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Insights from i-Tree Eco-efficiency Assessment Management of Urban Trees in Oxford, UK

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Abstract In the era of stock development following the acceleration of urbanization, the revitalization of urban green space has assumed an increasingly significant role. Consequently, the management of urban trees has emerged as a critical focus of urban governance, contributing to the enhancement of livability in human settlements. This study offers a comprehensive analysis of the urban tree management system in Oxford, UK, identifying that its primary objective is to optimize and maintain a harmonious balance between human activities and the natural environment through the implementation of high-quality planting practices. The system emphasizes enhanced management practices and establishes a robust framework for the development of targeted policies and management regulations, utilizing i-Tree eco-efficiency assessment and real-time feedback mechanisms. China's urban tree management is in its nascent stages, and there is an urgent need for the development of urban green space. By adopting the refined management assessment methodologies employed for urban trees in Oxford, UK, it is possible to enhance the ecological value of urban trees, which represent a significant green resource within cities, and contribute to the creation of more livable urban spaces.

Keywords Oxford, Urban tree management, i-Tree eco-efficiency assessment, Insight, Reference

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In recent years, the ongoing development of China's economy and society, coupled with the rapid pace of urbanization, has led to the emergence of various "urban diseases" in large urban areas. Green spaces have emerged as an effective means of addressing the challenges associated with urban diseases. The construction of urban green spaces, characterized by principles of "knowledge economy" and "ecological civilization", is experiencing significant growth[1]. Simultaneously, within the framework of urban construction stock development, the management of urban trees constitutes a critical component of urban renewal and environmental governance. Furthermore, it significantly influences the urban ecological environment and the health of residents, serving as a vital strategy for sustainable urban development and embodying substantial ecological value[2]. The urban environment serves as a reflection of a city's overall strength and the advancement of its spiritual civilization. Furthermore, the management of urban trees is indicative of the level of modernization and sustainability achieved by the city throughout the urban development process. The progressively sophisticated and systematic management model of urban trees has consistently enhanced the capacity of cities to adapt to climate change. Furthermore, trees have emerged as the most substantial green resource within urban environments, and their ecological value is of immeasurable significance[3].

1 Oxford urban tree fine management system

1.1 Overall framework construction

1.1.1 Planning background. The *Oxford Urban Forest Strategy: Master Plan 2050* serves as a significant planning framework and strategic development guide for the management of urban trees in Oxford. The objectives outlined in the plan facilitate the city's attainment of its vision, which encompasses addressing and adapting to climate change and habitat degradation,

Column introduction

With the rapid acceleration of urbanization, the prevalence of "urban diseases" becomes increasingly pronounced. In the context of stock development, the revitalization of urban spaces has assumed an increasingly significant role.

The City Observer examines the urban tree management system in Oxford, UK, and evaluates its enhanced urban management framework. Additionally, it assesses the ecological benefits and the real-time feedback mechanism utilizing the i-Tree software. The aim is to provide insights that may inform urban green space development in China, thereby maximizing the resource advantages and ecological value of urban trees.

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preserving and enhancing local character, promoting healthy development, fostering biodiversity, and enhancing resilience and livability[4]. Under the master plan of the Oxford urban forest strategic ecological services system, the ecological service values generated encompass a range of benefits, including the enhancement of residents' physical and mental health and well-being, the mitigation of the urban heat island effect, the optimization of air quality and reduction of pollutant emissions, the promotion of community cohesion and participation, the increase of biodiversity, the mitigation of flood-related damages and improvement of water quality, the enhancement of carbon storage, the improvement of landscape character and the preservation of traditional culture, as well as the augmentation of economic benefits and tourism resources, etc.(Fig.1).

1.1.2 Theoretical framework for tree refined management assessment. The Oxford Urban Tree Management Assessment (OUTMA) serves as a strategic framework for the management of trees and other woody vegetation in an urban setting. This framework is organized into four distinct components: the establishment of principles and goals, the evaluation of existing data, the formulation of management plans, and considerations for future development.

Firstly, the principles and objectives of urban tree management must be established. The fundamental principle of "high-quality planting that maximizes the benefits for both humans and nature" should be implemented in order to achieve the objectives related to the protection, improvement, management, expansion, enhancement, and development of urban green spaces, as well as fostering participation, promotion, and employment opportunities within the city. The primary objectives of Oxford urban tree planning and management are delineated into four key components: (1) enhancing the biodiversity and ecosystem service value of urban trees; (2) reinforcing the role of urban green spaces in mitigating climate change and addressing related challenges; (3) fostering the creation of healthier environments conducive to physical activity; and (4) promoting increased engagement among community members and residents.

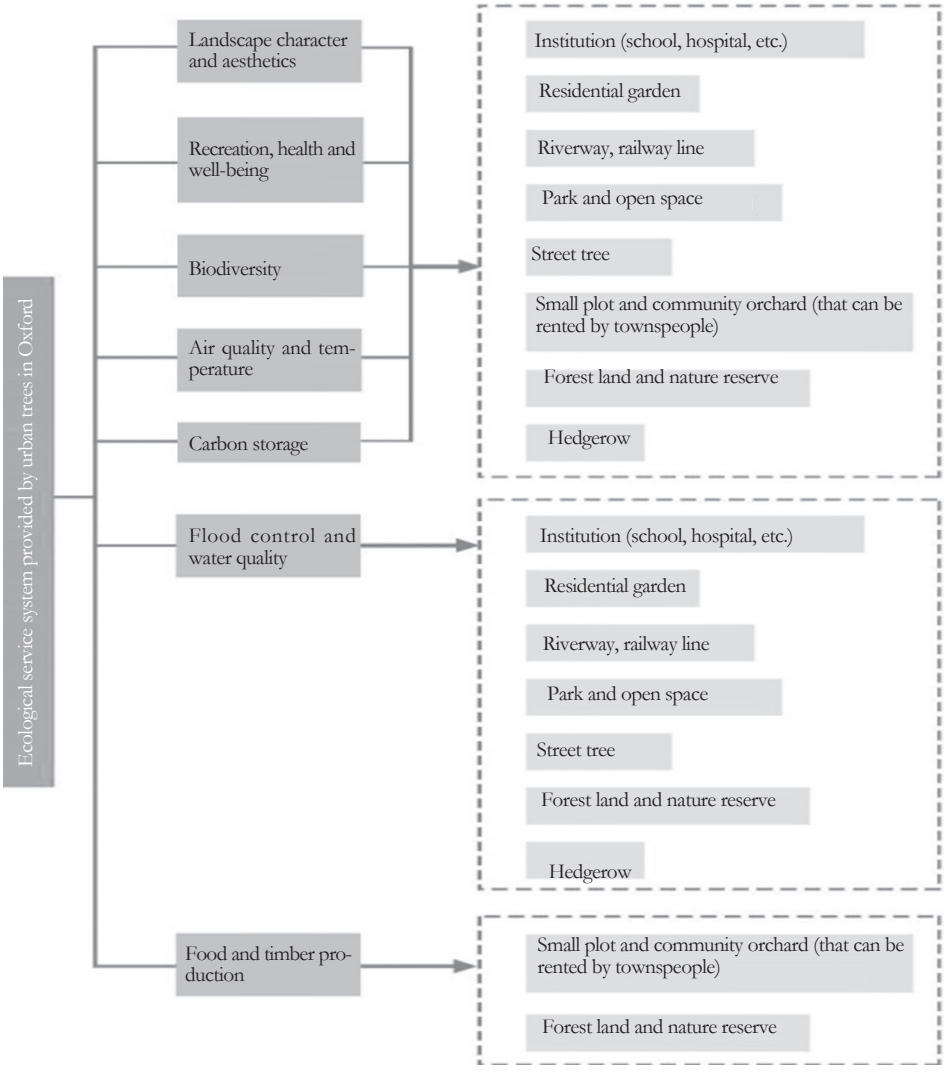

Fig.1 Relationship of ecosystem services provided by urban trees in Oxford

Secondly, a comprehensive data collection effort should be undertaken to assess the current status of urban trees. The collected data are subjected to thorough analysis and evaluation. This involves detailed and specific methodologies for data collection, including sampling surveys, field mapping, aerial imaging, and other approaches. These methods facilitate the gathering of information regarding land use type, canopy cover, surface impermeability, and other relevant plot characteristics of urban trees. Additionally, tree-specific data such as species, height, diameter at breast height (DBH), and other pertinent information are collected. These data are then imported into the i-Tree platform, which generates outputs related to the structure and composition of trees, the value of ecological services, the structural and functional attributes of trees, and the potential impacts of diseases. The resulting data is subjected to a replacement cost assessment and a tree capital asset value assessment (CAVAT). Areas requiring urban tree planting, management, and protection are identified based on the relationship between canopy cover and poverty, in order to establish a natural restoration network (NRN).

Thirdly, drawing upon the findings from the data analysis, a comprehensive conservation and management plan for urban trees can be formulated and executed. This plan will encompass specific policies aimed at the management and protection of urban trees, including the establishment of thorough inspection procedures, engineering standards for tree work, routine maintenance protocols, management principles, communication strategies, applications for tree development, mechanisms for damage compensation, review processes, practices for waste recycling management, and programs for tree replacement. The allocation of authority and responsibility for the implementation of urban tree management and preservation programs among individuals, landowners, and managers is advocated to achieve a balance in tree risk management. This approach should incorporate asset management principles in tree management and evaluate both the potential for planting and the natural regeneration capabilities of the land.

Finally, the future development of urban

tree management is critically examined. The maintenance of a robust urban tree infrastructure is essential for the effective utilization of the planning system to achieve strategic objectives. It is essential to coordinate and enhance stakeholder engagement in order to collaborate on comprehensive planting plans. Additionally, it is important to address the limitations posed by constrained funding for urban tree planting and maintenance by investigating innovative funding mechanisms. Furthermore, there is a need to explore higher-level strategic directions in greater depth.

1.2 Eco-efficiency assessment based on the i-Tree

1.2.1 Basic survey and data analysis. Assessing the eco-efficiency of urban trees in Oxfordshire represents a significant initiative undertaken by the Oxford Council in 2021. This effort aims to ensure the effective implementation of planning objectives and specific strategies for the management of urban trees in Oxford, culminating in the publication of the *Oxford i-Tree Eco Report 2021*.

The preliminary survey for this report involved the selection of a sample comprising 201 randomly assigned plots, each measuring 0.04 hm^2, within a total survey area of 4,560 hm^2. The sampling framework included both public and private lands, encompassing 0.18% of the total surveyed area, which equates to one plot per 22 hm^2. Data regarding land use type, ground cover, tree coverage rate, shrub coverage rate, proportion of plantable space, and surface impermeability of the sample plots were collected and documented. Furthermore, data regarding non-shrub trees with a DBH exceeding 7 cm within the sample plot were documented, including information on their species, category, height, DBH, crown width, crown health, crown light, as well as the distance and direction to the nearest building. The collected data were input into the i-Tree Eco software to facilitate calculations that yield outputs in four key areas: the structural composition of urban trees, ecosystem services, structural and functional values, and the disease impacts of potential pathogens and insects[5].

1.2.2 Value and evaluation. According to data presented in the *Oxford i-Tree Eco Report 2021*, Oxfordshire exhibits a tree canopy cover of 22.3%, which surpasses the UK average of 17% and the average for London, which is 21%. The canopy cover for Oxfordshire, as derived from aerial imagery using the i-Tree Canopy tool, is 21.4%. This figure is marginally lower than the estimate obtained through the i-Tree Eco method, reflecting a difference of 0.9%[6]. Estimates of tree canopy cover furnish Oxfordshire with the necessary data to strategically manage urban tree planning, thereby enhancing the master planning framework for urban tree management in Oxford. The survey conducted in 2021 identified a total of 74 species of trees and shrubs, none of which exhibited dominance within the surveyed area. Traffic in Oxford is responsible for 75% of the total pollution in the area, while trees contribute to the removal of approximately 43 kg of pollutants annually. This ecological service is valued at over 1.1 million pound. The carbon emissions of Oxfordshire are nearly 10 times greater than the total amount of carbon sequestered by the trees within the city. Nevertheless, the trees in Oxford continue to make a positive contribution to the overall carbon balance. Based on the capacity of vegetation to retain rainfall, specifically the variation in annual runoff volume with and without vegetation, i-Tree Eco has calculated the annual volume of surface runoff that is avoided. The estimated annual reduction in runoff volume attributable to urban trees in Oxford is 53,718 m^3, which corresponds to an ecological service value of 81,455 pound[5]. The aforementioned data comprehensively demonstrate the significant ecological benefits provided by urban trees.

1.2.3 Strategic recommendations and conclusions. To ensure the effective planning vision and implementation strategy for urban tree management in Oxford, ongoing assessments of ecological benefits using the i-Tree framework are conducted, alongside a comprehensive inventory of all trees. It is essential to implement replacement tree planting in accordance with the regulatory framework established by the Environment Bill Policy Statement and the Town and Country Planning Act. Additionally, real-time data on urban trees and anticipated changes are made accessible through an online platform. This initiative aims to summarize the progress of urban tree master planning management, while also facilitating the monitoring, review, and reporting of relevant developments.

The potential areas suitable for planting are systematically prioritized in the context of urban tree planning and management. A comprehensive analysis is performed utilizing the Multi-Criteria Decision Analysis (MCDA) method, which takes into account various factors, including social deprivation, current low canopy coverage, and proximity to transportation networks, particularly in regions with elevated levels of air pollution. It is essential to allocate funding to support initiatives that demonstrate the maximum impact of tree planting efforts. Additionally, a visualization platform has been established to map the progress of the tree planting project and to engage with local communities in order to enhance planting outcomes.

2 Inspiration and reference significance of Oxford urban tree management system to the construction of urban green space in China

2.1 Refined tree management and supervision processes

Oxford urban tree management has refined its tree planting approach in three key aspects: the overarching concept, the selection of planting species, and the actual planting process. Within the conceptual framework, a multi-dimensional decision-making mechanism is employed, which takes into account the spatial constraints available for tree planting, so as to enhance the efficiency of both the tree planting process and the subsequent management of urban trees. In the context of selecting tree species for planting, it is essential to choose species that are compatible with native varieties. This approach aims to prevent the introduction of invasive species, which can disrupt the local ecosystem and adversely impact the biodiversity of indigenous species. Simultaneously, the introduction of new species emphasizes the necessity of predicting climate change to facilitate adaptation to a warming climate. In the context of actual planting, the MCDA method is employed to identify priority areas for tree planting. This approach incorporates various factors, including social deprivation, existing low canopy cover, and proximity to transportation networks, thereby enabling a more scientific and accurate determination of tree planting strategies. In the context of tree supervision, the initial step involves conducting a thorough inspection of urban trees and enhancing the research pertaining to the ecological value of the i-Tree system. A comprehensive inventory of urban tree data, along with supplementary information, is compiled, and this data is updated in real time on the ArcGIS platform, so as to enhance the timeliness of management efforts and reduce associated management costs. Regular inspections are conducted based on various geographic environments and tree characteristics, with urban trees being inspected every 2-4 years. The data obtained from these inspections allow for the identification of

Fig.2 Landscape of urban public space in Oxford

Fig.3 Oxford city streetscape

high-risk and low-risk areas concerning tree health and growth environments. Consequently, zoning inspection schedules are developed accordingly. Additionally, tree management information is promptly updated in both the database and the ArcGIS system, ensuring that the management of urban trees is executed in a healthy, orderly, and efficient manner (Figs.2–3).

2.2 Smart, digital tree management tools

The i-Tree platform has been instrumental in the survey and monitoring phases of urban tree management in Oxford. The i-Tree software utilizes data gathered from urban tree plots and individual tree information to assess the ecological service value of urban trees. This assessment includes their roles in mitigating air pollutants, enhancing carbon sinks, sequestering carbon, reducing rainwater runoff, and improving overall comfort. Furthermore, the platform integrates the beneficial functions of urban trees in a multidimensional framework that supports the development of urban residents, urban economy, urban ecology, and urban culture. The ultimate goal is to formulate and plan a sustainable development strategy for the long-term management of urban trees.

Furthermore, an intelligent urban tree management system has been developed utilizing the big data platform of ArcGIS. This system facilitates the upload of comprehensive location data pertaining to urban trees, which encompasses specific positioning, land use type, and ecological environment, as well as detailed tree information, including species, height, DBH, age, crown width, crown health, crown illumination, and the distance and direction to the nearest building. Additionally, the system incorporates the deployment of sensors and other detection instruments within a designated range, organizes specialized equipment maintenance, and ensures the systematic collection, statistical analysis, and real-time uploading and updating of data. In the context of urban networks and offline multimedia channels, the planning strategies and real-time development processes associated with urban tree management are regularly updated and disseminated, thereby enhancing public awareness regarding urban tree management, as well as the ecological environment and its inherent ecological value[7].

2.3 Public participation by multiple subjects

The Oxford urban tree management implementation pathway underscores the importance of communication and collaboration among all stakeholders, and advocates for the active participation of individuals in tree-planting initiatives within local communities and educational institutions. Furthermore, it encourages businesses and governmental entities to enhance their coordination regarding urban tree planting, maintenance, and other related management projects. The pathway also seeks to engage a broader array of stakeholders in the collaborative development of a comprehensive tree-planting plan, thereby ensuring systematic and adequate planning to meet the objectives of urban tree management. It also actively investigates innovative cooperative mechanisms aimed at promoting corporate funding and individual engagement to address the financial constraints associated with the planting and maintenance of urban trees. Additionally, it explores management strategies that involve generating revenue from urban tree management, thereby providing economic benefits to the regions and enterprises in which these trees are situated. Simultaneously, appropriate network channels are established to facilitate citizens in uploading information regarding trees, thereby enabling the timely monitoring and identification of issues related to urban tree management. Consequently, each citizen's mobile device serves as an information collector for urban tree management, enhancing the sensitivity of data collection on urban trees. This initiative also strengthens effective communication with the public, ultimately improving public awareness of urban tree management[8].

The involvement of multiple stakeholders in the management of urban trees can, on one hand, effectively address the challenges associated with government funding for the development of urban green spaces. On the other hand, it can also reflect a humanistic approach in subsequent maintenance, management, and evaluation processes. This collaborative effort effectively embodies the concept of "people's city" into the management of the urban green space environment[9-10].

3 Conclusions

Oxford possesses a multi-dimensional management framework for urban tree management that is recognized as internationally advanced. The management framework emphasizes the importance of high-quality planting practices that serve the interests of the community. It ensures the effective management of existing urban tree resources while establishing guidelines for the planting of new urban trees, thereby maximizing the ecosystem benefits for the population. The management framework encompasses comprehensive specifications and adopts a holistic perspective, thereby offering a systematic approach to urban tree management.

(To be continued in P12)

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Simultaneously, the urban tree management practices in Oxford are distinguished by sophisticated and intelligent management techniques. These practices involve the utilization of the i-Tree platform to gather data on urban trees and assess their ecological value. Additionally, an information network should be established for the real-time uploading of data to the ArcGIS data analysis platform, thereby facilitating the implementation of efficient urban tree management strategies. The future planning of urban tree management in China can benefit from the overarching principles of Oxford urban tree management, which emphasize high-quality planting and maximizing the benefits for both people and nature. These principles offer a reference for enhancing the comprehensiveness and consistency of urban tree management planning in China. Simultaneously, by drawing upon the sophisticated and intelligent management technology attributes developed by Oxford, platforms such as i-Tree and ArcGIS, along with other online resources, can be utilized in management planning to establish a timely and effective mode of urban tree management.

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