



Urban Forests as Nature-Based Solutions: a Comprehensive Overview of the National Forest City Action in China

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Abstract

Purpose of Review In tandem with China's rapid urbanisation and economic growth, some negative impacts on the eco-environment and human wellbeing have arisen, such as the urban heat island effect, air pollution and lack of recreational spaces. To address the degradation of urban eco-environment and improve residents' quality of life simultaneously, China's central government launched the National Forest City action in 2004, which essentially promotes urban forests as nature-based solutions (UF-NBS) and contributes to achieving sustainable development goals. Whilst this key national action has been implemented for about two decades, it has received limited scholarly attention within and beyond China. This paper is the very first to summarise comprehensively the development of the action, focusing on its rationale, evaluation and management.

Recent Findings By establishing urban forests as cost-effective solutions to various environmental and social issues, the action integrates novel knowledge and best practices accumulated in Europe and North America into China's traditional ideology, pertinent to the human-nature relationship in urban landscape design, and further adapts and renovates these to the country's unique socioeconomic context. It highlights the multi-functionality of urban forests underpinned by a set of key performance indicators covering both qualitative and quantitative aspects of the National Forest City's planning, construction, management and review. Additionally, it reflects a dynamic interaction within the science-policy-practice continuum hinged on field experiments, knowledge transfer, public engagement, policy agenda and greening actions. Challenges, such as unbalanced geographical distribution and KPIs on ecological integrity and functionality of urban forests, should be addressed for further refining and scaling-up this action.

Summary China's National Forest City action promotes UF-NBS as a pathway to sustainable urbanisation, serving as a demonstrative exemplar for other developing and developed countries that may wish to avoid their dependence on traditional development pathways. This paper sheds light on how to implement urban forests as effective and sustainable NBS to addresses global societal challenges.

Keywords Urban forest · Nature-based solution · The National Forest City action · Socio-ecological systems · Societal challenges

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Introduction

Since the early 1990s, China has embarked on a unique road into unprecedented urbanisation and economic growth, which is neither identical to that of the global north nor similar to the model found in the global south [1–3]. This has led to profound changes in human society and the living environment [4]. Geographers, planners, sociologists and economists have attempted to depict a comprehensive profile of China's urbanisation from various perspectives, such as natural resources, environment, population, society, industry and economy [2, 5]. In tandem, there has been increasing interest on how urban forests, which cover all vegetation

stands across a city's urban–rural continuum as key natural components of the city, are tailor-designed and actively constructed from a place-based perspective to serve as nature-based solutions (UF-NBS, i.e. solutions that build on urban forest-based ecosystems to address various societal and environmental challenges) to various socio-environmental issues brought by unprecedented urbanisation. There is also interest in how UF-NBS could contribute to transforming China's industrialisation-oriented urbanisation towards a new-form of harmonious, inclusive and sustainable urbanisation [5–7].

Whilst lagging behind the field experimentation and theorisation in North America and Europe, China's urban forest research was initiated with the support of the Ministry of Science and Technology in selected cities, such as Beijing and Guangzhou, in the late 1990s. Subsequently, a number of key milestones have been achieved, including the first systematic study “Research on Urban Forestry Strategies for Sustainable Development in China” funded by the State Council in 2002, a core academic publication “*Journal of Chinese Urban Forestry*” inaugurated by the Chinese Academy of Forestry in 2003 and exchange platforms like “The First Urban Forest Forum” initiated jointly by the State Forestry Administration (now renamed as the National Forestry and Grassland Administration, NFGA) and Guizhou provincial government in 2004. At this forum, Guiyang, the capital of Guizhou province, was first awarded the title of China's National Forest City. In the same year, an “Asia-Europe International Workshop on Urban Forestry” organised by the NFGA, the Ministry of Science and Technology, Jiangsu Provincial Government, Beijing Municipal Government, the Finnish Ministry of Trade and Industry and the Danish Ministry of Environment was also held for both Chinese and international scholars to exchange their latest research. This series of milestone events have contributed to knowledge generation and accumulation, laying the foundation of the most influential initiative, the National Forest City action.

By the end of 2022, a total of 218 cities in 27 provinces have been awarded the title of “The National Forest City” (Fig. 1), and over 440 cities are actively engaged in various greening projects for building up their application portfolio for this national accolade [8]. Whilst the National Forest City action has become well received and vigorously developed in the last two decades [9], how this national campaign has promoted UF-NBS [10] and contributed to sustainable urbanisation is worthy of exploration [11]. To date, very limited scholarly attention within and beyond China has been devoted to understanding comprehensively this key national greening campaign [12•]. This paper thus aims to fill this gap by laying out systematically the action's rationale, key performance indicators (KPIs), management and challenges facing further refining and scaling-up this action, which holds the promise to enrich our understanding of UF-NBS across the science-policy-practice continuum as

an innovative concept coined in western context but increasingly transferred to and adopted in developing countries [13].

Development History and Characteristics of China's National Forest City

Upon the arrival of the urban forest concept and relevant initiatives being introduced to the rapidly urbanising China in 1992 [14, 15••], several far-sighted municipal governments (such as Changchun, the capital of Jilin province, and Hefei, the capital of Anhui province) initiated comprehensive greening projects based on the western experience yet taking local contexts and distinct issues into account [16]. These greening projects integrated and coordinated forestation in peri-urban and rural areas together with landscape greening in urbanised areas in order to address environmental problems (such as sandstorms) and social issues (such as the lack of recreational spaces) brought by the unprecedented pace of urbanisation [17, 18]. However, the overall progress of these pioneer projects experienced some hiccups, mainly due to the institutional barriers pertinent to the long-established urban–rural dualisation in China [19]. Within the traditional governance system, management and forestation on peri-urban and rural lands had been the responsibility of various forestry administrative authorities with a clear focus on economic returns of tangible forest products [20]. Forestation in rural areas was totally separated from urban landscape greening (or the landscaping of urban open spaces) under the jurisdiction of urban landscape design/management departments, which overwhelmingly emphasised recreational function and landscape beautification of greenspaces [21, 22]. Whilst the introduction of the urban forest concept offers a much-needed opportunity to break down-or bypass-the institutional barriers between urban and rural land governance [15••], it ignited heated debates amongst scholars, landscape designers, foresters and policy-makers on how to define urban forest and more importantly, how to establish ecologically resilient and socially satisfied urban forests in increasingly densifying cities in China [14, 23, 24].

These debates stimulated early research focusing the knowledge and technologies in urban forest planning. Meanwhile, those early pilot projects increased the recognition of the importance of urban forests and trees in urbanising society in China [14, 18]. Against this background and inspired by the conceptualisations of urban forest [25, 26] and forest city (focusing on tree plantations for improved regulating and provisioning services) [27] that have been proposed and promoted in North America and Europe since 1960s, an innovative initiative, the National Forest City action, was launched in 2004. It was led by the NFGA together with the National Greening Committee as a national greening action

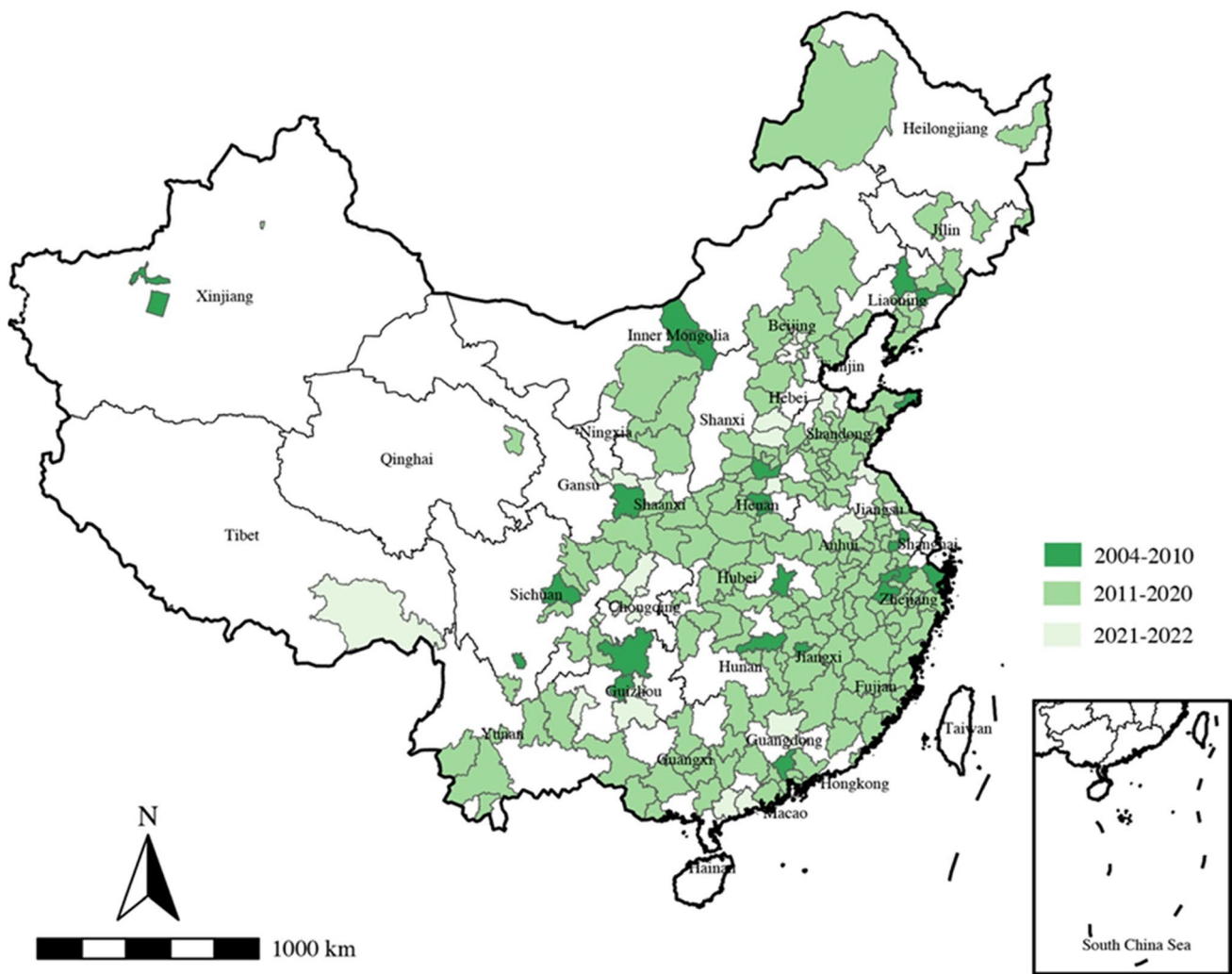


Fig. 1 The distribution of China’s National Forest City. During the initial period (2004–2010) and the rapid growth period (2011–2020), a total of 22 and 170 cities were awarded with the title of National

Forest City, respectively. More recently during 2021–2022, an additional 26 cities won this title

to guide and promote the construction of forest cities across China [28–30].

Serving as an overarching definition, urban forest covers all woody and associated vegetation distributed in and around human settlements ranging from small communities in rural/peri-urban settings to metropolitan areas [31]. This definition enabled all types of vegetated spaces within and beyond the boundary of urbanised areas to be viewed more holistically and in a more integrative way, so as to effectively solve the environmental and social problems of complex urban ecosystems that urban society is facing [32, 33]. In China, urban forest is regarded as a core concept and critical natural infrastructure and a cost-effective pathway to restore degraded urban environments/ecosystems and enhance ecological and social resilience [34, 35]. It has become the cornerstone to what the National Forest City should be and how it could be constructed [36]. “Let the

forest enter into the city and let the city be embraced by the forest” and “planting green for the people and planting green benefiting the people” have been publicised as the leading principles to the National Forest City action [37, 38]. The National Forest City is officially defined as a city whose ecosystem is dominated by forest and associated vegetation, and where ecological conservation/restoration via urban forest activities/projects can bring about multiple environmental/ecological benefits, better liveability, enhanced image and competitiveness of the city, as well as synchronised sustainable development across the urban–rural continuum [12, 30, 39].

The promotion and implementation of the National Forest City action holds the promise to transform China’s industrialisation-oriented development model towards a new-form of sustainable development and ecological civilisation, which represents a new paradigm of sustainable

development embodying the construction of ecologically advanced and modern beautiful cities [40••].

Firstly, urban forests, which cover various greenspaces serving as integrative green infrastructure network, are considered as a crucial factor in the exploration of harmonious coexistence between human and nature and an essential part of urban infrastructure system in the National Forest City [11]. Urban forests serve as recreational spaces for citizens and also provide natural/semi-natural habitats for various faunal species such as birds and invertebrates [41–43]. Hence, urban forests are positioned as the only and dominant living ecological infrastructure [44]. It transforms relatively passive urban nature into active components of cities, so that co-existent relationship between nature and human beings can be established during urban construction, and coordinated development of society, economy and nature based on ecological principles can be achieved [45]. Urban forest construction actively advocates maintaining, restoring, establishing forested spaces and more importantly, integrating the green network into traditional urban grey infrastructure systems that are not sufficient to support resilient urban ecosystems suffering from the negative impacts of urbanisation and climate change [10, 46]. Guided and facilitated by national and local authorities through a top-down governance mechanism but focused on individual cities' achievement in urban forest construction from a place-based perspective (instead of cities' response to a targeted programme of work dictated by the central government) [7], the construction processes of the National Forest City have been co-evolutionary, involving changes of society and urban ecosystems. On the one hand, the urbanising society in China increasingly appreciates the benefits of urban forests. On the other hand, the ecological resilience has been enhanced along with the establishment of urban forests. Undoubtedly, urban forest and the National Forest City action have contributed to bringing diverse nature back to cities, providing close-to-nature opportunities for urban dwellers [47] and paving a pathway towards sustainable urban transformation and ecological civilisation [48•].

Secondly, the multi-functionality of urban forest has been emphasised, serving as NBS to various environmental and social issues [38, 48•]. Even though NBS is a concept forged in the western context aiming to restore natural and restored ecosystems in ways that address various challenges and simultaneously provide environmental, social and economic benefits [49, 50••], the construction of place-based urban forests as highlighted as the most important mission of China's National Forest City could serve as cost-effective, adaptive and responsive solutions to a series of environmental and social issues arising during China's urbanisation. Through this way, UF-NBS is successfully embedded into China's social and environmental context. Beyond the traditional focus of peri-urban/rural forests on tangible products

(such as timbers and fruits) and associated economic returns and the focus of urban greenspaces on landscape beautification and recreational opportunities, the joint production of environmental, ecological, social and cultural benefits of urban forest has been highlighted in the National Forest City action as solutions to multiple social and environmental issues arising from rapid urbanisation. These issues include creation of liveable neighbourhoods [12•], improving social inclusion and cohesion, enhancing the life quality of rural/urban residents, facilitating rural revitalisation [51], improving air quality [38], reducing flooding risks [51] and increasing biodiversity and the ecological resilience of city [43]. The multiple benefits (related to ecology, human settlements, landscape, leisure, economy and culture) of urban ecosystems are synergistically facilitated via an optimised design of all vegetated spaces and ecological corridors that are adaptive to local society, economy and environment [48•]. For instance, it is found that those cities with the National Forest City title in the Beijing-Tianjin-Hebei agglomeration (north China) have enjoyed better air quality in terms of PM_{2.5} concentration (via the use of various species of *Ulmus*, *Populus*, *Ailanthus* and *Sophora* that are effective in PM_{2.5} removal) than those who have not adopted urban forest interventions in the same region [30]. Additionally, Liao et al. [39] found that the construction of the National Forest City helped mitigate climate change via not only direct carbon sequestration by urban vegetation, but also the adoption of innovative green development models like green transportation and low-carbon industries. And urban forest construction does not solely focus on green vegetation. To develop as a National Forest City, Weifang, a city in Shandong province, formulated a “Water Network Ecological Greening Plan” that aims to provide green–blue integrated infrastructure to reduce water pollution, mitigate urban flood and provide recreational opportunities simultaneously [51].

Thirdly, a severe challenge facing China's society and development pertains to the widening gap between urban areas and rural areas in terms of land, industry, environment and public service management [52] coming from opposite social structure of urban–rural dualisation in governance system [19]. It is well known that the construction of urban forests that integrates all vegetated patches across urbanised town centres, peri-urban areas and rural settlements and the National Forest City that concerns the performance of greening both urban and rural areas and for all residents of the city enable a balanced and integrated urban–rural development pattern [9, 47, 52, 53]. In contrast to the previous segmentation model in urban greening and rural forestation, urban forest and the National Forestry City incorporate all vegetated patches into an integrated urban–rural continuum to form a comprehensive, ecologically sound and socially beneficial greening network [24, 48•, 53, 54]. In order to achieve such a multifunctional goal, all relevant governmental authorities,

such as urban and rural planning offices, land and natural resources management offices, urban landscape design office, development and reform department and finance office, are required to break down the institutional barriers and work jointly to coordinate the restoration and construction of forests and other ecosystems across the whole city, including mountains and river valleys in rural areas, as well as parks and gardens in urbanised areas. Such a cross-sector and inter-departmental collaboration is able to optimise the spatial distribution of various land uses, address locally specific environmental and social issues via serving as cost-effective NBS [40••, 55], improve the wellbeing of rural and urban residents and achieve harmonious development between urban and rural areas in economy, society and ecology [48•, 53, 56].

Lastly, the National Forest City, together with other innovative initiatives including sponge city, green city, garden city, eco-city, low-carbon city, climate-neutral city, smart city, sustainable city and Shan-Shui city (Table 1), offers a new notion and a feasible pathway to sustainable urbanism and envisions a model of a city for future [11]. To win the title of the National Forestry City is much than achieving the tangible objectives like constructing more urban forests. This title is commonly accompanied by wider connotations. In a National Forest City, the planning and designing of urban forests with diverse types and configurations are based on a holistic thinking about the human-nature relationship and integrated into the city's unique fabric as NBS to

address various social and environmental issues. As a result, the local economy, society and ecology can be developed in a coordinated pattern. Additionally, National Forest City can serve as living labs [57], where UF-NBS models can be tested and optimised for better effectiveness, resilience, adaptability and urban liveability.

Standardising China's National Forest City

A key distinctive feature of the National Forest City is that an explicit set of key performance indicators (KPIs) have been established as a nation-level standard to adequately evaluate and depict what the National Forest City should be. This contrasts many other forms of green cities (such as sponge city, eco-city, smart city, garden city and Shan-Shui city) that also involve different greening approaches or NBS but which remain vaguely, or inadequately, defined [58, 59]. This in turn renders their performance evaluation, benchmarking and accreditation with prestigious titles as problematic [60]. Even though there was no standard for the National Forest City at the initial stage (2004–2006), early field practices and knowledge accumulation helped the NFGA formulate a set of forest industry standards in 2007, based on extensive discussion and communication with various stakeholders who have engaged in the construction and evaluation. These sectoral standards have been tested and validated afterwards, which became an official

Table 1 A comparison of various initiatives aiming at sustainable urban development in China

Sustainable initiative	Keywords	Key authority	Starting year
Garden city	Urban landscape design and improvement of urban green areas	Ministry of Housing and Urban–Rural Development	1992
Shan-Shui city	Emphasising the aesthetic role of nature (particularly mountains and rivers) in public space and calling for creating easily accessible nature for urban residents	Ministry of Housing and Urban–Rural Development	1992
Eco-city	Emphasising environmental protection, economic development and social progress	Ministry of Environmental Protection	1995
Forest city	Constructing living solutions based on urban forests for addressing environmental and social challenges	National Forestry and Grassland Administration	2004
Low-carbon city	Reducing the intensity of energy consumption and CO ₂ emissions	National Development and Reform Commission	2010
Smart city	Developing and applying information and communication technology to improve the efficiency of urban management and achieve sustainable urban development	National Development and Reform Commission	2012
Green city	Lower environmental impacts, less resource-consumption and higher ecological efficiency	National Development and Reform Commission	2014
Sponge city	Effective stormwater management via integrated green–blue–grey infrastructure	Ministry of Housing and Urban–Rural Development	2014
Climate-neutral city	Zero emission of GHG and being resilient to the negative impacts of the changing climate		

Climate-neutral city is a relatively new initiative, which has not yet become a national action

guideline (LY/T2004-2012) with a primary focus on forest industry per se in 2012. Eventually in 2019, a series of key performance indicators, which cover not only the forest industry, but also other relevant socioeconomic aspects, were developed and officially recognised as a national standard for kite-marking China's National Forestry City (GB/T37342-2019). Such an evolving process demonstrates that constructing, evaluating and kite-marking the National Forest City has been a dynamic system, through which UF-NBS best practices and knowledge have been created, shared and consolidated.

This standard covers five evaluation categories (i.e. the quantity dimensions, the ecological quality/health dimensions, the multi-functionality, the social-cultural aspects and the administrative/management mechanisms) and comprises a total of 36 KPIs (Table 2). Overall, this overarching standard centres on three fundamental principles to guide the construction of the National Forest City. Firstly, taking the nation's varying natural conditions (i.e. climatic-ecological-geographical factors) into account, it highlights that the National Forest City should be ecologically sound, focusing on ecological health and resilience underpinned by a comprehensive vegetated network, which lays the foundation for the functionality of cities as healthy and resilient ecosystems. A total of 20 KPIs characterise urban forests per se, expanding upon the traditional focus on mainly the quantity dimensions of urban forests to cover both the quantity (12 KPIs) and the quality (8 KPIs) aspects, from detached/fragmented urban greening or rural afforestation/reforestation [61] to a well-connected comprehensive forest network linking green infrastructure across urban and rural areas, from monoculture plantations to biodiverse and near-nature forest composition and configuration.

Secondly, aiming to address locally specific environmental/social issues that influence human wellbeing, the provision of multiple functions/ecosystem services via urban forest construction is stressed. In addition to the provision of adequate and equal recreational opportunities (the traditional objective of urban greening), environmental benefits (such as urban heat island mitigation, air pollutant removal, urban flooding control), cultural benefits (such as historical culture, city image, knowledge generation and dissemination, public education) and economic benefits (such as tourism, business opportunities, eco-industries) are clearly defined via specific KPIs and are adequately covered in the standard. Three unique indicators pertain to (1) subsidising innovative greening activities and enterprises [62], (2) promoting UF-NBS knowledge generation and dissemination via national and international collaboration and innovative learning platforms and (3) mobilising social support and acceptance of the National Forestry City construction [63] whilst encouraging behaviour change of the general public [64] and various firms [59] towards nature appreciation and

environmental protection. Thus, the National Forest City pivots at the science-society-policy-practice interface, transcending from technological solutions to contextually rooted problems towards transformative change in the society and decision-making processes.

Lastly, rather than focusing only on the snapshot of urban forest status for kite-marking of the National Forest City, the national standard also strengthens the monitoring, recording and evaluation of the state and functionality of urban forest as a continuous evolving process from idea incubation, planning/designing, construction activities, accreditation and certification, to after-certification monitoring over time for subsequent reviewing and auditing. In essence, this national standard not only concerns the realisation of a broad range of intended benefits in the short term via urban forest projects, but also the sustaining of these benefits in the long term by considering the lifespan and dynamics of urban vegetation and the complexity of urban ecosystems within which urban forests are embedded. The institution of this national standard reflects a political commitment and institutional mechanism [65] that integrates the conventional outcome-oriented framework that ensures desired outcomes are achieved within a certain urban context, with a process-oriented framework which places at the centre an active monitoring and evaluation of how urban forests can serve as adaptive and resilient solutions to ever-changing environmental and societal challenges.

Governing and Monitoring the National Forest City

Supportive Institutional Framework

The construction and the follow-up monitoring/auditing of the National Forest City have gradually matured over the last two decades, thanks to the supportive institutional framework. Lead by the NFGA and supported by the Ministry of Science and Technology and other national authorities, a supportive environment and mechanisms have been established for advancing UF-NBS knowledge via research funds and transferring that knowledge into UF-NBS practices via the National Forest City construction. For instance, a technical group was established by the NFGA encompassing scholars and experts from universities, research institutes, policy-making authorities, companies and representatives of the general public to provide professional/societal advice for improving relevant policies such as KPIs. Meanwhile, international co-learning and knowledge-sharing mechanisms between China and other countries (such as the EU-China Horizon 2020 CLEARING HOUSE project) have been established to help generate transferable and adaptable knowledge focusing on practice-based solutions centred on

Table 2 Key performance indicators (KPIs) for standardising China's National Forest City

No	KPI	Description of relevant requirement	Measurement
Quantity of urban forests			
1	Forest coverage across the whole city	≥ 25–35% (depending on eco-region)	Forest area/city area
2	Greenspace coverage in urbanised centre	≥ 40%	Greenspace area/urbanised area
3	Tree coverage in urbanised centre	≥ 20–25% (depending on eco-region)	Area covered by woody trees/urbanised area
4	Park area per capita in urbanised centre	≥ 12 m ² /person	Total park area/total urban population
5	Street greening in urbanised centre	≥ 60%	Length of vegetated roads/total length of roads
6	Parking lot greening in urbanised centre	≥ 30%	Total area of green coverage/total area of parking lots
7	Greening in rural settlements	≥ 30%	Public greenspace area/rural settlement area
8	Road greening in rural areas	≥ 80%	Length of vegetated roads/total length of roads in rural area
9	Riparian greening	≥ 80%	Length of riparian greening/length of riparian corridors
10	Agroforestry network	Forest network established for protecting agricultural land	Experts' field assessment
11	Greening of water resource sustainability	≥ 70%	Forest coverage/area of protected zone of water resources
12	Ecological restoration of brownfields	≥ 80%	Restored area/brownfield area
Quality and health of urban forests			
13	Floral species diversity	Single dominant species ≤ 20%	Species inventory
14	Use of native species	≥ 80%	Amount of native species/total amount of plant species
15	Seedlings for natural regeneration	Healthy seedlings supply and use	No transplantation of large trees
16	Forest soil conservation	Artificial surface ≤ 40%	Artificial surface/total greenspace coverage
17	Forest health and quality	Annually 10% improvement	Subjective evaluation of experts
18	Habitat conservation	Protection of core habitats	Percentage of core habitats
19	Prevention/control of forest-related disasters	Forest pests and fires management	Prevention and control system in place
20	Public safety	Zero public incidents	Zero public incidents
Multi-functionality of urban forests			
21	Accessibility of neighbourhood parks	500 m service ≥ 80% urban area	500 m service area/total urban area
22	Accessibility of urban parks	20 km service ≥ 70% urban area	20 km service area/total urban area
23	Free accessibility	All public parks	All public parks open to the public
24	Availability of rural greenspaces	One park/rural settlement	One park established in each rural settlement
25	Ecological network	0.5 km/10,000 residents	Length of ecological corridor/total population
26	Ecological industry	Forest tourism, food provision, etc	Records associated with relevant industrial activities
Social-cultural benefits of urban forests			
27	Ecological education	≥ one educational venue	≥ one educational venue open to the public
28	Knowledge generation and dissemination	≥ 5 events per year	More than 5 events per year, national and international
29	Heritage trees	100% protection rate	All heritage trees are recorded and protected
30	City tree and city flower	Successfully specified	City tree and city flower are specified as part of local identity
31	Public engagement	≥ 90 public awareness and engagement	Social survey
Management mechanism			
32	Planning and design of urban forests	Short- and long-term construction plan	Short-term and long-term construction plan in place
33	Documentation	All activities recorded and open to the public	Document availability
34	Science and technology support	Long-term supporting framework	Long-term supporting framework constructed
35	Exemplary best UF-NBS practices	≥ one exemplary project	≥ one exemplary project constructed
36	Digitised administration system	Digital administration system in place	Digital administration system in place

urban forests for problems associated with urban environment, quality of life and sustainable development [66].

Additionally, the National Forest City action has been continuously incorporated into the Chinese long-term strategic development plan (since the 13th Five-Year Plan released in 2016) as important content in the ecological civilisation strategy. In 2018, the NFGA published the Development Plan for the National Forest City (2018–2025), to further promote the construction of National Forest City at multiple scales, including Forest City Agglomeration (focusing on interconnected and coordinated urban forest construction across several neighbouring cities in a larger region), Forest City (focusing on urban forest development within individual cities), Forest Town (focusing on urban forest construction within individual towns, which is a lower-level administrative structure under the jurisdiction of cities) and Forest Village (focusing on forestation and associated achievement in rural villages) [67]. Consequently, the National Forest City action has been granted with a statutory status.

Furthermore, as a national vision and top-down initiative, the National Forest City action mobilises local governmental

support and appreciation via establishing innovative collaboration mechanisms. With funding resources provided by the central government, local municipal governments are tasked to monitor and experiment with various UF-NBS that are designed on the basis of local knowledge or borrowed from overseas experiences, so as to accumulate more site-specific knowledge and best practices pertaining to UB-NBS [48•]. At present, a total of 22 long-term monitoring stations (Fig. 2) have been successfully established jointly by the NFGA and local governments to collect first-hand field data and experiment with innovative UF-NBS [68]. Local governments are empowered to make decisions relevant to urban forest design and installation according to their local settings, capacities and constraints, whilst the NFGA systematically orchestrates local experiments. Through such a corroboration with local governments, the NFGA can gather information about what UF-NBS works and what does not, and then refine relevant policies and KPIs. With this multi-level governance system in place, UF-NBS has been placed high in the national and municipal policy agenda. The National Forest City action has been promoted and attracted



Fig. 2 The distribution of UF-NBS monitoring stations in China

considerable attention amongst local governments, and the accolade of the National Forest City has also been widely regarded as an important benchmark for evaluating local governors' political performance.

Administrative Procedure for Constructing the National Forest City

Firmly grounded on UF-NBS knowledge and relevant best practices generated within and beyond China and guided by the national policies and relevant technical standards, the whole process of the National Forest City construction consists of six interlinked steps in a roughly chronological order, including (1) project initiation, (2) planning and UF-NBS design, (3) field implementation, (4) KPIs compliance verification, (5) accreditation and kite-marking and (6) follow-up reviewing and auditing.

The first step is project initiation. Normally, the municipal forestry and/or urban/rural landscape management departments proactively seek support from a working group encompassing various stakeholders comprised of policy-makers from relevant governmental authorities, scholars, practitioners and local residents. Thereafter, an administrative decision is formally made to participate in the National Forest City action and this decision is communicated to the NFGA.

The second step is to carry out UF-NBS design/plan, taking into account a city's baseline situation. Prior to the start of UF-NBS construction, information about the status quo of urban forests (covering all greenspaces across the city's rural–urban spectrum) and socioeconomic characteristics, as well as local context-specific key environmental/social issues (short term and long term) and societal expectations/preferences, is collected via comprehensive field work and social survey. A 10-year master plan for constructing the National Forest City is then developed, in accordance with the city's baseline situation and KPIs. It should be not only feasible and functional (aligning ecosystem services provided by urban forests with local eco-environmental and socioeconomic context), but also forward-looking (considering future challenges brought by urbanisation and socioeconomic changes). In this plan, the tasks, spatial scale and locations and timeline pertinent to all UF-NBS practices/projects should be explicitly justified, depicted and demarcated. The draft of this plan should be reviewed and refined by the working group and then endorsed by the NFGA.

The third step focuses on the implement of UF-NBS plan, which normally starts from the municipal government popularising its National Forest City construction master plan, securing financial sources and identifying relevant municipal authorities (such as Forestry and Landscape Bureau, Water Affairs Bureau, Transportation Bureau and Environmental Management Bureau) to undertake sector-specific tasks. Inter-departmental coordination is important

for municipal government to overcome the rural–urban barriers and effectively implement their urban forest strategies [54], as observed in western context [44]. Through open or negotiated tendering processes, eligible and interested greening/environmental companies/contractors who win the tender are assigned construction tasks to be finished within a certain period. These construction processes and project outcomes are tracked, supervised and evaluated by relevant municipal authorities.

The fourth step is to verify KPIs compliance. With a minimum 2-year construction, an internal evaluation is conducted by the city, to examine the compliance of construction outcomes with what was included in the 10-year master plan and the National Forest City KPIs. The city can apply to the NFGA for KPIs compliance verification. In response, the NFGA assigns a group of experts to verify the self-evaluation report through field investigation and public survey. At the end of this process, a review report is drafted by the NFGA verification group.

The fifth step pertains to accreditation. Based on the review report, the NFGA determines whether the city is qualified and can be awarded the title of the National Forest City. The result is disclosed in the annual Forest City Forum. In this event, a wide range of stakeholders including city mayors, urban forest experts and citizens share construction experiences, research results and suggestions for further improving UF-NBS during the process of the National Forest City construction.

The last step focuses on follow-up reviewing and auditing. After securing the national accolade, the city continues to implement the remaining tasks specified in its 10-year master plan and submit construction summary reports in the fifth and tenth years. These reports are reviewed and audited by the NFGA verification group. New UF-NBS knowledge and best practices are shared by the NFGA group and incorporated into the ongoing urban forest projects and relevant practices. About 1 year before the expiration of the 10-year master plan, another 10-year urban forest construction plan should be drafted to refine/improve UF-NBS strategy and practices to address emerging and pressing environmental and socioeconomic challenges.

Further Thinking About the National Forest City Action

The National Forest City Action and China's Ecological Civilisation

To solve various ecological and environmental problems and to address socioeconomic challenges that have emerged with China's unprecedented urbanisation in the late decades [69], the National Forest City action was launched in 2004 by

China's central government (i.e. the NFGA). This initiative was continuously improved—as a feasible and cost-effective pathway underpinned by the construction and restoration of comprehensive and multi-functional urban forest systems. It resonates with and supports the high-level discourse of ecological civilisation [30, 70], China's new city development narrative and innovative future-oriented paradigm of sustainable development [71, 72], thereby illustrating local governments' commitment to aligning local actions with the central government's political agenda. Additionally, this action successfully embraces “clear waters and green mountains” as invaluable assets and “building a beautiful China” as one of the core principles, promotes a shift from economically functional cities to pro-nature cities that incorporate the natural elements and functionality into urban fabric [40••] and articulates green transformative yet implementable pathways towards a society that human beings live in harmony with nature [12•, 30, 73]. China's embracement and advocate of NBS has been criticised as a superficial way to enhance its discursive power and political leadership associated with addressing global challenges facing humans such as climate change and biodiversity conservation [74]. However, the recognition and success of the National Forest City as a flagship initiative showcases relevant innovations in UF-NBS construction from a place-based perspective and being regulated by a national standard and coordinated UF-NBS governance amongst various departments across the urban–rural continuum [48•].

Additionally, whilst the National Forest City action is typically conceptualised and operationalised as a government-led and top-down initiative, this paper reveals that an enabling institutional framework has been established, in which local governments are empowered to make decisions according to their local settings, capacities and constraints, and local governments are proactively engaged in devising and experimenting with various UF-NBS approaches. These are key for nurturing bottom-up pragmatic innovation for further refining top-down policies such as KPIs and relevant measurements. Moreover, dynamic mechanisms built in the National Forest City action signal an evolving process driven by the interactions between local and national authorities, research institutes and general public [73], by the co-learning and knowledge-sharing pertinent to all aspects of UF-NBS between China and other countries, which constantly transform empirical findings and novel knowledge generated by the state-of-the-art research into evidence-based guidance for improving the National Forest City construction. Overall, the National Forest City action has been oriented and supported by the central government, yet experimented and implemented by local governments following standardised guidance. The top-down initiation is coordinated with bottom-up input, helping to harness the power of science, innovation and social capital. The follow-up monitoring

and review can ensure the action's continuous improvement. Taken together, the title of the National Forest City enjoys a high degree of authority, validity and credibility, which facilitates better public awareness and engagement, mobilises local governments' willingness to join the action and connects the ambitious national vision with local governments as implementers and citizens as key beneficiaries.

Challenges in the National Forest City Action

Notwithstanding the positive outcomes and smooth progress in the last two decades, there are some notable concerns and challenges facing the further development of China's National Forest City action.

Firstly, the geographical distribution of the National Forest City action is unbalanced. The majority of the National Forest City (Fig. 1) and UF-NBS monitoring stations (Fig. 2) established to date are located in the populous eastern or central part of China. Only a few cities in the western region that possess unique forest resources and valuable natural heritage have won the title of the National Forest City [73]. Municipal governments' decision and engagement in the National Forest City construction is affected by their socioeconomic status, scientific and technological condition and policy factors. To mobilise western cities to integrate UB-NBS into their urban planning and development plan and participate in the National Forest City action, the central government can provide necessary support, such as establishing a research grant, for those cities without a strong economy that have a shortage of relevant science and technology.

Secondly, though a suite of KPIs is established for evaluating and validating the construction of the National Forest City, specific indicators and measurements are lacking to adequately gauge the ecological integrity and functionality of urban forests distributed across the spectrum from urban, peri-urban, to rural areas. Advancing the interdisciplinary study of coupled human-natural systems is crucial to understand the interactions and feedback mechanisms between people's quality of life and urban forests structure green–blue-grey integrated interventions and ecological resilience in continuously urbanising ecosystems across different temporal and spatial scales [75]. Thus, better monitoring approaches and more appropriate indicators should be developed on the basis of scientific research, which, in turn, would improve the likelihood of integrating UF-NBS into long-term urban development plan focusing on the National Forest City construction.

Lastly, UB-NBS and the concept National Forest City have been widely received in China. Meanwhile, similar concepts like sponge city underlying the integration of urban nature for addressing societal challenges thereby serving as cost-effective pathways to sustainable urbanisation have increasingly

been promoted [76]. However, the effectiveness of these pathways under uncertain future scenarios remains unclear, which deserves ongoing research and analysis by Chinese scholars who can access the living labs situated within the National Forest City and focus on China's environment, society and development, but also calls for collective and collaborative efforts on which the future of humanity is hinged.

Conclusion

This paper provides a holistic overview of China's National Forest City action over the course of its two-decade development, revealing how it contributes to the theoretical and practical progress of UF-NBS via a dynamic and interactive system covering scientific research, planning and design, field implementation and assessment. The construction of the National Forest City not only contributes to addressing China's own environmental and socioeconomic challenges, but also serve as a demonstrative exemplar for other developing and developed countries that may wish to avoid their dependence on traditional development pathways and forge greener and NBS-driven sustainability pathways [40••]. Whilst the value of urban forests as NBS has been highlighted in various countries [77, 78] and UF-NBS as a strategy guiding sustainable urbanisation has been promoted by the Food and Agriculture Organization of the United Nations [79, 80], the overall construction progress has been hampered by a shortage of long-term studies and scientific insights on UF-NBS designs that could function well in different ecological, climatic and socioeconomic contexts as well as across various geographical scales [50••, 81]. The development and success of China's National Forest City action demonstrates clearly the importance and necessity of the availability of an enabling institutional framework, guaranteed funding resources, supportive technical innovation, alignment between interdisciplinary research and in situ practical needs, clear KPIs guidance and inclusive stakeholder engagement. However, the overall impacts of the National Forest City on society, economy, culture and environment have not yet been adequately assessed [12•, 40••, 64], which is urgently needed in order to better promote urban forest construction and align urban forest initiatives with societal demands and environmental contexts as illustrated by an urban forest project in Louisville, KY, USA [80]. Nevertheless, UF-NBS knowledge accumulated, and best practices experimented in China's context offer insights for other cities about which kinds of UF-NBS interventions are able to achieve intended outcomes and address context-specific environmental and socioeconomic challenges. In this regard, China's National Forest City action is conducive to promoting a green and sustainable future and benefiting all people inhabiting the planet earth.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

Conflict of Interest Cheng Wang, Jiali Jin, Clive Davies and Wendy Y. Chen declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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