Nature-based Solutions Building Urban Resilience for People and the Environment

Tiny Forest as a case study

Macarena L. Cárdenas, **Bethany Pudifoot**, **Claire L. Narraway**, **Caroline Pilat**, **Victor Beumer** and **Daniel B. Hayhow** describe how creating tiny areas of forest aim to have a big impact.

The challenges caused by climate change and social disconnection from nature in urban areas are becoming increasingly evident, creating an urgent need to improve human and environmental health. If the estimated trend of population growth in cities continues, 68% of the world population will live in urban areas by 2050 (UN/DESA, 2018). As the urban population increases, the built environment expands, adding pressure on natural resources, requiring significant and pressing action to reduce the contribution of grey infrastructure and energy use to greenhouse gas emissions (UN-Habitat, 2011).

Nature-based solutions (NbS) are critical to the sustainable development of urban environments (Childers et al., 2019) and can vary from landscape-scale interventions such as catchment restoration to small scale actions including green walls and swales. High quality, diverse, green infrastructure in urban areas brings a wide range of benefits; from social cohesion, to health and wellbeing, as well as cognitive and educational improvement (Cox et al., 2017; Hartig et al., 2014; Hartig and Kahn, 2016). Trees in particular have been shown to boost connection to nature, health and wellbeing (Cox et al., 2019). Trees also provide vital environmental services, including: capturing and storing carbon, supporting flood management, improving thermal comfort, supporting biodiversity, and reducing noise pollution (Cox et al., 2017; Gill et al., 2007; Kuehler et al., 2017; Margaritis and Kang, 2017; Nowak and Crane, 2002; Salmond et al., 2016; UK National Ecosystem Assessment, 2011).

Nevertheless, NbS in urban environments face multiple challenges in terms of land use and urban planning; knowledge gaps leading to barriers in evidence-based implementation as well as regulatory and financial barriers that hinder buy-in (Bush and Doyon, 2019; Seddon et al., 2020). These challenges, and others besides, can cause the complete failure of urban NbS operations. In this article we talk about the implementation, monitoring and upscaling of one urban NbS intervention – Tiny Forest.

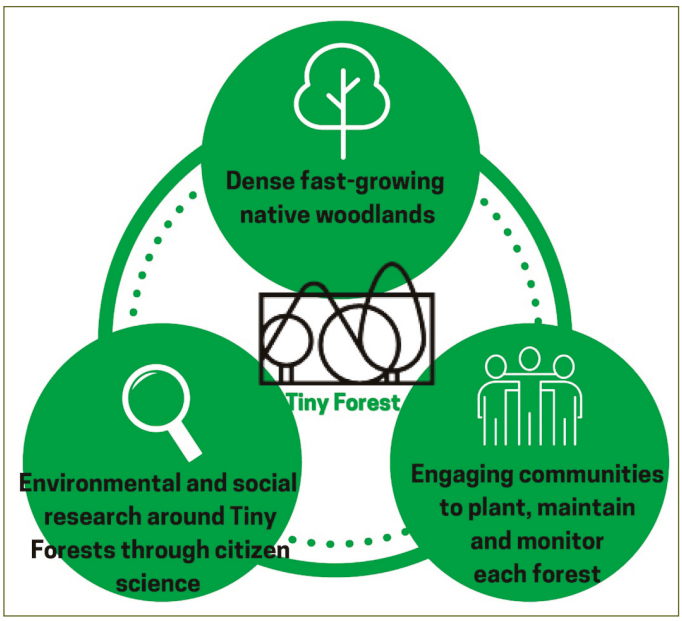


Figure 1. Summary diagram of the Tiny Forest concept.

Tiny Forest is an intervention to create small patches of woodlands made exclusively with native species in urban areas where space may be limited for high quality greenspace developments. The aim of Tiny Forest is to engage communities and local stakeholders in co-designing, co-creating, and raising environmental awareness through the planning, maintenance, education and citizen science monitoring of environmental and social benefits. The highly engaging nature and potential of the Tiny Forest programme has brought extensive interest, leading to an exponential planting rate in the UK. From one Tiny Forest planted in 2019-2020, 16 in 2020-2021, to a total of 149 up to the planting season of 2021-2022. This article provides a description of the key elements that aim to have a positive impact for people and the environment..

The Tiny Forest programme: a comprehensive approach for environmental and social urban resilience

The Tiny Forest programme combines planting small (usually 200m^2), native-species-rich woodlands in urban areas, with a facilitated engagement programme consisting of educational, social and citizen science modules (Figures 1 and 2). Tiny Forest follows a standardised approach based on the Miyawaki method (Maarten Bruns et al., 2019) (see Box opposite), with a detailed implementation plan developed to scale up the programme across the UK and beyond.

The addition of a facilitated engagement programme to these small urban woodlands results in the concept of Tiny Forest. The engagement programme includes the formation of a Tree Keeper team consisting of highly engaged citizens, school teachers, corporate employees, local community and/or land owners. Engagement modules consist of simple citizen science monitoring surveys suitable for citizens or school children to assess the environmental and social benefits the forests provide. Citizen science, defined as a scientific research method conducted by non-professionals in one or more stages of the process (Haklay et al., 2021), fosters an open and participatory approach to science (Vohland et al., 2021), and is at the heart of the Tiny Forest engagement programme.

Tiny Forest employs a comprehensive and integrative process to engage with a range of stakeholders. Engagement of diverse stakeholders has been identified as the best method of adapting to and mitigating negative impacts of the climate and biodiversity crises sensitive to social, economic and ecological factors in cities (IPBES, 2019). From planning and implementation to the engagement activities, Tiny Forest provides a participatory method to face the sense of powerlessness due to real or perceived obstacles to environmental solutions (Iniguez-Gallardo et al., 2021). The engagement of the public through citizen science supports prompt action towards climate and social resilience, alleviating the sense of being overwhelmed by the urgency of climate change and biodiversity loss in urban areas (Moser, 2016). Local governments, corporations, communities, schools, and academics can all engage with different stages of a Tiny Forest project, from co-creation and co-design, to management, and monitoring through citizen science. The Tiny Forest programme engages participants in physical and tangible actions, while they learn about the important benefits provided by trees within the urban environment,

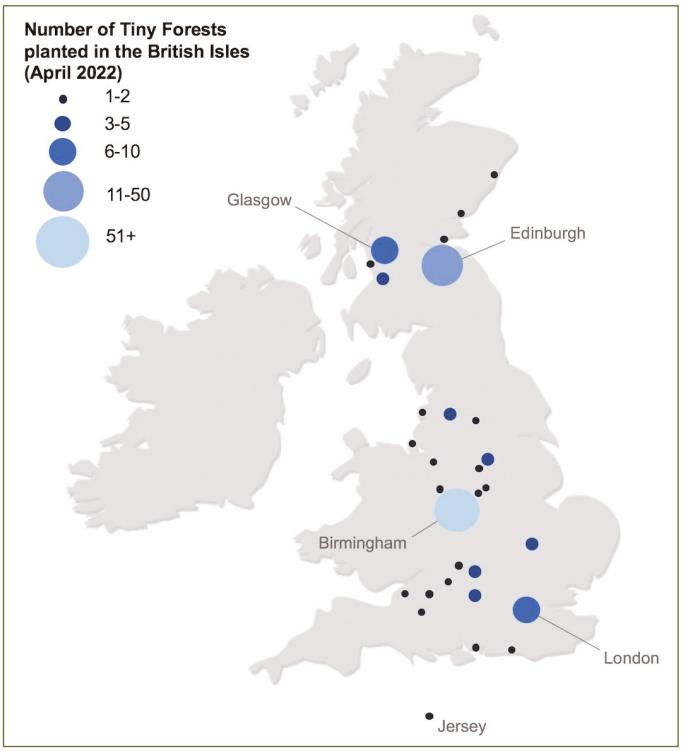


Figure 2. Map of the Tiny Forest network planted in the British Isles by Earthwatch Europe and partners, as of April 2022. Larger points indicate more numerous Tiny Forest sites in the given locality.

> "The Tiny Forest programme involves planting small (usually 200m^2), native-species-rich woodlands in urban areas."

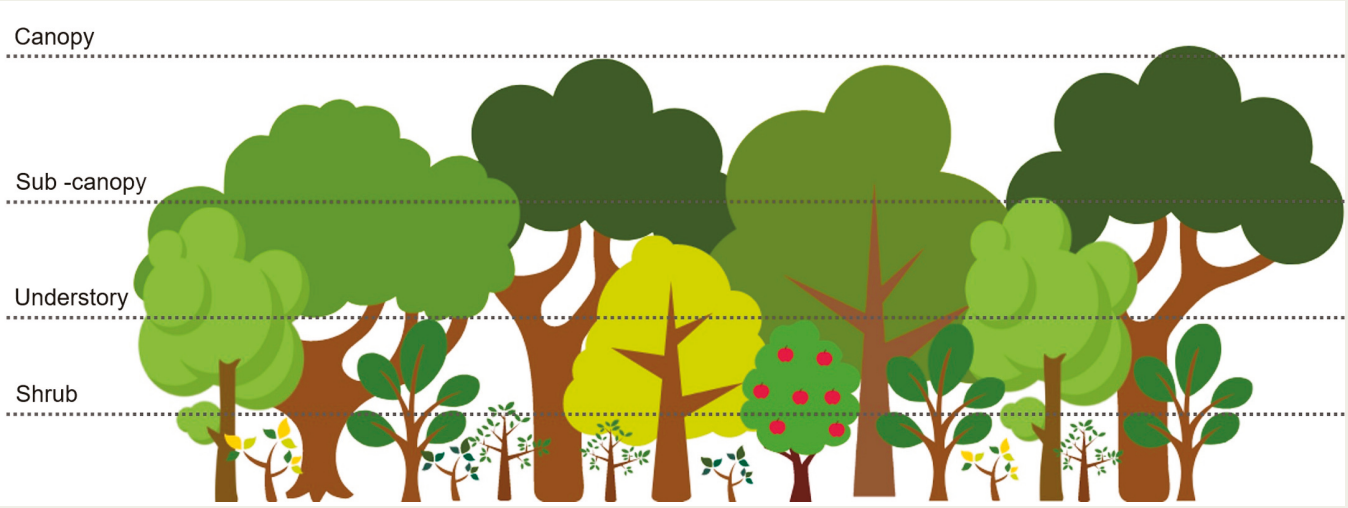
Using the Miyawaki planting method

A 4-year-old Tiny Forest in Zaandam, the first Tiny Forest planted in the Netherlands. (Photo: IVN)

The Miyawaki method was established in the 1970s by Japanese botanist Professor A. Miyawaki. The method is based on ecological succession (Clements, 1916); planting species that make up the composition of an advanced forest right from the start by choosing well-adapted plant communities suitable to the site (Miyawaki, 1999). Following the potential natural vegetation concept, the Miyawaki planting method enables rapid forest development using native species (Miyawaki, 1999). The Miyawaki approach creates a community of trees with a very dense structure and offers an alternative functional approach to traditional urban tree planting methods as above-ground biomass occupies all forest layers optimally from the early stages of growth, thus rapidly establishing a multi-strata forest ecosystem. Forests planted following the Miyawaki method have low mortality, and show accelerated tree growth and forest development (Miyawaki, 1998; Miyawaki and Golley, 1993). Therefore, Tiny Forest supplies environmental benefits associated with adult trees at a much earlier phase than traditional tree planting.

The planting method can be applied in small spaces, which makes it particularly apt for urban areas where space is often limited and soil preparation methods (e.g. decompaction, enrichment, and/or improvements to water holding capacity) act to overcome compaction and degradation issues, common to urban soils (Watson et al., 2014). Species selection is performed at a local scale resulting in appropriate ratios that reflect the potential natural vegetation, and are adapted to the geography, soil characteristics and climatic system of the site. Thus, only native species are used.

The Tiny Forest programme advances the Miyawaki-based planting method through engagement and citizen science monitoring (provided by Earthwatch Europe), enhancing the people-nature connection. The citizen science monitoring assesses the effectiveness of the planting methodology and facilitates people's experience in nature, their understanding of critical environmental challenges, and the ecosystem services that trees bring to the community.



Forest layers composing a Tiny Forest.

such as biodiversity conservation, storing carbon and mitigating the effects of climate change. Altogether, Tiny Forest uses a comprehensive approach that facilitates long-term environmental and social resilience to climate change and urbanisation, by reconnecting people with nature.

Tiny Forest implementation across the UK

Implementing each Tiny Forest on the ground involves detailed site research, working closely with landowners and the community. Detailed below are the key steps for creating a Tiny Forest, drawing from our experience planting the first Tiny Forest in the UK in Witney, Oxfordshire (Figures 3 and 4).

Site selection

Our site selection strategy is focused on: urban areas with above average deprivation, areas where there are opportunities to plant multiple Tiny Forests supporting habitat connectivity, and opportunities to engage school children and young people. Local authority engagement and corporate partner priorities are also important considerations. A Tiny Forest needs a minimum area of 200m^2 that is clear of utilities and overhead infrastructure.

Soil assessment

Once a land agreement is completed, the process continues with thorough soil surveys at the site. The soil surveys inform decisions that need to be taken for soil preparation (i.e. depth of excavation), the soil supplements that will be needed, as well as the best tree species to be planted.

Design

The design of each Tiny Forest is decided, with input from our partners, early in the process. Each Tiny Forest is tailored in shape and can feature paths and seating areas. For example, Witney Town Council (for the first UK Tiny Forest) were keen to replicate the octagonal shape of their Church steeple and also include a woodchipped outdoor classroom area that could be used by both local residents and schools.

Species selection

Species are selected by considering the geography, soil type, and native ancient semi-natural reference forests in the area. Trees species that are suitable for the site are then identified to meet the standards of the Miyawaki method (Miyawaki, 1998; Miyawaki and Golley, 1993), which considers canopy, sub-canopy, understory and shrub layer species. For example, the tree species selected at our Witney Tiny Forest were: crab apple (*Malus sylvestris*), downy birch (*Betula pubescens*), silver birch (*Betula pendula*), blackthorn (*Prunus spinosa*), dogwood (*Cornus sanguinea*), elder (*Sambucus nigra*), guelder rose (*Viburnum opulus*), hazel (*Corylus avellana*), field maple (*Acer campestre*), English oak (*Quercus robur*), sessile oak (*Quercus petraea*) and goat willow (*Salix caprea*).

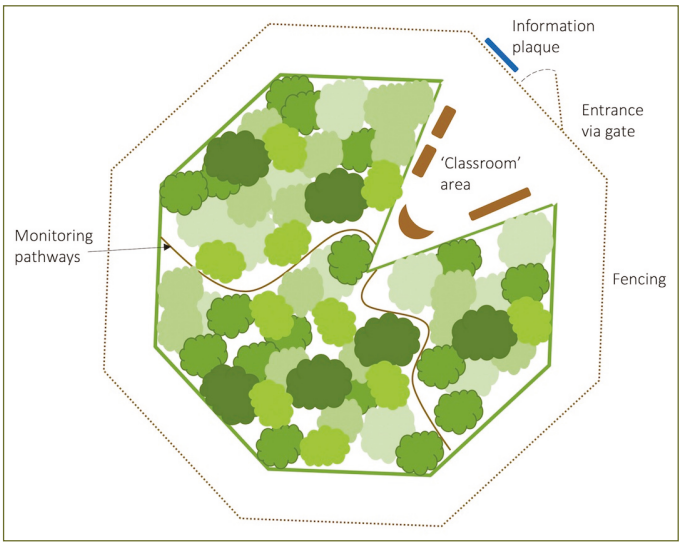


Figure 3. Example of a Tiny Forest: Witney Tiny Forest design.

Trees are obtained from UK nurseries, all of which adhere to the Woodland Trust UK and Ireland Sourced and Grown Assurance Scheme (UKISG). Whips are usually between 20 and 80cm in height and are planted as bare-root, which are from one to two years old, and cell grown which are from one year old and under. The latter is preferred for those Tiny Forests that are planted very early (i.e. October) or late in the planting season (i.e. March).

Soil preparation

Contracted landscapers prepare the soil and create the shape with the desired Tiny Forest design, which is usually done around one week before the planting day. In order to meet the nutritional demands of the fast-growing, densely planted forest, soil supplements are added. For example, organic green compost and chopped straw were added and mixed with the original soil at Witney Tiny Forest to enhance nutrient content and increase infiltration of the largely clay-rich soil. A 2-3cm thick layer of soft and aged native wood chip mulch is added after the trees have been planted, usually in the same day, to maintain the soil moisture through the summer and suppress competitive weeds.

Planting day

Community engagement is a key component of the Tiny Forest model and a planting day offers an excellent opportunity for the community to get involved, taking positive action for our planet. Each planting includes an introduction and demonstration of how tree planting is done. Everyone collects tree whips and plants them one at a time at 30cm apart, throughout the area. Witney's Tiny Forest was planted on Saturday 14 March 2020, prior to Covid-19 restrictions, by 50 volunteers, of all ages, from the local community.

Maintenance

To maximise each Tiny Forest's chance of success, groups of 4-5 local volunteers are engaged to act as Tree Keepers. They take ownership of the Tiny Forest and its development, and help to maintain it for the first few growing seasons.

Vicky Gwatkin from Witney Town Councils says: "It has now been over a year since our Tiny Forest was planted and it's been fantastic to see it being used by the whole community. Following on from the large community planting day, people often go and visit it and spend time in the classroom area. Local residents and families have helped to collect scientific data on our forest at the first citizen science monitoring day. As our Tiny Forest continues to grow, we are looking forward to our next monitoring day, to see how the forest's ecosystem services have changed."

Multidisciplinary research to enhance social and environmental understanding

Tiny Forest research informs implementation, enriches engagement, and addresses fundamental and applied topics to influence policy and share best practice. Tiny Forest research therefore addresses the current knowledge gaps on the ecosystem services provided locally by Miyawaki forests in urban landscapes.

The standardised approach to Tiny Forest planting methodology combined with the research programme allows research into delivery of ecosystem services as well as success factors and trade-offs in implementation across a range of land uses, soil types, climatic conditions and in relation to surrounding habitat heterogeneity and connectivity. Tiny Forest research tackles two major needs related to urban living: assessing the delivery of ecosystem services provided by this urban tree planting NbS, and expanding understanding of the role of NbS in addressing the disconnect between people and nature.

To analyse the complexities of ecosystem services to inform best practice for NbS, multidisciplinary research is needed, allowing different perspectives to come together on a topic. Hence, the Tiny Forest research programme involves different disciplines of research to understand environmental and social impact within urban areas (Figure 5). Four environmental benefits provided by Tiny Forest in urban environments are monitored at each location: carbon

Figure 4. Witney Tiny Forest, 17 months after it was planted. (Photo: Witney Tree Keepers)

Table 1. Summary of central questions and methods to the Tiny Forest research programme.

BENEFIT	Questions	METHOD
Environmental		
Carbon storage	**How much carbon is stored annually by Tiny Forest? How do carbon storage and growth rates vary across the Tiny Forest network?**	A subset of tagged trees (representative of the forest mix) are measured at each Tiny Forest to estimate above ground carbon stored in a Tiny Forest.
	How does this vary by species, status (pioneer/climax, major/supporting) and forest layer?	Participants measure tree height and diameter at decimeter height (ddh - 10cm height) for saplings and diameter at breast height (dbh) for trees with a ddh >100mm.
Biodiversity	**How does abundance and composition of target invertebrate groups vary between Tiny Forests and change over time?**	Participants carry out three invertebrate surveys to explore development of soil fauna and resources for pollinators in Tiny Forest: ground-dwelling invertebrates, pollinators and butterflies.
	How does this vary seasonally and how does surrounding green infrastructure (connectivity and heterogeneity) affect plant and animal assemblages?	To facilitate non-expert participation ground-dwelling invertebrates and pollinators are identified into different broad groupings (based on physical body shape) rather than species. For example, in the pollinator survey options are bumblebees, hoverflies, other flies etc (following methodology from UK Pollinator Monitoring Scheme FIT Counts).
Flood management	**What is the potential capacity of Tiny Forest to store water by changing soil conditions, improving local permeability throughout their development and compared to surrounding soils?**	Participants observe soil moisture, infiltration, texture, colour, and compaction to quantify and compare the capacity to absorb and store water and overall soil health in and around the Tiny Forest.
Thermal comfort	**Is there a cooling effect of Tiny Forest? Do local microclimatic conditions differ within the Tiny Forest compared to their urban surroundings; if so by how much, and to what distance does this effect extend?**	Participants record the key climatic factors that are indicators of thermal comfort (temperature, humidity and windspeed) inside the forest and in the surrounding area using weather stations. In addition, participants answer questions to determine personal perceptions of the thermal conditions.
Social benefits		
Connection to nature	**To what extent does participation in Tiny Forest improve people's 'connection to nature'?**	Surveys using the Nature Relatedness Scale (Nisbet and Zelenski, 2013) to understand people's emotional, cognitive and behavioural attitude to the environment.
	What are the factors that influence a participant's 'connection to nature'?	Interviews to explore how people perceive Tiny Forest and feel about the activities to better understand the impact of different routes to engagement; through volunteering, citizen science, the education programme and nature experiences through simply being in the forest.
Engagement and broader social benefits	**What is the social reach of Tiny Forest – does the scheme help a diverse range of people to engage with this targeted place-based intervention engagement and monitoring programme?**	Sociodemographic data will be gathered to understand the diversity of participants with respect to age, education level, ethnicity, sex, religion and work status.
	What is the social impact of engaging participants and communities in Tiny Forest in terms of health and wellbeing?	We will encourage local residents and community groups (not previously involved in the Tiny Forest) to share their views and feelings about the presence of a Tiny Forest in their neighbourhood and work with social scientists to explore the wider impacts of Tiny Forest on health and wellbeing for participants and local communities.

***Core monitoring questions in bold**

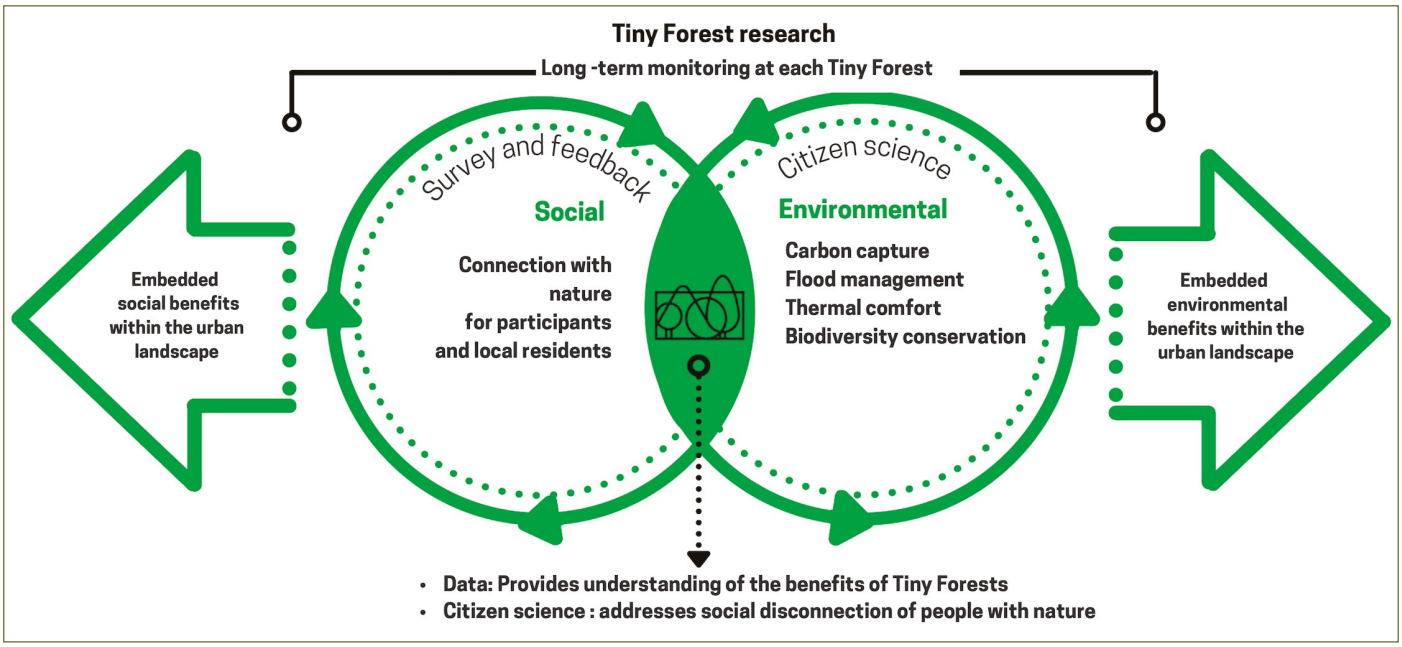


Figure 5. The Tiny Forest research programme includes multidisciplinary environmental research (carbon capture, flood management, thermal comfort and biodiversity support) and social science research (effects of connection with nature on citizen scientists and local residents). The research examines the environment and social impact within each Tiny Forest, which in turn expands beyond the Tiny Forest. The research seeks to close the gap in understanding both the ecosystem services of the network of Tiny Forest forests as NbSs and the disconnection of people with nature.

capture, flood management, thermal comfort and biodiversity conservation. The research also considers which factors affect the environmental benefits: age of forest, species composition, forest design, and geographic location across multiple scales (e.g. locally within a city, and nationally across the UK). Social surveys will determine the potential benefits of Tiny Forest in fostering wellbeing and connection to nature. There is increasing evidence that higher levels of nature connectedness are associated with improved wellbeing and pro-environmental behaviours – both of which increase resilience in a community (Martin and Czellar, 2017; Pereira and Forster, 2015; Richardson et al., 2020). Tiny Forest research engages a range of audiences through in-person and online training and engagement to incorporate different perspectives on Tiny Forest citizen science data collection and social surveys (Table 1).

Citizen science is beneficial to science and society; it advances scientific knowledge and supports people through awareness raising, skill acquisition, capacity building, improving community cohesion, and providing the opportunity to contribute to scientific discovery. Participation in scientific activities can inform the audience about environmental challenges and improve scientific literacy (Aristeidou and Herodotou, 2020; Cronje et al., 2011). By combining action and education, citizen science provides inspiration for people to take meaningful positive action toward nature (Cárdenas et al., 2021) (Figures 6 and 7).

Citizen Science data collected through monitoring surveys at each Tiny Forest is entered live into the Tiny Forest Portal (https://tinyforest.earthwatch.org.uk/). This bespoke digital online portal facilitates data collection from all forests in the Tiny Forest programme in a consistent format to allow easy comparison of forests across the UK and future international locations. Online surveys are

Figure 6. Citizen scientists monitoring a local Tiny Forest. School pupils taking measurements to estimate the carbon stored by their Tiny Forest. (Photo: Megan Evans)

available to any participant with a phone, computer or tablet. The advantage of online data collection means that survey responses are governed by data quality rules ensuring that data is entered in a consistent manner across all Tiny Forest locations maximising data accuracy. The data is stored securely and participants, funders, and landowners can explore the data through regularly updated data visualisations, outputs and access to downloaded raw data. In addition, surveys conducted in a consistent manner at these sites allow for the comparison of data between Tiny Forest methodology and alternative land management approaches.

What we know so far

Understanding the benefits of Tiny Forest

The monitoring methodology created for understanding the ecosystem services of the Tiny Forest network has proven successful from its first year of implementation. A total of 774 volunteers were engaged and trained as citizen scientists to monitor a total of 17 forests in the network between June and November 2021. A total of 1,442 surveys with data were submitted across the four topics of research: carbon storage, thermal comfort, flood management and biodiversity. The results for the first year of monitoring provide opportunities to assess the appropriateness of the citizen science methodologies for capturing ecosystem services of each Tiny Forest, and to establish a baseline against which we can quantify development of these services across the Tiny Forest network in coming years.

Figure 7. A group of 'Tree Keepers', devoted volunteers who look after the Tiny Forest and collect data to inform flood management. (Photo: M.L. Cárdenas)

The results from the first monitoring of the Tiny Forest network indicate that the citizen science methodologies, the use of the portal and overall implementation of the Tiny Forest are appropriate, successful and powerful. For example, the trees studied by the citizen scientists allowed us to determine a vital baseline from which we can assess how much carbon is stored annually. Currently the baseline shows that in total the studied Tiny Forests (17) are storing ~290kg of carbon. This small amount of carbon reflects the young age of the trees planted as 8 to 24-month-old whips. Establishing this baseline value for the carbon stored at young Tiny Forest forests is a basic requirement for future calculation of their carbon capture capacity. Moreover, we have been able to assess that Witney Tiny Forest, which is one year older than most of the forests (in 2020), had trees on average 37.5cm taller and was storing 8% more carbon than the rest of them. A summary of the main results of the carbon stored so far in the Tiny Forest networks and its main characteristics can be found in Figure 8. More details on the results from our Tiny Forest network monitoring can be found in our annual report (https://earthwatch.org.uk/images/downloads/Tiny_Forest_Monitoring_Report_2021_003.pdf).

Addressing social disconnection with nature

Tiny Forest research encourages and facilitates the connection between people and nature. Volunteers collecting data at each Tiny Forest varied in age, including Year 1 school children (5-6 yrs old) to retired people (>70 years old), coming from varied backgrounds and cultures, with sociodemographic groupings broadly reflecting the national population (Carew, 2021). Most participants were part of the local community, including school children or employees from the funding corporate. Volunteers expressed great excitement before the monitoring day and

they mostly described themselves as 'happy' and 'satisfied' after taking part in the citizen science monitoring. Initial results from Nature Relatedness surveys showed most participants had moderate to high levels of nature connectedness (Carew, 2021). Further research is required to explore how this varies with different levels of engagement with the Tiny Forest network.

"To date, a total of 149 Tiny Forests have been planted since 2020 in the UK."

Scaling up

While each individual Tiny Forest may be small in size, the positive socio-ecological impact on communities adds up, and is growing in ambition and in scale. To date, a total of 149 Tiny Forest forests have been planted since 2020 in the UK. Earthwatch Europe plans to establish a Tiny Forest movement and this has already begun with a growing network of engaged stakeholders, partners and communities across the UK and Europe.

Research on Tiny Forest will be enriched by collaborating with academics and students to explore questions outside Earthwatch Europe's current core citizen science programme. This could include: extending Earthwatch Europe's research to look at other potential ecosystem services provided by the Tiny Forest network (e.g. air quality) that are not currently part of the citizen science monitoring scheme; using new technologies and approaches or increasing the frequency of data collection events to explore fundamental questions across fields including climate mitigation, biodiversity conservation, citizen science, and social implications of engaging with the Tiny Forest programme.

Tiny Forest as an example: positive and lasting ripple effect

The climate and biodiversity crises clearly extend far beyond what Tiny Forest can achieve, but it can help set the ball rolling. Tiny Forest represents a powerful investment in urban NbS, and, crucially, provides an actionable example

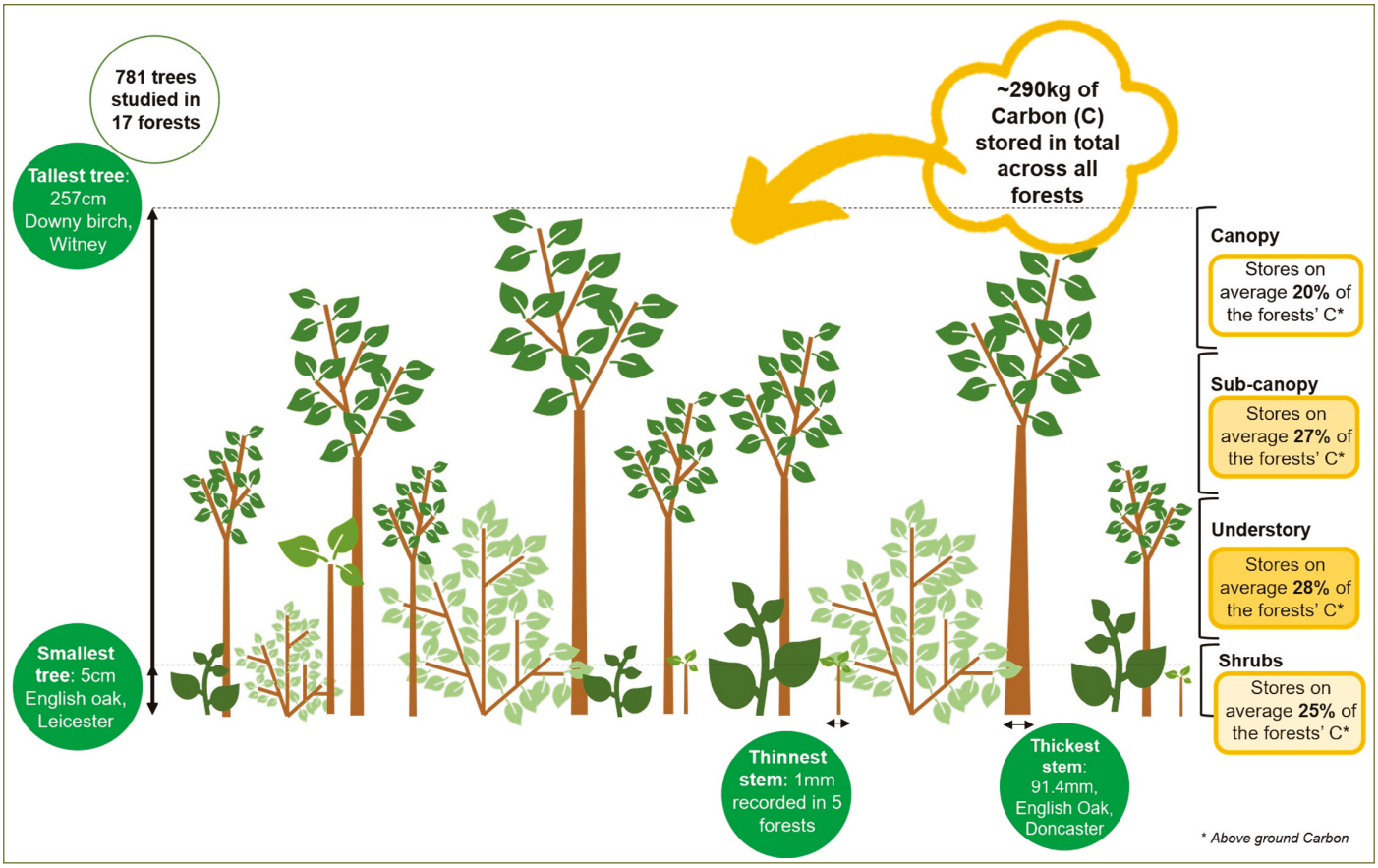


Figure 8. Average above-ground carbon storage results within 17 Tiny Forest forests. Carbon storage was calculated by estimating their average dry weight. The final calculation was the extrapolation of a subset of individuals per species. Relative values of average carbon (%) contributed by each forest layer assumes same number of individuals.

of collaborative participation toward a better future. Most importantly, Tiny Forest showcases the role of raising awareness, of educating citizen scientists and supporting all generations (van Noordwijk et al., 2021). This ripple effect could make Tiny Forest a powerful tool for contributing to a resilient and sustainable future in urban areas.

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Dr Macarena L. Cárdenas is Research Manager for Climate-Proof Cities at Earthwatch Europe. Macarena is a multidisciplinary researcher focused on urban sustainability through the understanding and implementation of nature-based solutions, social awareness and engagement, and has nearly 20 years of experience in environmental field research and ecosystem services in temperate, subtropical and tropical forests.

Beth Pudifoot is the Tiny Forest research assistant working intimately in the preparation and delivery process of Tiny Forest forests across the country. Beth has spent the past few years working in urban nature-based solutions following studies in Conservation Biology. She is inspired by opportunities to engage with people from diverse backgrounds, but who share a common focus of improving the environment that we live in.

Dr Claire L. Narraway is Research Manager at Earthwatch. She is a multidisciplinary researcher working in the fields of citizen science, urban ecology, and behavioural ecology, focused on understanding how environments shape the success of the organisms that inhabit them and passionate about creating environments for humans and wildlife. She works on engaging non-professional scientists in the process of science, building understanding of the human-nature relationship, and driving positive environmental impact.

Caroline Pilat is a Research Intern at Earthwatch Europe working on Tiny Forest. Her work combines social sciences with Earth system processes to build nature-based solutions. Caroline has contributed to forestry cases internationally and has delivered accessible research outcomes to rural and indigenous communities. Her multi-disciplinary work is focused on improving resilience in social-ecological systems.

Dr Victor Beumer is a landscape ecologist and senior research lead Climate-proof Cities at Earthwatch Europe, working on urban biodiversity and climate adaptation through nature-based solutions. Currently, he is responsible for the upscaling of citizen science programmes like Tiny Forest and Naturehood internationally.

Dr Daniel Hayhow, Research Lead, is a conservation scientist with ten years' post-doctoral experience in conservation research and citizen science in the UK and Europe. Daniel has a strong network of connections in the environmental monitoring sector having led on the 2016 and 2019 State of Nature reports. He provides scientific leadership to the research elements of Tiny Forest.