maintaining soil integrity. As cities continue to grow and face environmental challenges such as increased stormwater runoff and the urban heat island effect, the conservation and proper management of ancient trees is becoming essential for sustainable urban soil management. Recognising and protecting the soil stabilisation functions of these woody plants is crucial for creating sustainable and resilient urban ecosystems.

The architecture of the root system of ancient trees is a key factor in their ability to stabilise the soil. These trees develop extensive, deep root systems over centuries, with roots extending laterally up to 2-3 times the width of the canopy and vertically several metres deep, depending on soil conditions. The central mass of roots near the trunk, known as the structural root plate, provides primary stability and can extend 3-7 times the diameter of the trunk. In addition, the extensive network of fine roots increases soil adhesion and constantly grows and dies, adding organic matter to the soil. Mechanical soil stabilisation is one of the main ways that ancient trees contribute to soil integrity. Tree roots act as a natural soil reinforcement, much like reinforcement in concrete, increasing the soil's shear strength and reducing the risk of landslides and erosion. This is particularly effective on slopes, where roots create a stable network that holds soil particles in place. The crowns of ancient trees also play a role by reducing wind speeds at ground level, thereby reducing wind erosion.

The hydraulic effects of ancient trees are important for soil stabilisation. Their root channels improve water infiltration into the soil, reducing surface runoff and associated erosion. Trees regulate soil moisture through absorption and transpiration, helping to maintain optimal soil moisture levels and preventing both waterlogging and severe drying. Some ancient trees can even perform hydraulic lifting, where deep roots lift water from the lower soil layers to the upper layers, helping maintain soil moisture and plants with shallow root systems. Biological soil stabilisation is another important aspect of the role of ancient trees. Over time, these trees develop extensive mycorrhizal associations that improve soil structure and stability. The constant supply of leaf litter and root decomposition contribute to soil organic matter, improving soil structure and water retention capacity. The rhizosphere of ancient trees supports a variety of soil organisms, improving soil structure and stability through various biological processes.

In urban environments, ancient trees provide benefits for soil stabilisation. In areas prone to soil compaction, their roots help maintain soil structure by creating channels for air and water movement. Areas around ancient trees are often left unpaved, providing permeable surfaces in urban landscapes that help manage stormwater and recharge groundwater. By stabilising the soil and providing shade, these trees also help to mitigate the urban heat island effect, indirectly contributing to soil health by lowering its temperature. However, the soil stabilisation function of ancient trees in urban areas faces several challenges. Urban infrastructure often limits the amount of soil available for root growth, impeding the full potential of ancient trees to stabilise the soil. Urban

soils are often contaminated, which can affect tree health and root function, although some trees can help phytoremediate contaminated soils.

Urban development can also damage the roots of trees, compromising their soil stabilisation function, making protection of root zones during construction critical. Ancient trees are the most important agents of soil stabilisation in urban ecosystems (Dwyer *et al.*, 1992). Their multifaceted role in maintaining soil integrity through mechanical strengthening, improved water infiltration, increased biological activity and chemical stabilisation is invaluable. As cities continue to grow and face environmental challenges, the conservation and proper management of ancient trees are becoming essential for sustainable urban soil management. Recognising and protecting the soil stabilisation services of these tree elders is crucial to creating sustainable, resilient urban ecosystems.

The continuity of ecosystem services provided by ancient trees in urban environments is of great value. These trees offer a unique combination of long-term, sustainable benefits that are difficult to replicate with other urban green infrastructure. From continuously improving air quality and climate regulation to the ongoing maintenance of biodiversity and cultural services, ancient trees provide a multitude of benefits that accumulate and often increase over time. As cities face challenges such as climate change, biodiversity loss and rapid urbanisation, the conservation and proper management of ancient trees are becoming crucial to maintaining these permanent ecosystem services. Recognising the long-term value of these plants, and integrating them into urban planning and management strategies, is crucial to creating a sustainable, resilient and better urban environment for present and future generations. The continuity of ecosystem services in the context of ancient trees in urban environments refers to the consistent and long-term provision of benefits. This concept is crucial to determining the unique value that ancient trees bring to urban landscapes, offering a perspective of environmental benefits that span centuries, not just years or decades.

One of the most important aspects of this continuity is the long-term improvement of air quality. Ancient trees, with their large crowns and extensive leaf surfaces, have been filtering air pollutants continuously and significantly for decades or centuries. They are constantly producing oxygen and sequestering carbon, and recent studies show that old trees continue to sequester carbon at a high rate, contrary to previous perceptions. Continuous air purification and carbon storage are invaluable in urban areas struggling with air quality issues. In terms of climate regulation, ancient trees offer sustainable benefits. They provide a constant cooling effect through shade and evapotranspiration, helping to mitigate the urban heat island effect over long periods. Their wind-blocking effect and contribution to local humidity levels create a more comfortable urban microclimate that is maintained over time. The hydrological services provided by ancient trees are also continuous and significant. They provide continuous stormwater management by intercepting and absorbing rainfall, permanently reducing runoff over the years. Their extensive root systems provide long-term soil stabilisation and erosion control and continuously improve water quality by filtering pollutants.

One of the most remarkable aspects of the continuity of ancient tree ecosystem services is their maintenance of biodiversity over time. As these trees age, they develop complex structures that provide an increasing variety of microhabitats. Hollows, dead wood and other features that develop over decades or centuries offer invaluable habitats for wildlife. Trees also constantly support complex food chains by providing food resources such as fruit, seeds, nectar and insects. The contribution of ancient trees to soil health and fertility is also continuous and cumulative (Heidt

and Neef, 2008). They participate in a constant cycle of nutrients through fallen leaves and root turnover, gradually improving soil structure and fertility. Over time, they develop and maintain complex mycorrhizal networks that benefit the wider ecosystem. However, the continuity of these ecosystem services faces challenges in urban environments. The pressures of urban development, the effects of climate change and vulnerability to pests and diseases can threaten the longevity and health of ancient trees. Therefore, management for continuity is crucial. This includes long-term urban planning that considers these trees, succession planning to ensure future generations of ancient trees, and adaptive management approaches to address changing urban conditions. Research and monitoring are vital in determining and maintaining this continuity. Long-term studies are needed to quantify and track the ecosystem services provided by ancient trees over time. Economic valuation of these services can help justify their preservation and inform policy decisions.

Ancient trees in urban environments are irreplaceable genetic resources that are primary to the sustainability and adaptation of the urban ecosystem. Their unique genetic makeup, shaped by centuries of adaptation to changing urban conditions, offers invaluable insights for conservation, urban forestry and climate change adaptation strategies. As cities continue to develop and face new environmental challenges, the conservation and study of these plants is becoming increasingly important. By recognising and protecting the genetic richness of ancient urban trees, it is possible to increase the sustainability of urban forests, ensuring that future generations benefit from the genetic heritage of such trees. Preserving trees is not only about preserving the past but also about protecting the genetic tools needed to create sustainable urban ecosystems of the future. One of the most important aspects of ancient trees as genetic resources is their long-term adaptation. These trees represent genotypes that have survived and adapted over the centuries, carrying genetic adaptations to local climate, soil conditions and historical environmental changes. They may possess rare genetic variants (alleles) that are no longer common in younger populations but may be crucial for future adaptation to a changing environment. They contain a genetic memory of historical environmental conditions and stresses that can be invaluable for understanding long-term environmental change.

The resilience and adaptability encoded in the genes of ancient trees are especially relevant in urban environments. These trees have been naturally selected for their resistance to urban stressors such as pollution, soil compaction and heat. They may contain genes for resistance to diseases that have affected urban tree populations for centuries. This genetic information can be used in breeding programmes to develop more resilient urban trees and provide insight into the ability of tree species to adapt to rapid environmental changes, which is crucial in the face of climate change. In terms of biodiversity, the genetic composition of ancient trees, which often act as key species in urban ecosystems, affects the diversity and composition of dependent species. Their genetic variation can support certain host-dependent organisms such as insects and fungi, making the conservation of these trees vital to maintaining the genetic basis of complex ecological relationships. From the point of view of conservation genetics, ancient urban trees act as gene banks, which is especially relevant for species that are rare or endangered in their natural habitat. They serve as genetic bridges between fragmented urban tree populations, facilitating gene flow and helping to maintain genetic diversity in urban forests. Their genetic material can be invaluable in environmental restoration projects, providing a locally adapted genetic pool for urban forest restoration efforts.

The evolutionary significance of these trees cannot be overestimated. They represent lines that have been preserved in the face of significant environmental changes and provide an insight into the evolutionary processes in urban environments. They provide unique opportunities to study long-term adaptation and potential speciation in urban environments. For use in urban forestry, the genetic material of ancient trees can be used in breeding programmes to develop tree varieties adapted to urban conditions and with increased resistance to urban stressors. Valuable genotypes can be preserved using clonal propagation techniques, allowing useful genetic lines to continue in urban forestry. However, the conservation of these genetic resources faces several challenges. The loss of ancient trees can lead to the irreversible loss of unique genetic resources, while urban development and climate change pose significant threats. Isolated urban populations can suffer from a decline in genetic diversity over time, a problem that ancient trees can help mitigate by providing diverse genetic material.

Research and monitoring are critical in determining and conserving these genetic resources. Ongoing efforts to map the genomes of ancient urban trees, long-term genetic studies and comparative genetics of ancient and young trees are essential to maximising the benefits of these genetic resources, and conservation strategies include the development of specific genetic resource management plans, seed banks and the establishment of collaborative networks between cities to share genetic resources and knowledge. Ancient trees in urban environments are irreplaceable genetic resources that are primary to the sustainability and adaptation of the urban ecosystem. Their unique genetic makeup provides invaluable insights for conservation strategies, urban forestry and climate change adaptation. As cities continue to develop and face new environmental challenges, the conservation and study of these genetic repositories are becoming increasingly important. By recognising and protecting the genetic richness of ancient urban trees, we can improve the sustainability and ecological integrity of our urban forests, ensuring that future generations benefit from the genetic heritage of these oldest woody plants.

The ecological significance of ancient trees in urban ecosystems is enormous and complex. These trees are not just remnants of the past, but active and important components of the urban ecology (Baycan-Levent and Nijkamp, 2009). They support biodiversity, improve ecosystem connectivity, contribute to climate change mitigation and provide many other environmental services. Their conservation is vital for maintaining healthy, sustainable and biodiverse urban ecosystems. As cities continue to grow and face environmental challenges, the role of ancient trees is becoming even more important in ensuring the ecological integrity and sustainability of the urban environment. First, ancient trees act as biodiversity hotspots in urban landscapes. Their complex structure, which has evolved over centuries, provides many microhabitats that support an incredible diversity of life. One ancient tree can harbour hundreds of species of insects, fungi, lichens and other organisms, many of which are specialists whose survival depends solely on these trees. This makes them crucial reservoirs of biodiversity in ecologically simplified urban environments. In terms of ecosystem connectivity, ancient trees are vital in maintaining ecological links in fragmented urban landscapes. They act as stepping stones, facilitating the movement of species across urban areas and helping to maintain genetic flow between populations. This function is particularly important in cities, where green spaces are often isolated and fragmented.

Ancient trees also significantly contribute to carbon sequestration and storage in urban areas. Contrary to some beliefs, they continue to sequester carbon at high rates, while their large biomass

represents a significant long-term carbon storage. This makes them valuable allies in efforts to mitigate urban climate change. The impact of ancient trees on soil health and nutrient cycling is significant. Their extensive root systems support complex mycorrhizal networks that enhance nutrient exchange in urban soils. The constant supply of leaf litter and root activity improves soil structure and water retention, and is critical in the nutrient cycle, especially in urban areas with disturbed soils. In terms of urban hydrology, ancient trees have a significant impact on water cycles. Their crowns and root systems reduce stormwater runoff increase water infiltration, and filter pollutants from water as it percolates through the soil. Thanks to transpiration, they significantly contribute to the local humidity and cooling effect.

Ancient trees are also major regulators of the urban microclimate. Their extensive crowns provide shade and cooling through evapotranspiration, helping to mitigate the urban heat island effect. They can significantly reduce wind speeds in urban areas and are particularly effective in filtering pollutants due to their large leaf area. Importantly, these trees serve as reservoirs of ecological memory. They carry genetic information about past environmental conditions, which can be crucial for adaptation to climate change. Their presence increases the resilience of urban ecosystems to environmental disturbances and changes. Ancient trees are indispensable for urban wildlife. They provide nesting sites, food sources and shelter for a wide range of animal species. Their complex structure offers a variety of habitats that support a diverse urban fauna, from insects to birds and mammals. The longevity of ancient trees ensures the continuity of ecosystem services for centuries, providing ongoing environmental benefits in contrast to shorter-lived urban infrastructure. They represent valuable genetic resources, potentially possessing genes for resistance to pests, diseases or climate stress, which could be crucial for the future of urban forestry.

3.2 Methods for assessing the health and value of urban ancient trees

Assessing the health and value of the city's ancient trees requires a combination of ecological, arboricultural and public approaches. These trees are vital not only for their historical and cultural significance but also for their ecological roles, such as carbon sequestration, habitat provision and improving urban biodiversity. It is worth presenting the main methods used to assess the health and value of ancient trees. Visual tree assessment is a fundamental non-invasive method used by arborists and tree experts to assess the health and structural integrity of trees. This is an important first step in diagnosing potential problems and assessing the overall condition of trees, especially in urban environments where tree health and safety are important issues. The visual tree assessment was developed by Dr Klaus Mattek, a German biologist, and is based on the principle that trees naturally respond to external and internal stresses by showing visible signs of weakness or stress (Wolf, 2004). The visual assessment of trees is based on the theory of tree biomechanics, which states that trees predictably respond to mechanical stress. When a tree becomes weakened (e.g. due to decay, disease or physical trauma), visible signs such as cracks, swelling or areas of abnormal growth appear in its structure. These signs can indicate underlying problems, allowing the arborist to identify risks before the tree becomes unsafe.

Trees naturally distribute mechanical stress over their structure through a process called adaptive growth. When a tree encounters external forces, such as wind or damage, it strengthens its tissues (e.g. bark and wood) to compensate. Signs of compensatory growth, such as unusual swellings,

bulges or localised thickening of the trunk or branches, may indicate areas of previous damage or decay. Trees often show visible signs when internal or structural problems occur. Common signs include:

- Cracks in the bark or trunk.
- Cavities or depressions in the barrel.
- Fungal growth (e.g. fruiting bodies such as mushrooms) indicates decay.
- Wounds from previous pruning or physical damage.
- Dead or dying branches (dead wood).
- Sloping or unbalanced crown structure.

Stress points, such as the junctions between branches and trunk (branch joints), can deform if the load-bearing capacity is compromised. Deformities such as bark ridges, branch collars and reactive wood (wood that forms to balance a slope or stress) can provide clues to where a tree is under stress. A visual tree assessment typically involves a multi-stage process that ranges from an initial visual inspection to a more detailed investigation if necessary. The initial phase of a visual tree assessment focuses on a basic visual scan of the tree to identify any obvious signs of damage or decay. During the examination of ancient urban trees, numerous critical regions are thoroughly evaluated to determine their health and structural integrity. The primary focus is the tree canopy, where leaf density, colour, and size are assessed. Subpar leaf quality may signify underlying problems, including nutrient deficits, root damage, or disease. A scant canopy typically indicates that the tree is under stress or in decline, warranting additional examination. The branches' structure is meticulously studied, evaluating their dimensions, morphology, and state of health. Dead or dying branches, referred to as dead wood, must be removed expeditiously due to their considerable safety risks. Cracks or fractures in the branches may indicate structural issues that could jeopardise the tree's stability.

The tree trunk is meticulously examined for fissures, voids, or mycological proliferation. Indicators of deterioration, such as cavities or the presence of fungi like tinder fungi, frequently signify internal disintegration, which significantly compromises the structural integrity of the wood. The assessment of the root socket and root zone, where the trunk intersects with the roots, is equally significant. This region is examined for indications of root injury, soil compaction, or inadequate anchoring. Exposed roots or evidence of root rot are crucial indicators of health issues that require prompt intervention to avert further decline in the tree's condition. Should any difficulties arise during the preliminary inspection, a further evaluation is performed to examine certain structural hazards. This involves inspecting cracks and crevices, where vertical or horizontal fissures in the bark or wood may signify that the tree is experiencing internal strain or stress (Miller, 1997). Bark splitting may occur due to environmental variables, including freeze-thaw cycles or accelerated development. Hollows and fissures in the trunk or substantial branches are examined, as these voids may jeopardise the tree's structural integrity. Cavities frequently arise from deterioration induced by fungi or insects, and their dimensions and positioning considerably influence the likelihood of tree failure. Additionally, branch splices, the junctions where branches connect to the trunk, represent prevalent vulnerabilities. Weak or fractured splices, particularly those exhibiting "turned on bark" where bark gets ensnared between growing branches, may fail under substantial stresses, such as those encountered during storms. The identification of decay is crucial, as fungal growth on the trunk or branches indicates internal rot, compromising the tree's structural integrity and requiring immediate intervention.

The biomechanical assessment phase involves analysing the tree's physical structure in relation to the pressures exerted on it. Trees inherently react to environmental stress, and their biomechanical reactions can yield significant insights about their sustainability. One component of this evaluation is assessing the inclination of the tree. A natural lean is not inherently hazardous; nevertheless, a sudden or pronounced tilt may signify underlying deficits or unstable soil conditions. Arborists evaluate the angle of inclination and the tensile or compressive stresses exerted on the roots and trunk to ascertain the tree's stability. A further emphasis is placed on reactive growth, when trees exhibiting structural flaws generate "reaction wood" as a response to mechanical stress. Arborists assess these regions to verify that the reaction wood adequately stabilises the tree and mitigates any structural deficiencies. After conducting visual and structural evaluations, the arborist provides a risk classification to the tree according to the severity of the detected flaws and the probability of failure. Trees are categorised under three risk levels: low, moderate, and high. Low-risk trees display minimal structural or health issues that do not present an imminent risk to their stability or public safety. Regular monitoring and moderate maintenance, such as pruning, are often advised for these trees to maintain their health. Moderate-risk trees have certain structural faults or health concerns that may worsen over time. These trees may necessitate further assessments or remedial measures, such as cabling, reinforcing, or disease management, to alleviate possible hazards. High-risk trees have significant faults that may result in their imminent collapse, particularly in zones with substantial traffic. Mitigation strategies for high-risk trees may encompass comprehensive trimming, the implementation of support systems, or, in severe instances, the removal of the tree to avert accidents and safeguard public safety.

The main advantages of visual tree assessment include non-invasiveness, as it does not cause any harm to the tree; early detection of disease signs; cost-effectiveness and increased safety. However, there are also disadvantages to this method, including the following: subjectivity, as the assessment depends on the experience of the arborist; hidden effects that cannot be seen from the outside and environmental factors. Visual assessment of trees is the cornerstone of arboriculture and urban tree management. Its main function is to provide an initial, non-invasive assessment of the health and structural integrity of a tree. Although it is an effective way for detecting early signs of stress and decay, visual tree assessment works best when combined with other diagnostic methods to provide a more complete picture of the tree's condition. Regular visual assessment of trees can significantly extend the life of urban trees, maintain public safety and contribute to the ecological and aesthetic value of old and mature trees in cities.

A tree risk assessment is a systematic process used to evaluate the potential risks associated with trees, especially in urban or populated areas where falling trees can pose a risk to people, property or infrastructure. Tree risk assessment is aimed at assessing both the probability of a tree or its parts falling and the potential consequences of such a fall. It is an integral part of urban forestry and arboriculture, helping municipalities, property owners and arborists to manage trees responsibly to reduce risk while maintaining the benefits that trees provide. Urban trees can pose a risk due to their location in high-traffic areas, proximity to buildings or exposure to extreme weather conditions. Trees can fall due to structural deficiencies, disease, age or environmental stressors, resulting in damage, injury or death. A tree risk assessment helps identify trees that may pose a safety hazard, enabling proactive management to minimise risk while avoiding unnecessary tree removal.

Tree risk assessments are designed to balance public safety with the environmental, social and economic benefits that trees provide. Effective tree risk management ensures that trees can safely coexist with urban infrastructure, reducing liability and preserving green spaces.

The tree risk assessment process has three main components:

- Probability of destruction
- Probability of exposure
- Consequences of the destruction

By combining these elements, the arborist can determine the overall risk posed by the tree and recommend management actions. The first step in assessing tree risk is to estimate the probability that a tree (or part of a tree) will collapse. This involves examining the physical condition of the wood and environmental factors that may contribute to deterioration. Categories of probability:

- Inevitable: destruction is highly probable within the next few hours or days.
- Probable: destruction is expected within the next 1-2 years.
- Possible: a reasonable probability that destruction could occur, but it is not inevitable.
- Unlikely: destruction is not expected unless extreme conditions, such as a severe storm, occur.

Once the probability of failure has been established, the next step is to assess whether the tree or the part most likely to fail will affect the target. The target can be a person, vehicle, building, power line or any other object that could be damaged. Categories of probability:

- High: the target is frequently present, such as pedestrians on a busy street or vehicles in a car park.
- Moderate: the target is present periodically, for instance, in a public park with rare visitors.
- Low: the target is rarely present, for instance, in a backyard or a remote area.
- Very low: the probability of impact is minimal, as targets are rarely present.

The final component of a tree risk assessment is to assess the potential consequences if a tree or part of a tree does fall and strike a target. The effects depend on the size of the tree, the type of target and the environment. Categories of consequences:

- Serious ones: high likelihood of significant damage, injury or death (e.g. falling on a building, crowded street or critical infrastructure).
- Significant: the possibility of moderate damage or injury (e.g. falling on a parked car or in a sparsely populated area).
- Insignificant: the possibility of minor damage, such as cosmetic damage to property or minor injury.
- Minimal: minimal or insignificant damage (e.g. a tree falls in an open field with no target).
- A tree risk assessment uses several methods to gather information about a tree's condition and potential risk:

- Visual inspection (basic). This inspection is the main method used in tree risk assessment, where arborists look for signs of decay, damage or structural weakness. Arborists evaluate the roots, trunk, branches and canopy of a tree, as well as the environment.

- Advanced diagnostic tools. If visual inspection raises concerns, advanced tools can be used for more detailed analysis, such as resistographs, CT scanners and ground penetrating radar.

- Excavation of the root collar. In cases where root problems are suspected, arborists can remove soil around the base of the tree to inspect the root collar. This can reveal problems such as girdling roots, rotting or soil compaction.

In areas with high winds, arborists can conduct biomechanical assessments to evaluate how well a tree can withstand wind loads. This analysis helps predict how wind will affect the structural stability of a tree. Once the level of risk has been determined, the next step is to decide on appropriate actions to mitigate the risk. Common management options include pruning, installation of support systems, tree removal, monitoring or target management. Tree risk assessment is imperative for managing urban forests and ensuring public safety. By systematically assessing the probability of failure, impact and consequences, a tree risk assessment enables arborists and property managers to make informed decisions about tree maintenance, retention or removal. Tree risk assessments balance the need to preserve valuable urban trees with the obligation to minimise risk to people and property, creating a safer and more sustainable urban environment.

Biotic and abiotic health indicators are critical to the determination of the overall health and vitality of trees. These indicators give an idea of the internal and external factors that can affect the growth, stability and durability of a tree. By assessing these indicators, arborists and urban foresters can identify stressors, diseases or environmental conditions that could compromise tree health and take appropriate action to reduce risks. Biotic indicators are those related to living organisms that affect the health of the tree, including pests, pathogens and other interactions with living organisms. Abiotic indicators include non-living factors such as soil conditions, climate, water availability, pollution and mechanical damage that can affect the health of a tree. Biotic factors include diseases, insect infestations, fungi and other living organisms that interact with or attack trees. These interactions can lead to stress, decay, or even death if not managed effectively. Insects can seriously affect the health of a tree by damaging leaves, branches, trunks or roots. The infestation can lead to leaf fall, weakening of the tree structure and even death if left untreated.

Pest infestations in trees might exhibit several discernible indicators. A prevalent signal is leaf abscission, wherein pests such as caterpillars or beetles, including the occasional silkworm and emerald ash borer, devour the foliage, thereby markedly diminishing the tree's photosynthetic capacity. Another indication is the existence of drilling insects; these pests, like as bark beetles and emerald ash borers, excavate tunnels beneath the bark, referred to as galleries. This tunnelling compromises the structural integrity of the tree and obstructs the transport of vital nutrients. The presence of sawdust-like debris near the tree's base or on its bark may indicate the activity of boring insects. Leaf damage, including chewed, skeletal, or discoloured foliage, frequently signifies the presence of pests such as aphids, caterpillars, or scale insects, hence signalling an infestation.

Fungal infections pose a considerable risk to tree health, resulting in numerous diseases that can induce decay and compromise structural integrity. Fungi can affect several components of the tree, such as roots, trunks, branches, or leaves. Root rot, induced by fungi like *Armillaria* or *Phytophthora*, leads to root deterioration, hindering nutrition absorption and resulting in wilting and ultimately tree mortality. Fungal malignancies, like those induced by *Cytospora* and *Nectria*, generate lesions on the bark or branches that may girdle the tree, impeding nutrient transport. Wood-decaying fungi like as *Ganoderma*, *Fomes*, or *Polyporus* infiltrate the heartwood or sapwood, resulting in internal decomposition, with the emergence of fruiting bodies on the trunk or roots acting as critical markers of decay. Moreover, fungal leaf spot diseases, such as anthracnose and septoria, induce lesions or necrosis on the foliage, resulting in early leaf abscission and diminished vigour (Benyus, 2002). Bacterial infections threaten trees, exhibiting symptoms such as wilting, galls, and other indicators of disease. Bacterial wilting, induced by bacteria such as *Erwinia* or

Pseudomonas, obstructs the tree's xylem, leading to an abrupt loss of turgor in the foliage and branches. Infections may also result in the development of abnormal growths or galls on roots, stems, or leaves. *Agrobacterium tumefaciens* creates crown galls, tumor-like formations that interfere with normal nutrition transport. Moreover, certain bacterial infections generate viscous exudates that ooze from fissures in the bark, further signifying the existence of disease.

Parasitic plants like mistletoe and dodder can invade trees by adhering to them and syphoning water and nutrients, thereby undermining the host tree's vitality. Mistletoe develops extensive spherical clusters on tree branches, extracting vital resources from the tree and jeopardising its health. Likewise, dodder, a vine-like parasitic plant, entwines its host, syphoning resources and inhibiting the tree's growth. Competition from other flora, especially invasive species, may result in the deterioration or demise of trees. Invasive flora such as ivy or climbing vines can surpass trees in acquiring light, water, and nutrients, suffocating the tree canopy and obstructing photosynthesis. Moreover, several plants emit compounds that suppress the growth of adjacent trees, a phenomenon referred to as allelopathy. The black walnut tree releases juglone, a poisonous substance that impacts numerous surrounding plants.

Abiotic variables, comprising non-living environmental circumstances, profoundly influence tree health. Suboptimal soil conditions, including soil compaction, diminish the accessibility of air, water, and nutrients to tree roots, resulting in stunted growth and deterioration. Indicators of soil compaction encompass inadequate root development, leading to a superficial root system that undermines tree stability, diminished vigour characterised by stunted growth and reduced leaf size, and water shortages due to impeded water infiltration and absorption. Nutrient imbalances resulting from inadequate soil quality or environmental stresses may cause deficient symptoms. Common nutritional inadequacies encompass nitrogen deficit, which induces chlorosis or yellowing of leaves and diminished growth; iron deficiency, which results in chlorosis of young leaves in alkaline soils; and phosphorus insufficiency, characterised by dark green or purple leaves and limited growth.

Water availability is a crucial determinant of tree health. Drought stress and waterlogging can cause considerable stress and deterioration. Drought stress is characterised by wilting leaves and branches that shrivel, curl, or become brown due to inadequate water availability. Trees may abscise their leaves prematurely to conserve moisture, and extended dryness can lead to the mortality of branches and stems while the tree preserves energy. Conversely, waterlogging can induce root rot by establishing anaerobic conditions that facilitate fungal proliferation, resulting in chlorosis, wilting, and ultimately, tree mortality. Trees in wet environments frequently display inhibited development and encounter difficulties in nutrient absorption. Temperature variations significantly impact tree health, as both high heat and cold can inflict damage. Heat stress may lead to sunburn, causing continuous exposure to intense sunshine to fissure and harm the bark, especially on the southwestern aspect of the tree. Leaf burn, or leaf scorch, transpires when the tips and margins of leaves become brown as a result of high heat. Cold stress can induce frost cracks, particularly in juvenile trees or those unaccustomed to frigid climes, and winter burn in evergreen species subjected to cold winds, resulting in browning or desiccation owing to moisture loss.

Mechanical damage resulting from storms, building, or anthropogenic activities can significantly affect trees. Typical forms of mechanical damage include fractured branches resulting from storms, substantial snowfall, or human activities, creating openings that serve as entry routes for pests and pathogens. Physical harm to the bark caused by automobiles, lawn equipment, or

animals renders the tree susceptible to diseases, whereas root damage from building or excavation can undermine the tree's capacity to stabilise itself and efficiently absorb water and nutrients. Ensuring tree health necessitates the identification of diverse hazards through diligent observation and suitable management strategies to promote the trees' lifetime and vigour. Pollutants in the air, water or soil can have a detrimental effect on trees, especially in urban areas. Trees exposed to pollutants such as sulphur dioxide, ozone and nitrogen oxides can show stunted growth, leaf drop and chlorosis. Ozone pollution can cause dots or spots on the upper surface of leaves, especially in sensitive species such as pine and maple trees. Pollutants, such as heavy metals or chemicals from industrial activities, can build up in the soil, leading to root toxicity and reduced growth.

Improper tree care practices, such as excessive pruning or topping, can stress the tree and increase its susceptibility to biotic and abiotic stressors.

- Excessive pruning: removing too much of the tree's crown at one time can reduce its ability to photosynthesise, resulting in reduced energy and growth.
- Trimming the tops: pruning large branches to stumps severely weakens trees, making them more vulnerable to decay, pests and structural damage.

Both biotic and abiotic health indicators play an important role in assessing and managing tree health. Biotic factors, such as pest infestation, fungal infections and competition from other organisms, can directly harm trees, while abiotic factors, such as soil quality, water availability, extreme temperatures and pollution, exert indirect pressures that affect growth and viability. By regularly monitoring these indicators, arborists can make informed decisions about tree care, reducing risks and contributing to the long-term health of urban and natural forests.

Advanced diagnostic tools are crucial for assessing the internal structure, health and sustainability of trees, especially when visual inspections alone are not sufficient to identify potential risks or hidden problems. These tools are used to collect accurate and detailed information on the condition of trees, such as decay, root health and internal structural defects. They are primarily in urban forestry, risk management and the preservation of valuable or historic trees. Below is a detailed overview of the most used advanced diagnostic tools for assessing tree health, including their functionality, importance and the types of information they provide.

A resistograph is a mechanical tool used to estimate the internal density of wood by drilling a thin needle into the trunk or roots of a tree. As the drill moves through the wood, it measures the resistance. Areas of high resistance indicate healthy, strong wood, while areas of low resistance indicate internal rot, cavities or cracks. The fine drill bit causes minimal damage to the wood, leaving only a small hole that can heal naturally. Resistographs are particularly effective in detecting internal decay that may not be visible from the outside. They can detect cavities, hollow sections or areas of weakened wood that compromise the structural integrity of the wood. The device provides quantitative readings that allow arborists to assess the degree of decay. This is particularly useful when deciding whether to keep a tree or remove it.

Tomography in tree diagnostics uses sound waves (acoustic tomography) or electrical impulses (electrical resistive tomography) to create an image of the internal structure of a tree. By measuring how quickly these waves or currents pass through the wood, arborists can detect irregularities such as cracks, cavities and rot. Acoustic tomography involves placing sensors around the circumference of a tree and sending sound waves through it. Healthy wood transmits sound waves faster than rotten or hollow wood. The data is then compiled into a 2D, or 3D image showing the internal state of

the tree. Resistance electrotomography works similarly but uses electrical pulses instead of sound. Rotten or damp wood conducts electricity differently from healthy wood, and these changes are used to map internal decay or structural defects. Tomography is a completely non-invasive method that does not require drilling or cutting into the wood, preserving its health and structural integrity, and provides detailed cross-sectional images that allow arborists to see the exact location, size and severity of internal defects. Tomography can detect early stages of decay or hidden cracks that are not visible on the surface, making it useful for proactive risk management.

Ground Penetrating Radar (GPR) is used to assess the root system of trees. The radar sends electromagnetic waves into the ground, and the reflected signals are analysed to create a picture of underground structures. This tool is crucial for assessing root health, density and extent of root spread without disturbing the soil or root zone of the tree. GPR is used to examine the root system without the need for digging, which can damage the tree. It can also be used to identify areas where roots have rotted or been damaged by pests, disease or soil compaction. In urban environments, GPR can help avoid conflicts between tree roots and infrastructure such as sidewalks, roads and underground utilities.

Sound and stress wave testing involves measuring how fast stress waves travel through the wood. Healthy, solid wood transmits these waves more quickly than wood that is rotted or structurally damaged. The sensors are placed on either side of the tree or section to be tested, and a small hammer is tapped on the tree to send a wave through it. This method provides a quick insight into the internal structure of the tree, ensuring immediate decision-making regarding the health of the tree. Stress wave testing can detect cracks and internal rot that are not visible from the outside, especially in large branches or trunks, and like CT scanning, it does not harm the tree, making it suitable for assessing valuable or protected trees.

Root collar excavation involves carefully removing the soil around the base of the tree (root socket) to expose the upper roots and root collar (where the trunk meets the roots). The root collar excavation provides direct access to the root collar, allowing for a thorough examination of the root condition and potential mechanical damage that could affect the stability of the tree. Arborists can identify root problems, such as girdling roots that can restrict the flow of nutrients and water or rotten roots that compromise the tree's anchorage. By examining the root collar, arborists can make more informed decisions about treatment, soil improvement or the need to remove the tree.

The ArborSonic Decay Detector is a handheld device used to detect internal decay by measuring the speed of sound waves travelling through a tree. It provides detailed information about the internal condition of the trunk and branches by sending sound waves through different parts of the tree and recording the results. ArborSonic provides a clear picture of the location and extent of decay within a tree, helping to identify potential weaknesses, similarly to many other advanced tools, it does not require invasive procedures such as drilling or cutting, preserving the health of the tree while assessing its internal condition. The ArborSonic is easy to transport and can be set up quickly, making it ideal for arborists working in the field.

Dendrochronology is an analysis of annual rings to define the age of a tree, growth patterns and past environmental conditions. By taking a core sample from a tree and examining the rings, arborists can gain insight into periods of stress, disease or environmental changes that have affected the tree's growth. Dendrochronology provides a historical record of a tree's health and the environmental conditions it has experienced, including droughts, floods and pest outbreaks, even

though a small sample is removed during coring, it does not cause significant damage to the tree. The analysis of annual rings helps to assess whether the tree has recovered from past stresses or is in a state of long-term decline.

Thermal imaging uses infrared cameras to detect temperature changes on the surface of wood. Thermal imaging can detect problems without physically interacting with the tree, keeping it healthy and collecting important data. It can be used to detect rot, pest infestation or water shortages at an early stage, even before visible symptoms appear. Thermal cameras provide a complete picture of the tree's condition, making it easier to assess large trees or trees with complex structures. Advanced diagnostic tools enhance arborists' ability to assess tree health and sustainability with accuracy and minimal invasiveness. Instruments such as resistographs, tomography, ground penetrating radar and thermal imaging provide detailed insight into the internal structure and root system of trees, while non-invasive methods such as acoustic testing and dendrochronology offer long-term data for informed decision-making. These technologies are essential for maintaining the health and safety of urban forests, preserving historic trees and managing risks in public spaces.

The ecological and biological assessment of urban trees focuses on assessing the contribution of trees to the local environment and ecosystems, as well as their role in maintaining biodiversity. Trees in cities do more than just beautify the landscape; they serve as important environmental assets, regulating the microclimate, providing habitat for wildlife, sequestering carbon and improving air and water quality. Determination of these roles through systematic assessment is crucial for effective urban forest management, conservation efforts and sustainable urban planning. Urban trees provide the necessary habitat for various species of birds, insects, mammals and other organisms. The structural complexity of trees, including their trunks, branches, leaves and root systems, creates many niches that support biodiversity in urban environments.

Assessing the ecological value of urban trees entails various critical variables that enhance their overall importance within the ecosystem. The dimensions and age of a tree are essential factors, as mature and aged trees generally provide greater ecological benefit. These trees offer diverse habitat opportunities, including cavities for breeding avians or chiropterans, substantial branches for perching, and decaying wood for invertebrates. Moreover, species richness is vital, as specific tree species such as oaks and willows sustain a diverse array of insects, birds, and mammals, whereas non-native species may provide diminished biodiversity value. Dead wood, encompassing standing dead trees, decaying branches, and fallen logs, provides habitats for fungus, insects, and small animals, while also facilitating the nutrient cycle and enhancing the overall urban environment. Avian and mammalian habitats are crucial in evaluating the ecological significance of trees. Trees exhibiting cavities, dense canopies, or abundant foliage are essential for avian nesting and nocturnal animals, like squirrels and bats. Furthermore, trees that sustain pollinators such as bees, butterflies, and moths are crucial for urban biodiversity and the vitality of plant ecosystems. A heterogeneous urban tree population bolsters environmental sustainability by offering several ecosystem services, such as carbon sequestration, temperature regulation, air quality enhancement, and stormwater management. This diversity enhances the sustainability of urban ecosystems and augments the overall biodiversity of the metropolis.

A vital component of assessment is the variety of tree species present in an urban setting. A varied assemblage of species fosters a more sustainable ecosystem by preserving biodiversity and improving resilience to environmental fluctuations. Diverse tree populations mitigate the

likelihood of extensive damage from pests or diseases that may target certain species. Evaluating forest cover is crucial, as the extent of canopy covering affects shade availability, cooling impacts, and habitats for avian and insect species. Both native and non-native species should be evaluated, as native species typically offer more ecological value owing to their adaption to local environments and their support for a wider array of fauna. Functional variety, denoting the various roles trees assume due to their physical and biological attributes, is also essential. Diverse trees, differing in size, age, and growth style, fulfil services including habitat provision, water retention, and temperature regulation.

Healthy soil serves as the foundation for a flourishing urban tree population, influencing both tree growth and the wider urban ecosystem. The composition of soil, encompassing texture and the presence of clay, sand, silt, and organic matter, is essential for promoting robust tree growth. Fertile, well-aerated soil enhances root growth and microbial activity, hence facilitating the nutrient cycle and promoting tree health. Nutrients in soil, especially nitrogen, phosphorus, and potassium, are crucial for optimal tree growth; deficits may result in compromised tree health and diminished biodiversity. Furthermore, microbial and fungal activity in the soil is crucial for the decomposition of organic matter, nitrogen fixation, and the enhancement of plant health. Monitoring soil pH and pollution levels is essential, as they influence nutrient availability and can hinder tree growth and biodiversity, particularly in urban environments where soil contamination is prevalent.

The configuration of trees and green spaces in urban environments is crucial for facilitating wildlife migration and enhancing biodiversity (Heidt and Neef, 2008). Well-connected green corridors facilitate species movement between habitats, hence boosting ecological resilience and mitigating the danger of local extinctions in isolated regions. Tree-lined roadways and urban forest patches, even in limited clusters, act as conduits for animals, aiding in the preservation of biodiversity within fractured urban environments. Moreover, trees situated along rivers, streams, and lakes offer essential homes for aquatic species and connect terrestrial ecosystems with aquatic ones, enhancing biodiversity across various environments. Metropolitan trees significantly contribute to mitigating climate change by sequestering carbon dioxide and controlling microclimates within metropolitan areas. Evaluating the role of trees in carbon sequestration and temperature modulation is crucial for measuring their ecological significance and validating conservation initiatives. Urban trees sequester CO₂ by photosynthesis, accumulating carbon in their biomass, while offering shade and emitting water vapour through transpiration, so cooling the environment and alleviating the urban heat island phenomenon. Additionally, trees capture precipitation and mitigate runoff, contributing to stormwater management and flood prevention by absorbing surplus water via their root systems.

The capacity of urban trees to endure climate change and various environmental stressors is a significant factor to consider. Urban trees encounter issues including heat waves, drought, pollution, and extreme weather events, all of which can impact their health and biodiversity. Assessing a tree's resilience to drought, pollution, and adaptability to fluctuating climate conditions is essential for guaranteeing the long-term viability of urban forests. Implementing drought-resistant species, enhancing soil moisture retention, and assessing heat stress are techniques that can bolster the resilience of urban trees against climate change. The ecological and biological evaluation of urban trees is crucial for comprehending their function in sustaining urban ecosystems and enhancing environmental health. These evaluations include habitat characteristics, species diversity,

soil vitality, connectivity, and ecosystem services such as carbon sequestration and climate regulation. Through the application of field surveys, sophisticated diagnostic instruments, and ecological modelling, arborists and urban planners may make educated judgements on the conservation and enhancement of urban biodiversity. Amidst swift urbanisation and climate change, these evaluations ensure that urban trees persist in delivering environmental advantages and fostering sustainable, resilient cities.

The assessment of ecosystem services is essential for comprehending the advantages offered by urban trees. These services encompass concrete advantages such as air purification and temperature regulation, with abstract benefits including biodiversity enhancement and increased mental well-being. Regulatory services, which are the advantages obtained from the regulation of environmental processes, are especially important. Urban trees enhance air quality by sequestering pollutants such as carbon dioxide, sulphur dioxide, nitrogen oxides, ozone, and particle matter, consequently promoting public health. They play a crucial role in carbon sequestration by absorbing CO₂ from the atmosphere and storing it in their biomass, thereby aiding in the mitigation of climate change. Trees also regulate temperature by offering shade and cooling the air by evapotranspiration, so mitigating the urban heat island effect and enhancing urban comfort. Urban trees provide crucial regulatory services for stormwater management and flood reduction. Trees mitigate flooding and alleviate the strain on urban drainage systems by capturing precipitation and decreasing stormwater runoff rates. Their root systems enhance water infiltration, hence reducing flood hazards and mitigating soil erosion. Trees facilitate noise reduction by absorbing and deflecting sound waves, so fostering quieter urban areas. Assessment methods for these regulatory services encompass air quality models, carbon sequestration estimates, energy conservation models, hydraulic models, and noise pollution analyses, all of which facilitate the quantification of the economic and environmental advantages of urban trees.

Supporting services, which are foundational to all other ecosystem services, are equally vital for sustaining the health of urban ecosystems. These encompass soil production and preservation, facilitation of biodiversity, and nutrient cycling. Urban trees preserve soil integrity, mitigate erosion, and facilitate the development of organic matter. They offer habitats for diverse species, serving as keystone species that preserve ecological equilibrium and augment species diversity. Trees recycle nutrients by dropping leaves and organic matter, so enriching the soil, promoting plant development, and diminishing the necessity for artificial fertilisers (Wilby and Perry, 2006). Evaluating these support services includes habitat assessments, soil retention models, and environmental footprint analyses that measure the significance of trees in preserving ecosystem sustainability. Cultural services encompass the intangible advantages individuals gain from urban trees, such as recreational, aesthetic, spiritual, and educational benefits. Trees augment the aesthetic allure of urban environments, enhancing the beauty of thoroughfares, parks, and communal areas, hence potentially elevating property prices and attracting visitors. They offer areas for recreational pursuits as walking, running, picnicking, and birdwatching, so encouraging physical activity and leisure. Proximity to urban trees and natural spaces enhances psychological health and well-being by alleviating stress, anxiety, and depression. Furthermore, certain trees possess cultural or historical importance, enhancing the identity and history of communities. Educational initiatives in botanical gardens, arboretums, and urban parks underscore the significance of trees in environmental education and scientific inquiry. Evaluating cultural services entails employing techniques such as

hedonic pricing, contingent valuation surveys, healthcare cost savings analysis, and assessing the value of tourism and recreation.

Surveillance and upkeep are crucial for safeguarding the vitality, security, and durability of urban trees. Regular monitoring includes evaluating tree health, structural integrity, and environmental factors to identify issues promptly, including diseases, pest infestations, or environmental stressors. Structural evaluations concentrate on detecting fissures, deceased branches, root deterioration, or trunk decay that may present safety risks. Soil and environmental monitoring facilitate the maintenance of a conducive growth environment for trees by assessing soil pH, moisture, nutrient concentrations, and pollution levels. Biodiversity monitoring evaluates the significance of trees in facilitating urban wildlife, guaranteeing their contribution to wildlife conservation. Maintenance efforts are designed to enhance tree vitality and mitigate dangers. Pruning entails the removal of dead, diseased, or damaged branches to foster healthy growth and mitigate risks. Mulching conserves soil moisture, moderates' temperature, enhances soil structure, and inhibits weed proliferation. Irrigation is essential, particularly in arid environments, to guarantee the survival of juvenile or recently planted trees. Fertilisation restores vital soil nutrients, facilitating optimal growth tailored to the individual requirements of each tree. Root care and soil management tackle problems such as soil compaction and inadequate drainage via techniques including vertical mulching, soil aeration, and root trimming. Integrated Pest Management (IPM) facilitates the management of pests and diseases, effectively managing infestations while reducing environmental impact. Furthermore, the installation of cables and spacers can offer structural reinforcement for trees with compromised branches, while the removal and replacement of trees may be required when they pose significant hazards owing to disease or structural deterioration.

Efficient urban tree management necessitates strategic long-term planning to guarantee the sustainability of the urban forest. This entails the selection and maintenance of diverse species appropriate for local conditions, strategising for tree succession to substitute ageing or removed trees, and adjusting to climate change by opting for drought-resistant and robust species (Loures *et al.*, 2007). Implementing systematic maintenance plans tailored to the requirements of various tree species facilitates continuous care and diminishes the probability of emergency interventions. Nonetheless, the preservation of urban trees encounters obstacles like insufficient financing and resources, competing urban demands such as infrastructure expansion, climate-related stressors, and divergent public attitudes towards trees. Addressing these difficulties requires public education on the advantages of urban trees, obtaining sufficient money, and including tree management into comprehensive urban planning initiatives. The thorough assessment and administration of urban trees are essential for improving urban biodiversity, facilitating ecosystem services, and advancing environmental sustainability. By considering aspects like as species diversity, soil health, spatial configuration, and efficient care procedures, communities can guarantee that their urban forests persist in delivering essential benefits to both the environment and residents. Strategic planning and proactive management are crucial for addressing the challenges of urbanisation and climate change, ensuring that urban trees continue to be valuable assets in the development of sustainable and resilient cities.

Monitoring and maintenance of urban trees are important practices to ensure their health, safety and ability to provide valuable ecosystem services. Through regular health assessments, structural inspections and proactive maintenance such as pruning, watering and soil management,

urban trees can continue to thrive in challenging environments. Long-term planning, including species selection, climate change adaptation and strategic maintenance schedules, further supports the sustainability of urban forests. Despite challenges such as limited funding and environmental stressors, cities can successfully implement tree monitoring and maintenance programmes that protect and enhance urban green spaces for future generations. Ancient urban trees are vital assets that contribute significantly to environmental sustainability, cultural heritage and community well-being. To ensure their preservation and continued contribution, cities should use a range of methods to assess both their health and value. Each approach provides important insights into how trees can be maintained, protected and valued in urban environments.

Visual tree assessments and tree risk assessments form the basis of physical health monitoring, allowing arborists to detect structural deficiencies, disease or decay that could compromise the safety or durability of a tree. Complementing these, an assessment of biotic and abiotic health indicators, including soil conditions, pests and environmental stress, provides a more complete understanding of the tree's habitat and sustainability. The use of advanced diagnostic tools such as tomography or remote sensing offers more accurate and non-invasive methods of assessing the condition of the tree at deeper levels, allowing for early detection of internal rot or root problems. Ecological and biodiversity assessments help evaluate the role of ancient trees in supporting local ecosystems and species diversity, increasing their ecological value in urban landscapes. Equally important are cultural and historical value assessments that recognise the symbolic and historical significance of ancient trees in shaping local identity and heritage.

These assessments ensure that trees are valued not only for their ecological functions but also for their role in community history and sense of place. Finally, the valuation of ecosystem services provided by ancient trees, such as air purification, temperature regulation, carbon sequestration and water management, allows cities to quantify the economic and environmental benefits that trees bring. This can lead to informed decisions about investing in their care, promoting policies that protect these green assets, and ensuring that their benefits are understood and integrated into urban planning. By combining these methods, urban planners, arborists and the people can collaborate to protect and preserve urban ancient trees. By doing so, they protect not only the trees themselves but also the rich ecological, cultural and economic benefits they offer to future generations.

3.3 Threats to urban ancient trees and mitigation strategies

Urban ancient trees, often hundreds of years old, are invaluable not only as ecological relics but also as cultural and historical symbols. These trees are central in biodiversity, air purification, carbon sequestration and shade in cities. However, they face significant threats from urbanisation, pollution and climate change. Knowing these threats and implementing effective mitigation strategies is vital to the conservation of this natural heritage. Urban development and infrastructure expansion are the most significant threats to ancient trees in cities. As the urban population grows, the demand for more housing, commercial space, transport networks and utilities increases. This rapid expansion often takes place at the expense of natural spaces, including areas where ancient trees have been growing for centuries. Determining the specific ways in which development affects these trees is crucial to developing strategies to protect them. One of the most direct consequences of urban development is the direct removal of trees to make way for new buildings, roads and other

infrastructure projects. In many cases, ancient trees are seen as obstacles to development rather than as assets to be preserved (Cadenasso *et al.*, 2013). The historical, cultural and ecological value of these trees can be overlooked due to economic pressures or the need for urban expansion.

While some cities have policies in place to protect important trees, these rules are not always enforced or may have loopholes. Developers may argue that tree removal is necessary for progress, citing issues such as safety risks, optimising land use or the high cost of preserving trees during construction. Even if ancient trees are not removed directly, development around them can seriously damage their root systems. The roots of large old trees often spread horizontally and can extend far beyond the crown of the tree. Construction activities such as excavation, trenching and levelling for new roads, pavements and buildings can cut through these extensive root networks. Root damage compromises the tree's stability and nutrient uptake, weakening the tree and making it more susceptible to disease, drought and windthrow (wind uprooting). Often this type of damage may not be immediately apparent, but leads to a gradual decline of the tree, with symptoms such as leaf loss, branch dieback or stunted growth appearing years later.

Construction sites often use heavy machinery and vehicles that can compact the soil around ancient trees. Compacted soil reduces the pore space, limiting the amount of oxygen, water and nutrients available to tree roots. It can also inhibit root expansion, causing roots to grow in shallow, weakened structures that can destabilise the tree. Ancient trees are particularly vulnerable to soil compaction because their roots are adapted to a natural, less disturbed environment. In urban environments, frequent constructions, foot traffic and traffic pressure around these trees further compact ground even further, making it difficult for trees to grow. Urban development often entails changes to the natural landscape, including the redirection of water flows through stormwater management systems, paved surfaces and drainage installations. Such changes can significantly affect the hydrological conditions around ancient trees. In some cases, water that would naturally seep into the ground near the tree is diverted, depriving it of the necessary moisture, especially during drought. Conversely, new drainage systems can direct excess water to the areas around the tree, causing waterlogging and a lack of oxygen for the roots. Either extreme can lead to stress, root rot or other health problems in the tree.

Urbanisation often results in impermeable surfaces such as concrete, asphalt and stone. These surfaces cover large areas of land, preventing water from seeping into the soil and reaching the roots of trees. For ancient trees, which often rely on extensive underground root networks to absorb water and nutrients, the introduction of impermeable surfaces can have devastating consequences. Paved areas, sidewalks and streets built too close to trees not only block water but also limit the access of oxygen to the roots, which leads to suffocation of the tree's underground system. In addition, these surfaces contribute to the urban heat island effect, raising temperatures around the trees, which exacerbates stress during heat waves and periods of drought. Urban development often involves the use of chemicals, including solvents, concrete additives and construction materials, which can leach into the soil. These chemicals can inadvertently get into the roots of nearby ancient trees, leading to toxic conditions that are detrimental to the tree's health. In addition, dust, debris and waste generated on construction sites can settle on tree leaves, blocking photosynthesis and making the tree more vulnerable to pests and diseases.

As cities expand, pressure on green spaces, including areas with ancient trees, often increases. The influx of people into urban areas leads to more recreational use of parks and open

spaces, which puts additional stress on ancient trees. Human activities such as trampling, picnics and gatherings near these trees can compact the soil and damage the sensitive roots. In some cases, the cultural or historical significance of ancient trees may attract attention, leading to unintended damage from excessive tourism or public interest. While urban development and infrastructure expansion are inevitable in growing cities, these activities must be balanced with the preservation of ancient trees. Ancient trees provide irreplaceable ecological, cultural and aesthetic benefits to the urban environment. By adopting tree-sensitive planning practices, protecting root systems and creating legislation that protects these natural giants, cities can ensure that their ancient trees continue to thrive amidst urban growth.

Pollution is a pervasive and insidious threat to ancient urban trees. These majestic trees, which have survived for centuries, are now exposed to a variety of pollutants, which are often more intense in urban areas than in their natural environment. From air pollution to soil and water, pollution weakens the resilience of these trees and undermines their health, making them more vulnerable to other environmental stressors. Determination of the specific ways in which pollution affects ancient trees and strategies to mitigate these effects is important for their long-term survival. Urban areas are centres of various sources of air pollution, including emissions from vehicles, industrial activities and heating systems. The main air pollutants that pose a significant threat to ancient trees include:

- Nitrogen oxides (NO_x): emitted mainly by vehicles and industrial processes, nitrogen oxides can damage plant tissue, reducing the ability of trees to photosynthesise and grow. Nitrogen pollution can also cause soil acidification, which affects the delicate balance of nutrients in the soil, which in turn harms tree roots and overall tree health.

- Sulphur dioxide (SO₂): produced mainly from the combustion of fossil fuels, sulphur dioxide can cause direct damage to tree leaves, leading to chlorosis (yellowing) and necrosis (tissue death). Over time, prolonged exposure can impair important functions of a tree, such as photosynthesis, rendering it more susceptible to other stressors such as drought or disease.

- Particulate matter (PM): fine particulate matter from vehicles, construction sites and industrial activities can settle on the leaves and bark of trees, blocking the pores (stomata) through which trees exchange gases. This limits their ability to absorb carbon dioxide for photosynthesis and release oxygen. In the case of ancient trees, this reduced gas exchange can weaken the overall vitality of the tree, slowing growth and making it more susceptible to disease.

- Ozone (O₃): while ozone in the upper atmosphere protects against harmful ultraviolet radiation, ground-level ozone, formed as a result of chemical reactions between NO_x and volatile organic compounds (VOCs), is highly toxic to trees. It can cause oxidative stress in plant cells, leading to leaf damage, reduced growth and impaired physiological functions. For ancient trees, which may already be stressed due to age or other urban conditions, this additional stress can accelerate the decline.

- Soil in urban areas can be contaminated by a variety of substances, including heavy metals, chemicals and industrial waste, road runoff and improper waste disposal. These pollutants can have a significant negative impact on the health of ancient trees:

- Heavy metals (lead, cadmium, arsenic): heavy metals are commonly found in urban soils due to vehicle emissions, industrial pollution and construction materials. These metals can accumulate in the soil over time, becoming toxic to tree roots. Lead, in particular, disrupts the absorption of

essential nutrients such as calcium and potassium, weakening the tree and making it more susceptible to disease and environmental stress.

- Chemical pollutants (pesticides, herbicides, fertilisers): the use of chemicals to manage urban green spaces can unintentionally harm ancient trees. Pesticides and herbicides can kill beneficial soil organisms that trees depend on for nutrient cycling, while excessive fertilisers can lead to nutrient imbalances, causing abnormal growth and reducing tree vigour.

- Salt from de-icing treatment: in cold climates, salt is commonly used to remove ice from roads and pavements. This salt can run off into the soil around the ancient trees, leading to salt stress. The high concentration of salt in the soil disrupts the absorption of water by the roots of trees, causing dehydration even when water is available. This salt stress can lead to leaf scorch, stunted growth and, in severe cases, tree death.

- Water pollution in urban areas can come from sources such as road runoff, industrial discharges and improper waste management. These substances get into the soil and groundwater, deteriorating the condition of trees:

- Oil and chemical spills: oil, petrol and chemicals from vehicles and industrial processes can run into nearby soil or water bodies, contaminating the water sources on which trees depend. These substances can be toxic to tree roots, disrupting the absorption of nutrients and water.

- Excess nutrients (eutrophication): runoff from fertilisers used in urban landscaping or agriculture can introduce excess nutrients such as nitrogen and phosphorus into water. Although these nutrients are essential for plant growth in small amounts, overloading can lead to nutrient imbalances that have a negative impact on trees. For instance, excess nitrogen can lead to rapid growth of trees, but with a weaker structure, making them more vulnerable to breakage and rot.

- Acid rain: airborne pollutants, such as sulphur dioxide and nitrogen oxides, can combine with water vapour in the atmosphere to form acid rain. When this rain falls on ancient trees, it can acidify the soil, leaching important nutrients such as calcium and magnesium. Acid rain can also directly damage the leaves and bark of trees, further weakening the tree's defences against other environmental stressors.

Urban areas tend to have higher temperatures than the surrounding rural areas due to the heat island effect, where buildings, roads and other infrastructure absorb and retain heat. Pollution from vehicles and industrial activity contributes to this phenomenon by trapping heat and raising the temperature even further. Higher temperatures combined with air pollutants create harsh conditions for ancient trees. Higher urban temperatures increase the rate at which trees lose water through evapotranspiration. In polluted environments where water quality and availability may already be compromised, this can lead to severe water stress, especially during heat waves. Ancient trees, which often have deep and extensive root systems, have difficulty finding sufficient water in such conditions. Heat and pollution exacerbate drought conditions in urban areas. Trees exposed to drought are more vulnerable to pests, diseases and other stressors. In addition, drought weakens the tree's ability to absorb nutrients, leading to further deterioration in health.

Pollution weakens the overall health of ancient trees, making them more susceptible to pests and diseases. Air and soil pollution can disrupt a tree's natural defences, reducing its ability to produce protective chemicals that protect against insect infestations or fungal infections. This creates a vicious circle: pollution weakens the tree, and a weakened tree becomes a target for pests and

pathogens, leading to accelerated decline and, in some cases, death. Pollution poses a significant and complex threat to urban ancient trees, affecting their health through air, soil and water pollution. Although urban environments are inherently more polluted, mitigation strategies such as reducing emissions, improving soil quality and increasing green infrastructure can help protect these plants. By undertaking coordinated actions to reduce pollution and increase the resilience of ancient trees, cities can preserve ancient trees for future generations.

Climate change poses an increasingly serious threat to ancient urban trees, which are often hundreds of years old and have adapted to specific climatic conditions over time. As global temperatures rise and weather patterns become more erratic, these trees face challenges they may not be prepared to handle. The impacts of climate change on ancient trees include extreme temperatures, altered precipitation patterns, increased storm frequency and increased levels of pests and diseases. Preserving trees in the face of climate change requires a combination of proactive planning, adaptive management strategies and community engagement. Global warming has led to an overall increase in average temperatures, but more importantly, it has increased the frequency and intensity of heat waves. Urban areas, with their abundance of concrete, asphalt and buildings, experience an “urban heat island” effect, where temperatures can be several degrees higher than in rural areas. Ancient trees that are used to more stable climatic conditions are particularly vulnerable to stress caused by excessive heat.

Higher temperatures increase the rate of evapotranspiration (the process by which water evaporates from the soil and transpires from tree leaves). During heat waves, ancient trees can lose water faster than they can absorb it, leading to dehydration. This can cause leaf wilting, reduced photosynthesis, and weakened overall tree health. Dehydrated trees are also more susceptible to pest and disease infestation. Extreme heat creates tremendous physiological stress for ancient trees. For instance, the stomata (small pores on leaves) may close to prevent water loss, but this restricts the flow of carbon dioxide, thereby reducing the photosynthesis ability of the tree. Over time, this can lead to reduced growth, reduced nutrient supply and reduced tree viability. Many ancient trees are species that are adapted to specific temperature ranges. A sudden increase in average temperatures or prolonged periods of extreme heat can push these trees beyond their temperature tolerance, especially if they do not have a natural resistance to high levels of heat. Species that have evolved in cooler, more temperate climates are particularly vulnerable, as their metabolic processes can be disrupted at higher temperatures.

Climate change is leading to significant shifts in precipitation patterns, which can manifest as prolonged droughts or intense rainfall. Both extremes can be devastating for ancient trees. Many regions are experiencing longer and more severe droughts due to climate change. Drought conditions deprive ancient trees of the constant water supply they need to maintain their extensive root systems. Over time, the lack of moisture can cause the soil to dry out, reducing the availability of nutrients and impairing the tree’s ability to perform basic physiological processes. As a result, trees can suffer from reduced growth, leaf loss and increased susceptibility to pests and diseases. On the other hand, some areas are experiencing more intense rainfall and flooding. Although trees need water, excessive moisture can be just as damaging as drought. Prolonged waterlogging can lead to a lack of oxygen in the soil, causing the roots of ancient trees to suffocate. This can lead to root rot and increased vulnerability to pathogens. In addition, sudden heavy rains after a period of dryness can cause soil erosion, exposing or damaging roots and destabilising trees.

Ancient trees often rely on predictable seasonal cycles, such as regular periods of rainfall and drought conditions, to regulate growth, leaf drop and dormancy. Climate change could disrupt these cycles, leading to disrupted or untimely growth patterns. For instance, warmer winters can prevent trees from entering proper dormancy, forcing them to expend energy at the wrong time of year and weakening their overall health. One of the most visible impacts of climate change is the increase in extreme weather events such as storms, hurricanes and high winds. Ancient urban trees are particularly vulnerable to the physical impacts of these events, given their age, size and exposure. Due to their age and size, ancient trees are often more susceptible to physical damage from high winds. Windfall (uprooting by the wind) can occur when the soil around a tree becomes waterlogged, weakening its anchorage. In addition, storms can break large branches or even break the tree trunk. This is particularly dangerous in urban areas, where fallen trees or branches can cause property damage or endanger human life.

Although ancient trees are usually strong, over time they can develop structural weaknesses such as hollow trunks or deadwood. These weaknesses can make them more susceptible to damage during extreme weather events, which are becoming more frequent due to climate change. A single storm or wind event can cause significant and irreversible damage to these ancient trees. Conversely, as extreme storm events become more frequent, ancient urban trees can suffer root damage from flash floods. Flash floods can erode the soil, exposing the roots and destabilising the tree. Roots can also suffer from suffocation if they remain submerged in water for long periods. In urban areas where drainage systems are often overflowing with heavy rainfall, flooding near old trees is becoming an increasing problem. Climate change is also changing the range and prevalence of pests and diseases that affect ancient trees. Higher temperatures and milder winters allow many pests and pathogens to thrive, increasing the risk of infection and disease. Many insect pests, such as bark beetles and aphids, are expanding their range due to warmer temperatures. These pests can cause significant damage to ancient trees by chewing through trunks, feeding on leaves or spreading disease. In particular, climate change may allow pests to survive milder winters, allowing them to reproduce faster and cause more damage during the growing season.

Higher humidity and higher temperatures create ideal conditions for certain fungi and pathogens to thrive. Diseases such as Dutch elm disease or sudden oak death, which are caused by fungi, can spread more easily in a changing climate. Ancient trees, already weakened by other environmental stressors, are less able to fight these infections, leading to decline or death. Climate change can also contribute to the spread of invasive plant species that displace native vegetation. These invasive species can change the ecosystem around ancient trees by altering soil chemistry, competing for water and nutrients, or increasing the risk of fires. As these invasive species spread due to climate change, the delicate balance of the ecosystems on which ancient trees depend is being disrupted, further threatening their survival. Ancient trees are substantial in carbon sequestration by capturing and storing large amounts of carbon dioxide over their long lifespan. However, as climate change worsens, the ability of ancient trees to continue to provide this important ecosystem service is being threatened. As ancient trees are stressed by heat, drought and pests, their ability to photosynthesise and store carbon is reduced. If these trees die prematurely due to climate-related stressors, the carbon they have stored for centuries is released back into the atmosphere, further exacerbating global warming. Protecting ancient trees is therefore not only about preserving history and biodiversity but also about maintaining critical natural processes that help mitigate climate change.

Ancient trees are often key species in their ecosystems, supporting a wide range of plant and animal life. Climate change threatens to disrupt these ecosystems by altering the availability of water, nutrients and habitat. As trees become weaker or die, species that depend on them, such as birds, insects and smaller plants, may also suffer. This loss of biodiversity can create a cascade of negative impacts on the wider urban environment. Climate change poses a significant and complex threat to urban ancient trees due to rising temperatures, changing precipitation patterns, extreme weather events and an increase in pests and diseases. These trees are facing environmental challenges they have never experienced before. However, with adaptive management strategies and a commitment to urban sustainability, these natural monuments can be protected. By protecting ancient trees, cities can not only preserve their historical and environmental heritage but also contribute to the global fight against climate change.

Urban ancient trees require constant care and attention to thrive, especially in challenging urban environments. However, neglect and lack of proper care pose a significant threat to these trees, often leading to decline and premature death. Although ancient trees survive for centuries, the stresses they face in urban areas, combined with inadequate care, can quickly weaken their health and resiliency. Neglect can take many forms, including failure to monitor tree health, inadequate watering, poor soil management and lack of pruning or structural support. Without proper care, urban ancient trees can become more susceptible to environmental stressors such as pests, disease, pollution and extreme weather conditions. Below are the main aspects of neglect and poor care that threaten ancient trees, as well as strategies to address these issues and ensure the longevity of these urban giants. One of the most significant aspects of neglect is the failure to regularly monitor the health of ancient trees. Urban ancient trees are often left unattended, even though they face greater challenges than trees in rural or natural environments. Without periodic inspections, early signs of decline may go unnoticed until the tree is weakened or irreversibly damaged.

Ancient trees are vulnerable to disease and pest infestations, especially in urban areas where air quality, soil health and biodiversity are often under threat. Regular health monitoring allows for early detection of problems such as fungal infections, pest infestations (e.g., woodworms) or symptoms of root rot. Without this proactive approach, infestations or infections can spread undetected, weakening the tree and making intervention more difficult or impossible. Over time, ancient trees can develop structural weaknesses such as hollow trunks, dead wood or cracked branches, which can increase the risk of failure. These problems are often not visible without a thorough inspection. Without timely intervention, weakened branches or trunks can collapse, causing significant damage to the tree and posing a safety risk to people and property in the vicinity. Watering and soil care are essential components of tree health, especially in urban environments where natural water sources can be limited and soils are often compacted or contaminated. Unfortunately, urban ancient trees are often neglected when it comes to proper irrigation and soil management, leading to severe stress and decline. Ancient trees, especially those growing in paved areas or surrounded by urban infrastructure, may not receive enough water through natural rainfall or groundwater. This is especially true during droughts or in regions where water availability is limited. Without adequate watering, trees become dehydrated, their root system weakens, and they are more susceptible to environmental stressors such as heat waves or disease.

Urban development often results in soil compaction, which limits water infiltration and oxygen access to tree roots. Improper soil management, including lack of mulching, aeration, or soil

additives, can lead to nutrient deficiencies that weaken ancient trees. Degraded soils are less able to support the expansive root system of the tree, which is necessary to absorb water and nutrients. Over time, this lack of attention to soil health can contribute to a decline in the overall health of the tree. In some cases, the lack of proper drainage systems around ancient trees can lead to waterlogging during heavy rains or floods. Waterlogged soils deprive the roots of the oxygen they need to breathe. Without oxygen, the roots begin to suffocate, leading to root rot and other problems that compromise the health and sustainability of the tree. Proper pruning and structural support are essential to maintain the health, stability and longevity of urban ancient trees. However, neglecting these methods or implementing them incorrectly can have devastating consequences.

Without regular pruning, ancient trees can develop a canopy that is too dense, which can block light from reaching the inner branches and create excessive weight on the tree structure. This results in weak or dead branches that are more prone to break during storms or strong winds. In some cases, the branches can break underweight, causing injury to the tree and creating entry points for pathogens or pests. Improper pruning, such as “topping” (cutting off the top of a tree’s crown), can seriously damage ancient trees. Topping leads to rapid, weak regrowth, which increases the tree’s vulnerability to pests and diseases. Improper pruning also leads to open wounds on the tree, which facilitates infection by fungi, bacteria and insects and causes rotting. Over time, these wounds weaken the tree, making it more prone to decline and fall. Ancient trees that have developed structural weaknesses, such as hollow trunks or leaning branches, may require additional support to maintain stability. This includes systems of cables or braces to help distribute the weight of heavy branches and prevent breakage. Neglecting such support leaves the tree vulnerable to falling, especially during storms or high winds. The absence of support systems also increases the risk of property damage or personal injury in the event of a fall.

Ancient urban trees often face a wide range of stressors, from pollution to physical damage from nearby construction. If these trees are not properly protected, they can suffer long-term damage. The urban environment is dynamic and constantly changing due to construction, development and human activity. Without protective measures, ancient trees are often damaged by heavy machinery, soil compaction due to nearby construction, or root disturbance caused by digging or paving. In some cases, trees may also be subject to vandalism, such as bark being cut or branches being broken. Such physical injuries can lead to infection, decay and structural weakening. The long-term health of ancient trees requires careful planning and a commitment to ongoing maintenance. Many ancient urban trees do not have specific maintenance plans in place to ensure their long-term health. These plans should include regular inspections, pruning schedules, soil management, and strategies for dealing with environmental stressors. Without a long-term care plan, ancient trees are often left to decline due to increasing urban pressure, and intervention is only undertaken after significant damage has been done.

Cities and municipalities may not allocate sufficient budgets or resources for the proper maintenance of ancient trees. Without adequate funding, regular inspections, maintenance and emergency interventions may be delayed or ignored altogether. This lack of investment in tree care can cause the gradual loss of valuable ancient trees, central to urban ecosystems and cultural heritage. Neglect and lack of proper care are often overlooked as threats to ancient urban trees, but they can have a profound impact on the health and longevity of these irreplaceable natural assets. By implementing regular monitoring, proper watering and soil management, professional pruning and

protection from urban stressors, cities can ensure that ancient trees remain sustainable. A commitment to long-term care is essential to preserve the ecological, cultural and historical significance of these majestic trees.

To protect urban ancient trees, mainly used mitigation strategies include:

- **Implementation of protective zoning and legislation.** One of the most effective strategies for protecting urban ancient trees is to create a legal framework that protects them. Municipal governments can enforce strict zoning laws that prohibit construction or infrastructure development near ancient trees. In addition, legislation requiring environmental assessments before urban projects can ensure that the health of these trees is taken into account in the planning stages.

- **Soil management and tillage methods.** To counteract the harmful effects of soil compaction, cities can use loosening techniques such as radial trenching or air digging to help restore soil aeration and permeability. Mulching around the base of ancient trees can also help improve soil quality, retain moisture and reduce competition from lawn grass and weeds.

- **Pollution reduction.** Cities can take measures to reduce air pollution, which will benefit not only the urban population but also ancient trees. Encouraging the use of electric vehicles, controlling industrial emissions and improving green spaces can mitigate the harmful effects of pollutants on trees. Buffer zones with vegetation can also help filter out pollutants and provide a healthier microenvironment for ancient trees.

- **Climate adaptation strategies.** Given the growing impacts of climate change, cities should prioritise planting a variety of tree species, including those that are resilient to changing conditions, to create a stronger urban forest. For ancient trees, creating microclimates by strategically planting other species or structures that provide shade and reduce temperature stress can help mitigate the effects of heat waves and drought.

- **Disease monitoring and control.** Regular monitoring for signs of pest infestation, disease or structural defects is crucial to maintaining the health of ancient trees. Integrated pest management techniques that utilise biological control and environmentally friendly treatments can be effective in reducing the risk of infestation without compromising the ecosystem of the tree. Early intervention can prevent fatal problems.

- **Resident participation and management.** Involving the local community in the care and preservation of urban ancient trees is a vital strategy. Educational programmes on the importance of these trees, combined with volunteer maintenance initiatives, can help build a sense of willingness to change. Encouraging citizens to report injuries or signs of disease can lead to timely intervention and better long-term preservation.

Urban ancient trees are irreplaceable ecological and cultural assets, but they face numerous challenges due to the pressures of modern urban life. To ensure their survival, cities must take proactive measures to mitigate the threats they face, from proper soil management and pollution control to legislative protection and popular participation. With the right strategies, ancient trees can continue to thrive and benefit future generations.

1.4 Best practices for preserving ancient urban trees

Ancient urban trees significantly contribute to biodiversity, aesthetics and the well-being of the urban environment. Their conservation is crucial but challenging, as urban stressors such as

pollution, limited space and soil compaction can threaten their survival. In recent years, advanced methods for improving the preservation of ancient trees have emerged, combining modern technology with ecological understanding. Arboricultural methods are aimed at the care, management and preservation of trees, especially in complex urban environments. Ancient urban trees, which are often hundreds of years old, require special attention due to their age, size and the stresses they experience from urban development, pollution and climate change. Effective arboricultural techniques help to keep these trees healthy, structurally stable and aesthetically valuable. Below are the main arboricultural techniques used to preserve ancient urban trees.

Crown reduction and pruning are vital techniques that involve selectively removing parts of a tree, such as branches or dead wood, to reduce stress and improve its overall health and resilience. These methods are particularly important for ancient trees, which can have large, heavy crowns that are prone to breakage. Crown reduction involves carefully pruning the outer parts of a tree's crown to reduce its overall size. The aim is not to change the natural shape of the tree, but to minimise the risk of failure, especially during storms or high winds. For older trees, crown reduction helps control the mechanical stress on the trunk and branches, thereby preventing potential structural failure. Selective pruning removes dead, diseased or weak branches that may pose a risk to the health of the tree or public safety. It also stimulates new growth by allowing light and air to penetrate the tree. Proper pruning, especially of old or weakened branches, can extend the life of the tree by preventing the spread of rot or insect infestation. For older trees, pruning should be carried out with great care, as excessive branch removal can lead to stress or reduced vitality. This is usually carried out by a certified arborist, ensuring that the cuts are made at the right points to minimise damage to the tree's natural cover.

Soil aeration and root protection. The health of a tree is closely related to the condition of the soil it grows on, especially in urban areas where soil compaction due to foot traffic, construction or vehicles is common. Compacted soil can limit the availability of water, oxygen and nutrients, which are crucial for root function. Soil compaction around ancient trees can be mitigated by aeration techniques, which involve loosening the soil without damaging the tree's root system. Specialised tools, such as an air shovel, use compressed air to gently loosen compacted soil, allowing air, water and nutrients to reach the roots more efficiently. Aeration is particularly useful in urban areas where soil tends to become compacted due to heavy traffic or nearby construction. Root protection zones are designated areas around a tree where activities such as excavation, construction or heavy machinery are restricted to protect the roots. The size of the root protection zone is generally dependent on the size of the tree, with larger ancient trees requiring more space. Establishing a RoWZ can help prevent root damage that could otherwise lead to tree instability or poor health.

Root pruning and relocation support. Urban development often puts old trees at risk of root damage due to construction or infrastructure improvements. When the roots are on the way to developing, root pruning may be necessary. However, this should be done with extreme caution, as root loss can reduce the tree's ability to absorb water and nutrients, leading to potential decline or destabilisation. Controlled root pruning involves carefully cutting back roots that interfere with construction or utilities while ensuring that the tree remains stable. Root pruning should be carried out by trained professionals, as cutting too many key roots can destabilise the tree or cause permanent damage. The goal is to balance the needs of urban development while preserving the health of the tree. In some cases, instead of cutting the roots, they can be covered or tunnelled underneath.

For instance, utility lines or sidewalks can be rerouted so that they pass over the roots without cutting them. This method helps to preserve the integrity of the tree while adapting to the urban infrastructure. In exceptional cases where ancient trees are threatened by imminent housing development, tree transplanting may be considered. Although this is a last resort for particularly old trees because of the associated stress, modern equipment and careful planning allow large historic trees to be transplanted safely. The success of transplanting depends on several factors, including the species of tree, size, and the health of its root system.

Stretching and strengthening. As ancient trees age, their large branches can become vulnerable to breakage, especially in urban environments where trees are exposed to strong winds or heavy snow. Stretching and bracing techniques help provide structural support for these trees, reducing the likelihood of branch or trunk collapse. Stretching involves placing flexible steel cables between branches or parts of a trunk to restrict movement and provide additional support. The cables are particularly useful for preventing the splitting of multi-stemmed trees, which are more prone to breakage. Bracing uses rigid rods to strengthen weak or cracked areas of a tree. Unlike cables, which allow for some natural movement, bracing is designed to hold parts of a tree together rigidly, often within the trunk or branches. Spacers are typically used for trees with structural defects that could lead to failure if left unmaintained. Spacers are non-invasive methods that preserve the natural appearance and function of ancient trees while ensuring their safety in urban environments.

Improving soil health by mulching and fertilising. Urban trees often grow on degraded soils that lack organic matter and essential nutrients. Improving soil health is essential for maintaining the vitality of ancient trees. Mulching is the application of organic mulch, such as wood chips or compost, around the base of a tree – a simple but effective method of improving soil conditions. Mulching helps retain moisture, regulate soil temperature, reduce soil compaction and slowly release nutrients as it decomposes. For ancient trees, mulch should be applied in a wide circle around the tree, avoiding direct contact with the trunk to prevent rotting. In cases where soil tests show a nutrient deficiency, targeted fertilisation may be necessary. However, over-fertilisation can cause stress to an ancient tree, therefore it should be done carefully. Slow-release fertilisers are often preferred as they provide a steady supply of nutrients without overwhelming the tree. In some cases, arborists use biochar, compost teas or mycorrhizal inoculants to enrich the soil. These natural soil enhancers increase microbial activity and help trees absorb more water and nutrients through their roots.

Health and risk assessment. Regular inspections are essential for managing the health of ancient urban trees. Arborists use advanced diagnostic tools to assess the health of a tree and evaluate potential hazards. They conduct visual inspections to look for signs of decay, disease or structural weakness. This includes checking the trunk, branches and root extensions for cracks, cavities or fungal growth. Resistographs and sound tomography are used to assess the internal condition of wood without causing damage. The resistograph drills a tiny hole in the wood and measures the resistance, which can indicate the presence of rot or voids. Sound tomography sends sound waves through the wood to map its internal structure, revealing areas of decay or weakness. These assessments can be used for informed decision-making on tree care, whether it needs to be pruned, cabled or, in extreme cases, removed. Arboricultural techniques are crucial in the ongoing effort to preserve ancient urban trees. By using advanced pruning techniques, improving soil health, protecting roots and using structural support systems such as cable tying, arborists can ensure that these valuable natural assets continue to thrive for many years to come. Combined with regular

health assessments and proper urban planning, these techniques allow ancient trees to coexist with modern urban infrastructure while preserving their ecological and historical significance.

Tree risk management is crucial in the preservation of ancient urban trees, ensuring both their long-term health and the safety of the environment. As urban trees age, they face increased risks due to environmental stressors, mechanical damage and structural deficiencies. Advances in monitoring technologies have revolutionised the way arborists and urban foresters assess and manage the risks associated with ancient trees, offering non-invasive and highly accurate methods for detecting internal decay, structural deficiencies and root health issues. Some tree health assessment technologies were mentioned earlier, but below we will explore the main monitoring technologies used to manage tree risk in more detail, including the effect on ancient tree preservation in the context of urban environments.

Resistograph and sound tomography for internal tree assessment. One of the most important challenges in assessing the health and sustainability of ancient trees is the detection of internal decay or structural defects that are not visible from the outside. The two key technologies used to assess internal conditions without causing damage to the wood are resistographs and sound tomography. A resistograph is a tool used to measure the internal density and integrity of a tree. The resistograph works by drilling a very thin needle into the tree trunk, which measures the resistance created when it moves through the wood. If the wood is healthy and dense, the resistograph will encounter significant resistance, while rotten or hollow areas will show less resistance. The results are displayed as a graph, giving arborists a clear picture of the internal structure of the wood. They are particularly useful for identifying internal decay, cavities or rot that could weaken the structural integrity of the tree. Arborists use this data to determine whether the tree is at risk of collapse or whether corrective measures such as cabling or reinforcement are necessary. For ancient trees, the minimally invasive nature of the resistograph is ideal as it provides critical information without causing additional damage to the tree.

Sound tomography is a non-invasive technique that uses sound waves to create a cross-sectional image of the internal structure of a tree. When sound waves are transmitted through a tree, they propagate faster through healthy, dense wood and slower through rotten or hollow areas. Sensors placed around the tree trunk pick up the speed of these sound waves, and the data is then used to create a detailed map showing areas of weakness or decay. Sound tomography is highly effective in diagnosing the extent of decay in large, older trees, allowing arborists to pinpoint problem areas before they become serious. The technology is also useful in deciding whether a tree can be preserved through interventions such as cabling or pruning, or whether removal is the safest option. For historic and protected trees, this non-invasive approach is crucial to balancing risk management and conservation.

Ground penetrating radar for root health and mapping. The health of a tree's root system is essential to its overall stability and longevity. In urban areas, root systems are often stressed by construction, paving, or soil compaction, but roots are hidden from view, making assessment difficult. Ground penetrating radar is a technology that is becoming increasingly valuable for assessing the condition and extent of tree roots without disturbing the soil. Ground penetrating radar sends electromagnetic waves into the ground, which are reflected when they encounter objects such as tree roots, rocks or buried infrastructure. The reflected signals are then analysed to create a subsurface image of the root structure, providing detailed information on the depth, size and distribution

of roots. This allows arborists to map the extent of a tree's root system and assess its health, which is especially important in urban environments where construction projects can pose a threat to tree roots. With ground-penetrating radar, urban planners can avoid damaging critical roots, and arborists can monitor root health to ensure that the tree remains stable. Ground penetrating radar can also help diagnose root rot, which is especially important for older trees that may have compromised root systems due to age.

Digital canopy imaging and drones to assess canopy health. The health of a tree's canopy is a prominent indicator of overall tree state. Monitoring canopy health can detect early signs of stress, disease or environmental damage. Traditional canopy inspections can be labour-intensive and time-consuming, especially for large or hard-to-reach trees. However, the use of drones equipped with digital imaging technology has greatly expanded the possibilities for canopy monitoring. Drones have high-resolution cameras and sometimes infrared or multispectral sensors that take detailed images of the tree canopy from different angles. These images can then be analysed to assess the condition of leaves, branches and the overall structure of the canopy. Multispectral imaging, which captures light outside the visible spectrum, is particularly useful for detecting early signs of disease or water stress in the canopy. Digital canopy imaging allows arborists to monitor foliage density, leaf colour changes and branch health in real-time. By taking pictures regularly and comparing them, arborists can detect subtle changes in tree health that may indicate stress from drought, pests or disease. For ancient trees, where early intervention is key to preservation, this technology is a valuable tool for proactive maintenance.

Thermal imaging for diagnosing tree health. Thermal imaging is another innovative technology used to assess tree health. By measuring temperature fluctuations on the surface of the wood, thermal imaging can reveal hidden problems such as water stress, infection or decay. Healthy trees maintain a constant flow of water through their trunk and branches, which helps regulate their surface temperature. Areas of the tree that are stressed, decayed, or infected with pathogens may exhibit abnormal temperature patterns due to impaired water flow or metabolic activity. Thermal imaging cameras detect these temperature changes, creating a thermal map of the tree that highlights potential problem areas. Thermal imaging is particularly useful for diagnosing tree health problems that may not yet be visible to the naked eye. It can be used to detect early signs of fungal infections, decay or drought stress, allowing arborists to address these issues before they cause significant damage. For older trees, early detection of health problems is crucial for timely intervention, as older trees may be less resistant to environmental stresses and diseases.

Dendrometers and sap flow sensors for continuous monitoring. Dendrometers and sap flow sensors are specialised tools used for continuous long-term monitoring of tree growth and water transport. These tools provide real-time data on physiological processes within a tree, allowing arborists to track changes in health over time. Dendrometers are devices that measure changes in the diameter of a tree trunk, which can indicate growth patterns or stress responses. By tracking the expansion and contraction of the trunk, arborists can monitor how environmental factors such as drought, heat stress or nutrient availability affect tree growth. Sap flow sensors measure the movement of water within a tree, providing information about the tree's water uptake and use. This data is particularly useful for managing ancient trees in urban environments where water availability may be limited or inconsistent. Monitoring sap flow can help arborists determine whether a tree is experiencing drought stress or whether its root system is functioning properly. Continuous

monitoring tools, such as dendrometers and sap flow sensors, are invaluable for ancient trees as they provide a constant stream of data that can alert arborists to changes in the tree's condition before they become critical. This enables more proactive management, reducing the risk of sudden death or decline of the tree.

Remote sensing and GIS integration for urban tree management. In addition to technologies for monitoring individual trees, remote sensing and geographic information systems (GIS) are being used to manage tree health and risk across urban landscapes. These tools can be used to assess tree health on a broader scale and integrate data from multiple sources into comprehensive tree management plans. Satellites and aerial photography collect data on urban tree cover, vegetation health and environmental changes over time. Remote sensing provides a bird's-eye view of urban tree canopies, helping city officials and arborists identify areas where trees may be under stress due to factors such as pollution, urban heat islands, or invasive species. GIS platforms can be used to map and track tree health data across a city or region. By integrating data from tools such as drones, ground penetrating radar and thermal imagery, GIS systems create detailed maps of tree health, root systems and potential risks. This spatial data can be used for long-term urban planning, risk assessment and resource allocation, ensuring that ancient trees receive the attention and care they need.

Monitoring technologies are indispensable tools in the conservation and risk management of ancient urban trees. Using advanced techniques such as resistographs, sound tomography, ground penetrating radar, drones and thermal imaging, arborists can accurately assess the internal and external condition of these trees without causing harm. Continuous monitoring tools such as dendrometers and sap flow sensors, combined with large-scale management systems such as GIS, enable more efficient and proactive care. These technologies not only help to protect ancient trees from urban stressors and environmental changes but also ensure public safety by reducing the risk of tree mortality. By combining high-tech solutions with traditional tree care methods, it is possible to preserve the beauty, history and ecological value of ancient trees for future generations.

Soil health is one of the most important factors affecting the vitality and longevity of ancient urban trees. In urban areas, soil conditions often deteriorate due to factors such as compaction, pollution, construction activities and the removal of organic matter. These conditions can limit a tree's access to essential nutrients, water and oxygen, leading to a gradual decline in health and eventual death. For ancient trees with deep and extensive root systems, poor soil conditions can be particularly detrimental. Restoring soil health is important to support the growth and survival of ancient trees in urban environments. A variety of methods are used to improve soil structure, increase nutrient availability and promote beneficial biological activity on which trees depend. Below are some of the main methods used to restore soil health for ancient trees, which have also been previously mentioned in the previous section of this monograph.

Soil compaction and aeration. Urban environments often suffer from severe soil compaction due to foot traffic, construction and the presence of heavy machinery. Compacted soil limits the availability of air and water, which are crucial for root function and growth. Soil aeration is one of the main methods used to solve this problem. One of the most effective methods of removing soil compaction around old trees is to use an air shovel. This tool uses compressed air to loosen compacted soil without damaging the roots of the trees. It gently loosens the dense soil around the root zone, creating space for air, water and nutrients to penetrate deeper into the soil profile. By improving soil aeration, arborists increase root respiration and water absorption. For older trees

with deep or wide roots, this method helps rejuvenate the soil environment and allows the tree to better access the resources it needs to thrive. Aeration also stimulates the growth of fine feeder roots, which are essential for nutrient absorption.

Another method of improving soil aeration is vertical mulching, which involves drilling small holes around the root zone of a tree and filling them with a mixture of organic matter such as compost or well-rotted mulch. This not only increases the infiltration of air and water but also ensures a slow release of nutrients to the tree. Urban soils are often deficient in essential nutrients needed for tree health, especially in areas where naturally fallen leaves and organic matter have been removed. Ancient trees, which require large nutrients due to their size and age, can suffer from nutrient deficiencies in depleted urban soils. Fertiliser and organic supplements can help restore these nutrients and support healthy tree growth. When soil analysis shows a nutrient deficiency, arborists often apply slow-release fertilisers. These fertilisers are designed to release nutrients gradually, allowing the tree to absorb them over time. This slow release minimises the risk of over-fertilisation, which can cause stress to ancient trees. Key nutrients such as nitrogen, phosphorus and potassium are added to stimulate root growth, improve leaf production and enhance the overall vitality of the tree.

In many cases, organic materials such as compost, leaf mulch or well-rotted manure are added to the soil to increase nutrient levels. Organic materials provide a steady supply of nutrients as they decompose, and improve soil structure and microbial activity. The application of organic materials around ancient trees mimics natural forest processes, where decaying leaf litter continuously replenishes the soil with nutrients. A popular method of increasing the availability of nutrients and soil biology is the use of compost tea. This liquid fertiliser is made by steeping compost in water, which extracts beneficial microorganisms, nutrients and organic compounds. The tea is then applied directly to the soil around the tree, enriching the soil ecosystem and improving nutrient absorption by the tree's roots. Compost tea is particularly beneficial for ancient trees as it promotes the growth of beneficial microbes that help to break down organic matter and make nutrients more readily available.

Biochar and soil structure improvement. In addition to adding nutrients, improving soil structure is important to restore soil health around ancient trees. Poor soil structure can limit root growth, water infiltration and nutrient availability. One increasingly popular method of improving soil structure is the use of biochar. Biochar is a form of charcoal that is produced by heating organic material in a low-oxygen environment. When added to soil, biochar improves its physical properties by increasing porosity and water retention. It also acts as a long-term soil fertiliser as it does not decompose easily and can remain in the soil for centuries, providing a stable environment for root growth. Biochar helps create air pockets in the soil, which improves root breathing and water movement. Biochar not only improves soil structure but also promotes the growth of beneficial microorganisms. It has a large surface area, which provides a habitat for soil microbes and can retain nutrients, preventing them from being washed away during heavy rains. For ancient trees, this means improved access to water and nutrients, as well as improved root development in previously compacted or degraded soils.

Ancient trees often rely on a symbiotic relationship with mycorrhizal fungi to absorb nutrients and water. These fungi form mutualistic associations with tree roots, expanding the tree's root network, and creating an extensive underground fungal filament system. In urban soils, the natural

populations of mycorrhizal fungi are often reduced due to disturbance, pollution or lack of organic matter. Arborists can restore this beneficial relationship by inoculating the soil with mycorrhizal fungi. This involves introducing a mixture of fungal spores into the soil around the root zone of the tree. After taking root, these fungi colonise the roots of the tree, significantly expanding the surface area available for nutrient and water absorption. Mycorrhizal fungi help trees access nutrients that would otherwise be unavailable, such as phosphorus, which is often lacking in urban soils. They also increase the trees' resistance to drought by enhancing water absorption. For ancient trees, mycorrhizal inoculation can be transformative, as it helps revive natural biological processes that have been disrupted in urban environments.

Mulching to retain moisture and protect the soil. Mulching is a simple but very effective method of improving the health of the soil around ancient trees. It mimics the natural forest cover, where fallen leaves constantly add organic matter to the soil and protect it from erosion, compaction and temperature fluctuations. Organic mulch, such as wood chips, bark or compost, is applied in a thick layer around the root zone of the tree. Mulching helps to retain soil moisture, reducing evaporation, which is especially important in urban areas where water availability can be variable. It also moderates soil temperature, keeping the roots cooler in summer and warmer in winter, thereby reducing the environmental burden on ancient trees (Chen *et al.*, 2014). Mulching also serves as a protective barrier against soil erosion, compaction and root damage from foot traffic. By creating a buffer zone around the tree, mulch helps prevent soil from being washed away during heavy rains or compacted by pedestrians and vehicles. This is especially important for ancient trees, whose roots often grow near the surface and are more vulnerable to damage. As mulch decomposes over time, it adds organic matter to the soil, improving its structure and fertility. This gradual addition of organic material helps to support beneficial microorganisms that play a crucial role in nutrient cycling and soil health. For ancient trees, this ongoing process helps maintain the health of the soil ecosystem, supporting their long-term viability.

The urban environment often disrupts the natural water cycle, making it difficult for trees to access the water they need. For ancient trees, especially those located in areas with altered drainage systems or impermeable surfaces (e.g. pavements), ensuring adequate moisture levels is crucial. To ensure that ancient trees receive sufficient water, deep irrigation systems are often installed. These systems deliver water directly to the root zone, where it can be absorbed by the tree's roots without being lost in surface runoff or evaporation. Deep irrigation is particularly effective in drought conditions or in areas where surface irrigation is ineffective. Another effective method of irrigation is underground drip irrigation, which slowly and directly delivers water to the soil around the roots. This method reduces water loss and provides the tree's roots with constant access to moisture, which is important for ancient trees in urban areas where there may be inconsistent rainfall or watering schedules.

To avoid over- or under-watering, moisture sensors can be installed in the soil around the tree. These sensors provide real-time data on soil moisture levels, allowing arborists to adjust watering methods as needed. For ancient trees, this ensures that they receive the optimum amount of water, reducing the risk of drought stress or root rot caused by waterlogged soils. Soil health restoration is important for the preservation of ancient urban trees, which often suffer from poor soil conditions due to the stresses of the urban environment. Through techniques such as soil aeration, nutrient

restoration, mycorrhizal inoculation and mulching, arborists can revitalise degraded soils and provide ancient trees with the resources they need to thrive. These soil health restoration techniques not only improve the physical and chemical properties of the soil but also promote the biological processes necessary for the long-term health of these historic trees. By improving soil structure, nutrient availability and moisture retention, it is possible to protect these irreplaceable natural landmarks for future generations.

As climate change accelerates, urban environments are experiencing changes in weather patterns, temperature fluctuations and the frequency of extreme events such as heat waves, storms and droughts (Weng *et al.*, 2004). These changes pose a significant threat to the survival of ancient urban trees, which are often more vulnerable due to their age, large size and long-established growth patterns. Climate-adaptive tree care is a new approach that aims to change traditional forestry practices to help ancient trees cope with and thrive in a changing climate. This approach combines monitoring, proactive management and innovative techniques that focus on resilience and adaptability. Key strategies for climate-adaptive tree care will then be demonstrated, highlighting the unique needs of ancient trees in urban environments.

- Drought resilience and water management. Water availability is one of the most relevant factors affected by climate change, especially given the increasing frequency and intensity of droughts in many urban areas. Ancient trees often have deep and extensive root systems, but even these can be severely affected by prolonged drought. Ensuring an adequate and sustainable water supply is crucial for maintaining tree health in drought conditions.

- Heat stress reduction. Rising temperatures and increasing heat waves can be particularly damaging to older trees. High temperatures increase the evaporation of water from the soil, strain the tree's physiological systems and can even lead to heat stress when the tree's natural cooling processes are disrupted.

- Wind and storm resistance. Extreme weather events, such as strong winds and storms, have become more frequent with climate change, increasing the risk of tree mortality. Ancient trees with their large crowns and often structurally damaged trunks or branches are particularly susceptible to wind damage.

- Managing diseases and pests in a changing climate. Climate change is altering the range and behaviour of many tree pests and diseases, often increasing their prevalence or intensity in urban areas. Higher temperatures and changes in seasonal patterns create more favourable conditions for pests to breed, which can put ancient trees at greater risk of infestation.

- Soil and root zone management in a changing climate. The impacts of climate change on soil conditions, such as increased salinity due to sea level rise or changing rainfall patterns, can have a significant impact on the health of ancient trees. Root zone management is crucial to ensure that the tree has access to the nutrients, water and oxygen it needs, especially as climate conditions change.

- Selecting climate-resilient tree species for urban environments. While this approach may apply more to new plantings and replacements, incorporating climate-resilient tree species into urban forestry is an important strategy for the long-term care of urban trees. For ancient trees, this principle can be applied to ensure that the overall ecosystem around them remains healthy.

Climate-adapted tree care plays an important role in the preservation of ancient urban trees as they face new and increasing environmental challenges caused by climate change. By focusing on proactive water management, heat stress mitigation, wind resistance, disease control and

soil health, arborists can help these valuable trees withstand the impacts of a changing climate. The combination of modern technology, traditional practices and ecological principles allows for a more sustainable approach to tree care, ensuring that ancient trees continue to thrive in urban environments for generations to come. Ancient urban trees are of great ecological, cultural and historical value. Their presence in cities provides shade, improves air quality, supports biodiversity and enhances the aesthetic beauty of the landscape. However, these trees often face significant threats from urban development, environmental stressors and a lack of public awareness of their importance. Public participation and legal protection are crucial components of preserving these natural landmarks for future generations.

By developing a culture of respect and care for ancient trees, the public can play an active role in their protection. At the same time, a strong legal framework is needed to protect these trees from damage or destruction due to construction, vandalism or neglect. In the following, we will investigate how public participation and legal mechanisms can collaborate to secure the long-term survival of ancient trees in urban settings. Raising public awareness of the importance of ancient trees is one of the most effective ways to engage people in their protection. Many people living in urban areas may not be aware of the significant environmental, historical and social benefits that ancient trees provide. Public education campaigns can help to foster a sense of pride and responsibility for the preservation of these trees. Organising tree tours and educational tours around important ancient trees in urban areas is a great way to engage the community. These events allow people to learn about the history, ecological value and special needs of ancient trees in their city. Arborists, historians and environmental educators can lead these tours, emphasising the importance of tree preservation and giving practical advice on how people can help protect them.

The involvement of the younger generation is key to ensuring the long-term protection of ancient trees. School curricula that include tree biology, ecology and urban forestry can inspire students to take an interest in tree conservation. Guided tours to visit ancient trees and interactive activities such as tree planting can help children develop a personal connection with these natural monuments. Teaching young people about the role of trees in combating climate change, supporting wildlife and improving urban life can inspire a lifetime of environmental stewardship. Public art projects such as murals, sculptures or photo exhibitions can help raise awareness of the importance of ancient trees. These initiatives can celebrate the beauty and heritage of specific trees while educating residents about their importance. In addition, storytelling activities, in which local elders share memories of the trees, can link cultural history to environmental conservation. In the modern digital age, social media platforms offer a powerful tool for spreading the word about tree conservation. Hashtag campaigns, tree-themed Instagram accounts, and digital storytelling about the history of local ancient trees can reach a wide audience and encourage more people to participate in protection efforts. Online platforms can also provide up-to-date information on the condition of specific trees and how the community can help.

Involving the public in monitoring and protecting ancient trees through citizen science initiatives is an effective way to create community engagement. Citizen scientists can help monitor trees by collecting data on tree health, identifying potential threats, and reporting illegal activities or damage to trees. Residents can participate in urban tree mapping projects where volunteers help document and map the locations, species, and health status of ancient trees. This data can be used to inform urban planning, guide conservation efforts, and raise public awareness of the distribution

of significant trees in urban areas. Digital platforms and applications can be used to collect and disseminate this information, making it accessible to urban planners, conservationists, and the public. Citizen science platforms can enable people to monitor the health of ancient trees. Community members can record observations related to tree health, such as pest infestations, signs of disease, or damage from storms or vandalism, using smartphone apps. This information can be shared with local authorities or tree care professionals, ensuring that problems are addressed promptly. Regular monitoring by the public also helps to detect early signs of decline, ensuring that ancient trees are proactively cared for. Adopt-a-Tree programmes allow members of the public to take responsibility for the care and monitoring of a specific ancient tree in their neighbourhood. Participants can help with watering, and mulching and report any damage or health issues. These programmes foster a sense of ownership and connection to local trees, encouraging long-term stewardship and vigilance.

Strong public advocacy is often the driving force behind legal protection and successful conservation efforts for ancient trees. Residents and grassroots organisations can be crucial in lobbying for the protection of trees threatened by development, construction or neglect. Grassroots organisations can bring together members of the public to protect ancient trees through public demonstrations, petitions and awareness-raising campaigns. These movements can be particularly effective when a particular tree is threatened by construction or urban development. By raising the profile of endangered trees and attracting media attention, tree protection groups can put pressure on urban planners, developers and local authorities to prioritise tree conservation. Organising petitions or participating in public hearings is another way people can advocate for the protection of ancient trees. By collecting signatures or presenting persuasive arguments at city council meetings, residents can push for stronger legal protection, the designation of trees as historic, or the development of urban forestry programmes that prioritise the care of ancient trees. Many cities have tree preservation societies or non-profit organisations dedicated to protecting urban forests and significant trees. These groups often cooperate in funds raisings, volunteer efforts and legal protection advocacy. Joining or supporting such organisations can amplify residents' voices and provide a more structured approach to long-term tree protection efforts.

While public participation is crucial, legal protection is often the most effective way to ensure the long-term survival of ancient trees. Municipal governments can adopt various legal frameworks to protect these trees from damage, destruction or improper pruning. Legal mechanisms can also regulate urban development around ancient trees, ensuring that construction activities do not negatively impact their health. Many cities and regions have cultural heritage tree programmes, which provide legal protection for trees of significant historical, cultural or environmental value. Once a tree has been designated as a cultural heritage tree, it cannot be pruned, felled or disturbed without special permission from the local authorities. The designation of a cultural heritage tree often comes with special care requirements, including regular inspections and maintenance to ensure the tree's health. Criteria for designating a tree as a cultural heritage site typically include factors such as age, size, rarity of species, historical significance or cultural significance. Members of the public can nominate trees for heritage status, and local arborists or tree experts evaluate nominations based on these criteria.

In many cities, tree preservation ordinances provide legal protection for trees on public and private land (Schwarz *et al.*, 2012). These ordinances may require property owners or developers to obtain permits before cutting down or significantly altering trees that exceed a certain size or age.

For ancient trees, conservation ordinances often provide for special protection measures, such as tree protection zones (TPZ), which prevent construction work from damaging the root system of old trees. Violations of tree preservation ordinances can result in fines, penalties or restoration requirements. Developers who illegally remove or damage ancient trees may be required to plant new trees or contribute to municipal reforestation funds. By imposing strict fines, municipalities can deter illegal tree cutting and encourage developers to avoid significant trees. In urban areas where ancient trees are located close to potential development sites, planning and zoning regulations play a crucial role in protecting these trees. For instance, municipalities may require developers to submit tree protection plans that describe how they will avoid damaging ancient trees during construction. Tree protection fences and root protection zones may be mandatory to ensure that construction activities do not damage the tree canopy or root system.

Where ancient trees are located on private property, conservation easements can be used to legally protect them from future development or destruction. These easements, often supported by conservation organisations, restrict certain activities on the property, ensuring that the trees are preserved for future generations. Private landowners can also receive tax incentives or grants in exchange for preserving significant trees on their property.

To ensure the long-term conservation of ancient trees, cities need to integrate the care of ancient trees into broader urban forestry policy and green space planning. These policies can guide urban forest management, allocate resources for tree care and ensure that ancient trees are prioritised in urban planning. Comprehensive urban forest management plans provide a framework for the long-term care of all trees in a city, including ancient and historic trees. These plans typically describe strategies for tree planting, maintenance, pest management and public engagement. For ancient trees, these plans often include specialised care protocols, such as increased monitoring, soil restoration efforts and climate adaptation strategies. As cities grow, the integration of green infrastructure into urban planning becomes essential for the preservation of ancient trees. Green infrastructure refers to natural systems that provide environmental benefits, such as parks, green roofs and urban forests. By prioritising green infrastructure, cities can create urban environments that support the long-term health of ancient trees while providing environmental and social benefits to residents.

In response to climate change, many cities are developing sustainability plans that include climate-resilient urban forestry practices. These policies may focus on planting climate-adapted tree species, strengthening water conservation measures and reducing the urban heat island effect. For ancient trees, sustainability policies often emphasise soil health, water management and protection from extreme weather events. Preserving ancient urban trees requires a combination of public participation and strong legal protection. Public awareness campaigns, citizen science initiatives, and grassroots advocacy can inspire residents to actively participate in tree conservation efforts. At the same time, legal frameworks such as historic tree preservation programmes, tree preservation ordinances and urban forestry policies provide essential safeguards for these trees. By developing a collaborative approach between society, government and conservation organisations, cities can ensure that their ancient trees continue to thrive and enrich urban life for the next generations. Ancient urban tree preservation requires a combination of innovative methods, environmental expertise and public engagement. As cities expand and the effects of climate change intensify, it is vital to adopt these best practices to protect these irreplaceable natural landmarks (Louv, 2010). By

integrating modern arboriculture with advanced technology and promoting public awareness, it is possible to ensure that ancient trees continue to thrive in the urban landscape for future generations.

This chapter highlights the crucial ecological role that ancient trees play in urban environments, demonstrating their importance for biodiversity, ecosystem services and resilience to environmental change. Ancient trees provide habitat for a variety of species, contribute to carbon sequestration, regulate water balance and improve soil fertility. As global climate change intensifies and human activities such as deforestation and urbanisation increase, ancient trees face multiple threats, including habitat loss, disease, pests and climate change. Ancient trees act as ecological bridges in fragmented urban landscapes, facilitating the movement of species and the flow of genetic material across isolated habitats. Carbon sequestration: contrary to previous perceptions, old trees continue to absorb carbon at a high rate, storing large amounts of carbon in their biomass, making them vital to climate change mitigation efforts.

Such trees improve soil structure and fertility through their root systems, fallen leaves and interaction with soil microorganisms. They are primary in nutrient cycling and soil moisture maintenance and help manage stormwater by intercepting rainfall and increasing water infiltration into the soil, reducing the risk of runoff and flooding. They provide shade, reduce urban heat islands and improve air quality by filtering pollutants, contributing to creation of a better urban environment. In addition to their ecological functions, ancient trees have cultural significance, enriching urban landscapes and offering psychological and recreational benefits to urban residents. This chapter emphasises the importance of preserving these natural monuments through legal protection, public participation and the integration of ancient trees into urban planning strategies. Without targeted conservation efforts, the disappearance of ancient trees could have cascading effects on biodiversity, ecosystem services and the resilience of cities to environmental stressors such as climate change.

Conclusion

Ancient urban trees play a key role in linking the natural heritage of cities with their historical and cultural evolution. These trees are not just biological entities; they are witnesses to centuries of human progress, embodying a wealth of historical, ecological and social values. Often predating the urban landscapes around them, ancient trees provide an invaluable link to pre-urban history, marking transitions from rural areas to vibrant urban landscapes. Their resilience in the face of urban development - from changes in architecture to changes in climate and air quality - has made them enduring symbols of stability and adaptability. Historically, such trees have withstood the impact of infrastructure expansion, demographic changes and even significant local and global events. They often have deep cultural significance rooted in local folklore, religious rituals and the identity of the people. Many people revere ancient trees as cultural references that inspire art, literature and local traditions. In this way, they continue to influence the fabric of urban life, offering a sense of continuity and heritage amidst the fast pace of urban development.

From an ecological point of view, ancient trees play an important role in maintaining urban biodiversity. They provide essential habitat for a variety of species, contributing to local ecosystems in ways that young trees cannot. The large crowns of old trees help clean the air, sequester carbon and mitigate urban heat through shade and transpiration. Their extensive root systems help stabilise soil, manage water runoff and reduce the risk of erosion and flooding. At a time of pressing environmental challenges, the conservation of such trees offers an irreplaceable source of ecosystem services that benefit both the urban environment and its inhabitants. Despite these benefits, ancient trees face many threats from modern urbanisation, including pollution, soil compaction and limited space for root expansion. Climate change introduces additional stressors such as rising temperatures, changing rainfall patterns and the potential spread of pests and diseases. Addressing these threats requires sound conservation strategies and policies that prioritise the health of these natural landmarks. This includes adaptive management practices, protective regulations, and incorporating ancient trees into sustainable urban planning.

Scientists, conservationists and urban planners around the world are advocating for the inclusion of ancient trees in urban development plans. This interdisciplinary approach emphasises the value of trees not only as natural relics, but also as dynamic contributors to cultural, historical and environmental sustainability. Preserving ancient trees is thus not just about protecting old plants; it is about adopting a holistic view of urban heritage that respects both natural and human history. Ancient urban trees embody and promote many humanistic values, contributing significantly to the well-being, social equity and cultural richness of urban communities. These trees offer publicly accessible natural spaces, helping to bridge socio-economic divides by providing opportunities for all city dwellers to benefit from nature. Their contributions to health, including air purification and stress reduction, improve environmental quality and help reduce health inequalities. The presence of ancient trees can also be a sign of environmental justice, as efforts to preserve them often align with broader environmental initiatives. Such trees support the interests of residents by enabling participation in urban planning and environmental decisions. In addition, ancient trees are vital for promoting mental wellbeing through their calming natural environment, providing therapeutic spaces in crowded areas, supporting natural therapy programmes and advocating for mental health

initiatives. By preserving these trees, future generations can continue to benefit from them, representing an intergenerational responsibility in urban planning. Ancient trees also have significance for different cultural groups, promoting cultural diversity and understanding. They serve as symbols of inclusiveness, representing the diverse heritage of urban populations.

Moreover, ancient urban trees contribute to the local economy through tourism or cultural activities, potentially increasing property values and contributing to more equitable urban development. The care and promotion of such trees creates employment opportunities in horticulture, tourism and education. In education, they serve as symbols of peace and continuity, promoting non-violence and inclusion, and are often used in peace education programmes, especially for youth. Some ancient trees, such as fruit or nut trees, contribute to urban food security, which is particularly important for low-income communities. By integrating such trees into urban forestry initiatives, cities can support sustainable local food systems. In addition, ancient trees often carry traditional knowledge about local food sources and preparation methods. Ancient urban trees, with their constant presence and multifaceted role in urban life, embody numerous humanistic values. They play a crucial role in creating a more equitable, healthy and socially cohesive urban environment. By offering accessible natural spaces, supporting community well-being and symbolising shared heritage and sustainability, such trees greatly enhance the quality of life for all city residents. Ancient trees in urban ecosystems serve as critical pillars for both biodiversity and environmental sustainability, enriching the urban environment with their benefits. These trees are not just relics of the past, but active participants in supporting diverse species, stabilising soils, filtering air and regulating water cycles. They act as centres of biodiversity, providing unique habitats and sustenance for a variety of organisms, including endangered species that rely on them for survival.

Their extensive root systems and large canopies help reduce stormwater runoff, mitigate urban heat and sequester significant amounts of carbon, contributing to efforts to adapt to climate change. As complex ecosystems in their own right, ancient trees support a wide range of life forms, from soil microbes to birds and mammals, thereby strengthening ecological networks within fragmented urban landscapes. The conservation of ancient urban trees is becoming increasingly important in light of urban expansion, climate change and environmental degradation. Their protection requires an interdisciplinary approach that integrates urban planning, environmental science and local participation. By valuing ancient trees not only as environmental assets but also as cultural and historical symbols, cities can create sustainable urban landscapes that honour both natural heritage and sustainable development goals. The continued presence of these trees provides a vital link to the ecological past and is a cornerstone for promoting a stable and diverse urban ecosystem for the future. Ancient urban trees serve as irreplaceable assets, embodying the harmonious blend of nature, history and culture in cities. Their presence is a reminder of the enduring power of nature and its potential to co-exist with human progress. As we look to the future, the preservation of these trees should inspire sustainable urban development that honours the heritage of the past while creating a sustainable and vibrant urban environment for future generations.

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