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FORESTS AND SUSTAINABLE CITIES

Mantova, Italy, will host the first World Forum on Urban Forests in November/December 2018

World Forum on Urban Forests

Mantova, Italy, 28 November–1 December 2018

The first World Forum on Urban Forests will showcase cities worldwide that are using urban forestry to provide economic benefits and ecosystem services and to strengthen social cohesion and public involvement. The Forum will bring together actors from around the world and across sectors to explore urban forestry strategies towards a greener, healthier and happier future.

An initiative of FAO, the City of Mantova, the Italian Society of Silviculture and Forest Ecology, and Politecnico di Milano

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World Forum on Urban Forests
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Cover: The Cheonggyecheon promenade, Seoul,
Republic of Korea. The area has been restored
in a major urban-renewal project to improve the
downtown environment. Cities need forests
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Contents

EDITORIAL

More than half the world's population now lives in towns and cities, and that proportion will continue to grow in coming decades. If planned and managed well, cities can be great places to live, but many urban developments cause environmental havoc – ultimately leading to problems such as urban "heat islands", flooding, and air pollution. The cost for citizens is borne in deteriorating well-being; the costs for the planet include increased greenhouse gas emissions and other waste and the degradation of soils and waterways.

Cities need forests. The network of woodlands, groups of trees and individual trees in a city and on its fringes performs a huge range of functions – such as regulating climate; storing carbon; removing air pollutants; reducing the risk of flooding; assisting in food, energy and water security; and improving the physical and mental health of citizens. Forests enhance the look of cities and play important roles in social cohesion; they may even reduce crime. This, the 250th edition of *Unasylva*, takes a close look at urban and peri-urban forestry (UPF) – its benefits, pitfalls, governance and challenges.

In the opening article, Borelli and co-authors describe the essential role that urban and peri-urban forests must play in meeting global commitments on sustainable development. The United Nations and other bodies have long recognized that unplanned urban growth can drive poverty and inequality and cause social and environmental problems on a global scale. Most recently, the Sustainable Development Goals explicitly address the need for sustainable urban development, aiming to "make cities and human settlements inclusive, safe, resilient and sustainable". Forests are increasingly seen as essential elements of this, and many international organizations, including FAO, are assisting countries and local governments to better integrate forests into city governance.

The article by Calaza and co-authors examines the role of UPF as part of an overall strategy to develop green infrastructure – the term used to describe the network of green spaces and water systems delivering multiple economic, social and environmental values and benefits to an area. The article presents international perspectives on the importance of good design in UPF and suggests that it can help solve a number of urban problems.

Dobbs and co-authors use case studies in Australia, Brazil, Colombia and the United States of America to demonstrate the benefits that urban and peri-urban forests can provide for city residents. They also discuss some of the challenges that urban forest planners and managers will need to meet in years to come.

In another article, Nowak sets out a four-step process for assessing, modelling and monitoring urban forest structure, which can have a profound impact on the benefits and costs of urban and peri-urban forests. This process, says Nowak, enables the development of local forest management plans that optimize forest structure to enhance human well-being.

Urban and peri-urban forests are often under pressure from poor urban development, and better ways of governing them are needed. According to Konijnendijk and co-authors, diverse models of urban forest governance are emerging in which local communities, not-for-profit organizations, municipal authorities and the private sector all have roles to play in ensuring that the benefits and costs of UPF are shared equitably.

Nagabhatla and co-authors point out that ensuring a sustainable water supply in cities looms as a major global challenge. They advocate nature-based solutions, which are actions to protect and manage ecosystems that both address societal challenges and provide benefits for human well-being and biodiversity. Forests increase soil infiltration, soil water-holding capacity and groundwater recharge; regulate flows; reduce soil erosion and sedimentation; and contribute to cloud cover and precipitation through evapotranspiration. UPF, say the authors, will increasingly be deployed as a cost-effective, nature-based solution for managing water in cities.

Cariñanos and co-authors examine the role of UPF in reducing risks and coping with disasters. Poorly managed urban and peri-urban forests can also create hazards, however, and the article looks at how these can be handled with the overall aim of increasing urban resilience to shocks.

The article by Castro and co-authors takes a somewhat different tack, looking at the role of "food forests" in city sustainability. It concludes that more work is needed to maximize the potential of such forests as part of the green infrastructure of cities.

Finally, the article by Jim looks at the cultural role, management and mismanagement of heritage trees, which are "outstanding" trees to which societies attach special value. If a city can take excellent care of its heritage trees, argues Jim, "it can inspire confidence in its capacity to care for all its urban and peri-urban forests". The article makes recommendations aimed at mitigating existing problems in the management of heritage trees and improving professional practice.

The world will continue to urbanize for decades to come. Villages will become towns, towns will become cities, and cities will become megacities. Ensuring that these urban expanses are both liveable and sustainable is a massive challenge to which UPF advocates and practitioners must rise. Safeguarding and sustainably managing forests and other green spaces in cities will be crucial for the health and well-being of the planet and its inhabitants. ◆

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Urban forests in the global context

S. Borelli, M. Conigliaro and F. Pineda

Cities can lead the way in meeting the Sustainable Development Goals and other globally established objectives by deploying urban and peri-urban forestry.

The last century has been characterized by (among other things) increasing urbanization, with cities worldwide expanding in both number and size. For example, the world urban population increased from 746 million people in 1950 to 4 billion in 2015 (more than a fivefold increase), and this growth is expected to continue in coming decades, with low- and middle-income countries projected to more than double and triple their urban populations, respectively, by 2050 (United Nations, 2016). Of the world's regions, Africa and Asia are urbanizing fastest: Africa had the highest urbanization rate of all the regions between 1995 and 2015; and Asia (already home to 17 megacities[1]) has by far the largest

number of people living in urban areas and, overall, 53 per cent of the world's urban population (United Nations, 2014).

Managing urbanization poses huge challenges. Cities can be hubs of socio-economic development, but the rapid pace of urban growth and the limited resources available to accommodate increasing demand for food and basic services can also present huge barriers for the equitability and sustainability of city development (United Nations, 2016). Particularly in less-developed countries, exponential urban population growth has not been matched by a corresponding increase in the availability of goods and services such as clean drinking water,

Above: A scene in an urban park in Viterbo, Italy. Urban and peri-urban forests are a crucial part of a sustainable future for the planet

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[1] A megacity is a city with more than 10 million inhabitants.

adequate housing and sanitation, and energy. In most less-developed countries, urbanization has translated largely into unplanned urban expansion accompanied by unsustainable production and consumption patterns, leading, in turn, to the overexploitation of natural resources in and around urban areas. As a result, cities have become more vulnerable to natural disasters and to the effects of climate change, and many urban and peri-urban communities are highly exposed to food insecurity and poverty.

This article outlines the international response to the urgent need to better manage urbanization, specifically through the establishment, management and sustainable use of urban and peri-urban forests.

URBAN ISSUES IN THE GLOBAL AGENDA

The international community and the United Nations have widely acknowledged that rapid, unplanned urban growth can drive poverty and inequality, especially in newly urbanizing countries. As far back as 1976, the first Habitat conference (held in Vancouver, Canada) drew international attention to the need to consider and discuss the challenges posed by increasing urbanization. Among other things, it led to the creation of the United Nations Commission on Human Settlements – an intergovernmental body – and the United Nations Centre for Human Settlements, the two precursors of the United Nations Human Settlements Programme, commonly known as UN-Habitat. The second Habitat conference, held in Istanbul, Turkey, in 1996, ended with the endorsement of the Habitat Agenda, a policy document containing more than 100 commitments and 600 recommendations for member countries, setting a plan of action and urban sustainability goals for the new millennium.

In 2015, urban sustainable development was also at the heart of the two main global development agreements endorsed by the international community: the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Building on the Millennium Development Goals, the 2030 Agenda (which includes 17 Sustainable Development Goals – SDGs) calls on countries to "mobilize

Participants in the Habitat III conference, held in Quito, Ecuador, in 2016, enjoy the ecosystem services provided by trees

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Residents and tourists in Ljubljana, Slovenia, enjoy outdoor leisure time in the shade of a large tree. There is evidence of an inverse relationship between tree canopy cover and crime rates. Green spaces increase social cohesion and provide documented health benefits

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efforts to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind".

The 2030 Agenda recognizes urban sustainability as a key element for achieving sustainable development and includes a specific goal on urban development (SDG 11): "make cities and human settlements inclusive, safe, resilient and sustainable". About one-third of the 231 indicators in the SDG Global Monitoring Framework are related directly to urban policies with clear impacts on cities and human settlements and can be measured at the local level (UN-Habitat, 2017).

The key role of cities in achieving the sustainability goals set in the Paris Agreement was recognized at the 22nd Conference of the Parties to the United Nations Framework Convention on Climate Change, held in Marrakech, Morocco, in 2016. Parties agreed that, given that cities are the main source of carbon emissions and contain most of the human population (UN-Habitat, 2011), the most important efforts for climate-change mitigation and adaption will have to be implemented in urban areas.

The Habitat III conference, held in Quito, Ecuador, in 2016, put equality and socio-economic and environmental sustainability at the heart of discussions on sustainable urban development. The main outcome of that conference was the endorsement of the New Urban Agenda (NUA), which sets out a global strategy for addressing urbanization issues in coming decades. According to the NUA, cities must develop urban strategies that are people-centric, helping their citizens to thrive rather than simply survive. The NUA is based on three "interlinked" principles: leave no one behind; ensure sustainable and inclusive urban economies; and ensure environmental sustainability. The NUA builds on the assumption that well-planned and -managed urbanization can be a powerful tool for sustainable development in both developing and developed countries. It also stresses its links with the 2030 Agenda and its role in implementing the latter.

ROLE OF URBAN FORESTS IN THE NUA AND THE SDGs

The NUA and the SDGs, particularly SDG 11, highlight the importance of green spaces in improving living standards in cities, increasing community cohesion, improving human wellness and health, and ensuring sustainable development, with the text of the NUA echoing the wording of the SDGs. Thus, countries commit themselves to the promotion of safe, inclusive, accessible and green public spaces (SDG 11) that:

- provide urban dwellers with multi-functional areas designed for social interaction and inclusion (SDGs 10 and 11);
- contribute to human health and well-being (SDG 3);
- promote economic exchange, cultural expression and dialogue among a wide diversity of people and cultures (SDG 8); and
- are designed and managed to ensure human development and build peaceful, inclusive and participatory societies (SDGs 10 and 16), as well as to promote living together, connectivity and social inclusion.[2]

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[2] The NUA addresses these bullet points in paragraphs 13b, 13h, 14c, 37, 38, 51, 53, 65, 67, 71, 100 and 109.

Urban forests, social cohesion and human health

If properly planned and managed, urban and peri-urban forests – defined as "networks or systems comprising all woodlands, groups of trees, and individual trees located in and around urban areas" (FAO, 2016) – can make valuable contributions to the quality of urban green spaces. In Baltimore, United States of America, for example, a strong inverse association was observed between crime rates and tree-canopy cover (adjusting for many confounding factors); this association was true for both public and private lands but was strongest for public lands that were accessible to all (Troy, Grove and O'Neil-Dunnea, 2012). A study on the collective efficacy[3] of various urban features found that parks are considered community assets. They bring people in surrounding areas to common places to participate in leisure activities – at times when people are most likely to be open to what they see around them and more receptive to others because they are pursuing recreation together and sharing common spaces (Cohen, Inagami and Finch, 2008).

Another study, in the Netherlands (Maas *et al*., 2009), found, after adjusting for socio-economic and demographic characteristics, that less green space in people's living environment coincided with feelings of loneliness and with a perceived shortage of social support. Overall, information collected through interviews showed that people with more green space in their living environments felt healthier, had experienced fewer health complaints in the previous 14 days, and had a lower self-rated propensity for psychiatric morbidity than those with less access to green areas. The study also found that the relationship between green space and health indicators was strongest

and most consistent for the percentage of green space within a 1-km radius of people's homes. A report by The Nature Conservancy (2017) considered that, given the increasingly well-documented benefits of urban and peri-urban forests for human health, "there is a strong business case for more investment in urban trees"; thus, "the health sector (whether public or private institutions) could supply some financial resources that help partially pay for activities in the urban forestry sector".

Socio-economic development

In the NUA, green spaces are no longer viewed simply as aesthetic features in landscapes but as drivers of socio-economic development that can be leveraged to increase socio-economic value, including by increasing property values, facilitating business and public and private investments, and providing livelihood opportunities for all (SDGs 8 and 10). Hedonic models used to determine the effects of green spaces and urban and peri-urban forests on house sale prices have found, for example, that the presence of green spaces within 80–100 m of a home increases its price by 7 percent (Conway *et al*., 2010). Wolf (2003) used contingent valuation methods to assess correlations between variations in urban forest character and shopper behaviour in a number of cities in the United States of America, finding that consumers were 9–12 percent more likely to make their purchases in shopping districts that had trees than in comparable districts without trees.

Environmental benefits

In line with SDG 13 (climate action) and SDG 15 (life on land), the NUA calls for the sustainable management of natural resources in cities and human settlements in a manner that protects and improves urban ecosystems and their ecosystem services, reduces greenhouse gas emissions and air pollution, and promotes disaster risk management. Urban and peri-urban forests and trees help mitigate climate change by directly capturing

and storing atmospheric carbon dioxide. Also, trees provide shade and reduce wind speeds, thereby indirectly lowering carbon emissions by reducing the need for air conditioning and heating and thereby cutting emissions from power plants (Nowak *et al*., 2013). Shaded surfaces can be 11–25 °C cooler than the peak temperatures of unshaded materials (Akbari *et al*., 1997); shading, therefore, can extend the useful life of street pavement by as much as ten years, thus reducing emissions associated with petroleum-intensive materials and the operation of heavy equipment required to repave roads and haul away waste (McPherson and Muchnick, 2005).

Urban areas are generally warmer than their surroundings – typically by 1–2 °C but by as much as 10 °C in certain climatic conditions (Bristow, Blackie and Brown, 2012; Kovats and Akhtar, 2008). Urban and peri-urban forests can reduce this "heat island" effect by providing shade and reducing urban albedo (the fraction of solar radiation reflected back into the environment) and by cooling through evapotranspiration (Romero-Lankao and Gratz, 2008; Nowak *et al*., 2010).

People in urban areas face many potential climate-related risks, such as the increased incidence and severity of storms and flooding. Urban trees can contribute to stormwater management in a number of ways. Stormwater run-off can be reduced by the evaporation of rainfall intercepted by tree canopies and through transpiration, and stormwater quality can be improved by the retention of pollutants in soils and plants (Stovin, Jorgensen and Clayden, 2008). Reducing stormwater flows also reduces the risk of hazardous combined sewer overflows (Fazio, 2010).

By increasing social cohesion, urban and peri-urban forests can help prevent deaths related to, among other things, the effects of climate change. Community stability is an essential component of effective long-term sustainable strategies for addressing climate change (Williamson, Dubb and Alperovitz, 2010). For example, the death rate in the severe 1995 Chicago heatwave

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[3] Collective efficacy, a form of social capital, is a standardized and well-tested aggregate measure of individual perceptions of "social cohesion among neighbors combined with the willingness to intervene on behalf of the common good" (Sampson, Raudenbush and Earls, 1997).

A family in the Republic of Korea look out over a forest canopy. Cities have the opportunity to lead the way towards a greener and healthier planet that ensures the well-being of all people by investing in nature-based solutions as a key tool for achieving sustainable urban development

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varied greatly by neighbourhood, due in part to differences in community cohesion (World Health Organization, undated).

ROLE OF INTERNATIONAL ORGANIZATIONS

There is increasing evidence that government institutions are no longer the only important actors in decision-making processes, and a key ingredient of sustainable urban and peri-urban forest management, therefore, is inclusive governance (Lawrence *et al.*, 2013). Civil-society actors are increasingly recognized as important partners in policy discussions and in promoting the potential benefits of urban and peri-urban forests. Intergovernmental organizations and non-governmental

organizations (NGOs) are playing crucial roles in closing knowledge gaps by conducting action research, providing policy guidance and building institutional capacities. Such organizations also facilitate dialogue between countries and cities and with civil society to increase people's awareness of the need to live more sustainably (Al Mubarak and Alam, 2012) and, ultimately, to achieve the full integration of urban and peri-urban forests and city planning and governance.

FAO supports its member countries through the development of technical guidelines and regional networks and the implementation of field projects. In addition to its work on urban and peri-urban forestry, FAO has initiatives and

programmes aimed at helping achieve SDG 11, and it is collaborating increasingly with partner organizations such as UN-Habitat on urban–rural linkages and land tenure.

UN-Habitat works in human settlements worldwide – from villages to megacities. The United Nations Environment Programme (UNEP) addresses the role of cities in climate change through its Urban Environment Unit. Integrating their complementary expertise, UN-Habitat and UNEP have developed the Greener Cities Partnership, which advocates and promotes environmental sustainability in urban development and the mainstreaming of environmental considerations in urban policymaking. For more than two decades,

Trees line this green space in Belgium. Urban and peri-urban trees and forests provide a wide range of environmental benefits, in addition to their contributions to social cohesion and human well-being

the Greener Cities Partnership has been an incubator of ideas for collaboration and innovation while also serving local, national and international stakeholders through various activities.

Launched in 2016, United for Smart Sustainable Cities (U4SSC) is a joint initiative of 16 United Nations agencies and programmes to assist in achieving SDG 11. Coordinated by the International Telecommunication Union and the United Nations Economic Commission for Europe, U4SSC has developed a set of international key performance indicators and a related data-collection methodology to assess the contributions of information and communication technology to the creation of smarter and more sustainable cities. A number of the key performance indicators are designed to assess the availability, accessibility and management of green and natural spaces in cities.

Environmental NGOs and international organizations such as the World Wide Fund for Nature (WWF), the International Union for Conservation of Nature (IUCN), The Nature Conservancy and Conservation International are playing growing roles in urban and peri-urban forest governance (Duinker *et al*., 2014). The aim of WWF's One Planet Cities Challenge, for example, is to support cities in enabling all their citizens to thrive while respecting the planet's ecological limits. WWF's Urban Solutions for a Living Planet is a platform for showcasing best practices in sustainable urban development. WWF also works with urban planners around the world through its Financing Sustainable Cities programme to promote investment in sustainable urban infrastructure.

In 2000, IUCN's World Commission on Protected Areas, a global network to help governments and others plan protected areas and integrate them into all sectors, created the Urban Conservation Strategies Specialist Group. This group works to strengthen the ability of the conservation community to serve urban people, places and institutions.

100 Resilient Cities is a not-for-profit organization dedicated to helping cities become more resilient to the physical, economic and social challenges they face. The 100RC global network provides cities with resources to develop resilience strategies. For example, the network gives guidance on establishing the position of "chief resilience officer" in governments to lead resilience efforts and provides access

to innovative solutions, service providers, and potential partners from the private, public and NGO sectors. Membership of the 100RC network enables cities to learn from and help each other in achieving common objectives.

CONCLUSION

Achieving the goals and targets of the 2030 Agenda for Sustainable Development, the Paris Agreement and other agendas and strategies requires a joint effort to move from global commitment to local implementation. Through urban and peri-urban forestry and greening solutions, cities have the opportunity to lead the way towards a greener and healthier planet that ensures the well-being of all people. To do so requires that city administrators:

- involve all key stakeholders in the governance of urban and peri-urban forests;
- develop policy and legal frameworks that support the integration of urban and peri-urban forests and other green spaces in overall "green cities" policies; and
- invest in nature-based solutions as a key tool for achieving sustainable urban development.

Networking and the exchange of experiences and knowledge among cities and disciplines are also crucial for achieving the global goals set by the international community (FAO, 2016). The C40 Cities Climate Leadership Group, Local Governments for Sustainability (ICLEI), URBACT and the Carbon Neutral Cities Alliance are some of many active national, regional and global networks that are sharing experiences and making joint efforts to increase the sustainability of urban development and raise local awareness of the key role that forests and green spaces can play in sustainable urban development worldwide.

First World Forum on Urban Forests
The increasing interest in urban and peri-urban forestry suggests that the time is ripe to initiate a global process to enhance communication and networking among practitioners, scientists and decision makers, support the NUA and optimize the potential of urban and peri-urban forests in achieving the SDGs. Thus, the first World Forum on Urban Forests will be held in Mantova, Italy, on 28 November–2 December 2018 with the aim of highlighting positive examples of urban and peri-urban forest planning, design and management. These examples will be drawn from cities with diverse cultures, forms, structures and histories that have used urban and peri-urban forestry and green infrastructure to develop economic and ecosystem services and strengthen social cohesion and public involvement. The event will bring together representatives of international organizations, national and local governments, research and academic institutions, NGOs, urban planners, urban foresters, arborists, landscape architects and designers, and professionals from many other sectors to exchange experiences and lessons learned. Participants will also discuss long-term collaboration on the development of urban and peri-urban forest strategies and the identification of nature-based solutions towards a greener, healthier and happier future. ◆

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Building green infrastructure and urban landscapes

P. Calaza, P. Cariñanos, F.J. Escobedo, J. Schwab and G. Tovar

Urban and peri-urban forests are the most important components of green infrastructure in cities – when well planned, designed and managed.

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James Schwab is a consultant and urban planning specialist based in the United States of America.
Germán Tovar is a specialist in the Office of the Mayor of Bogotá, Colombia.

The accelerated growth of the human population has been accompanied by a process of rapid and often poorly planned urban development, dramatic changes in lifestyle and poor dietary habits. Today, largely due to emigration from rural areas, more than 54 percent of the world's population lives in cities. The combination of globalization, rapid unplanned urbanization, and ageing populations is leading to an increase in the incidence of non-communicable diseases, the major cause of global mortality

Above: Grand Parc, Versailles Gardens, France. Sustainably managed urban and peri-urban forests can provide a wide range of ecosystem services that will increase the resilience of cities and societies to shocks and rapid change

(World Health Organization, 2017). Climate change, which is leading to increases in floods and heatwaves, is complicating the situation.

A major global challenge is to design and customize cities to overcome such problems. A possible strategy, supported by the European Union (EU), involves "nature-based solutions". The EU emphasizes green infrastructure[1] in cities for its multifunctionality, multiscalability and governance attributes. Urban and peri-urban forests are arguably the most

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[1] The EU defines green infrastructure as "a strategically planned network of high-quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings" (European Commission, 2013).

important elements of green infrastructure, connecting cities with nature and providing a wide range of ecosystem services.

This article examines the role of urban and peri-urban forests as part of an overall strategy to develop green infrastructure by presenting various international perspectives on the importance of proper design in urban and peri-urban forestry (UPF). In so doing, we propose that UPF can help solve urban problems through multiscalar, context-specific, socio-ecologically relevant strategic approaches.

A SOLUTION FOR IMPROVING WELFARE IN MODERN CITIES
As rural and agricultural communities have transformed into urban and technological societies, UPF has evolved from a practice with a limited purpose, such as growing certain tree crops and beautifying landscapes, to a strategic approach for meeting economic, social and environmental objectives. Increasingly, the scientific, practical, management and planning knowledge, tools and lessons derived from UPF – mostly from Australia, Canada, Germany, the United Kingdom of Great Britain and Northern Ireland, and the United States of America – are being used to help solve the problems caused by increasing urbanization. European and North American countries have established UPF teaching and research institutions and developed national-level and local political and regulatory tools and laws for conserving, regulating and incorporating the use of urban and peri-urban forests. Recently, too, Brazil, China and other developing countries have started using UPF to increase food security, create jobs, conserve biodiversity and mitigate the impacts of climate change. Rapid urban growth in Africa and South Asia provides an opportunity to adopt the latest findings and knowledge on UPF to address food security, human health and the environment in cities.

Leidsebosje, Amsterdam, the Netherlands. Urban and peri-urban forestry is evolving from a limited practice of tree-growing to the strategic use of trees to address multiple economic, social and environmental issues

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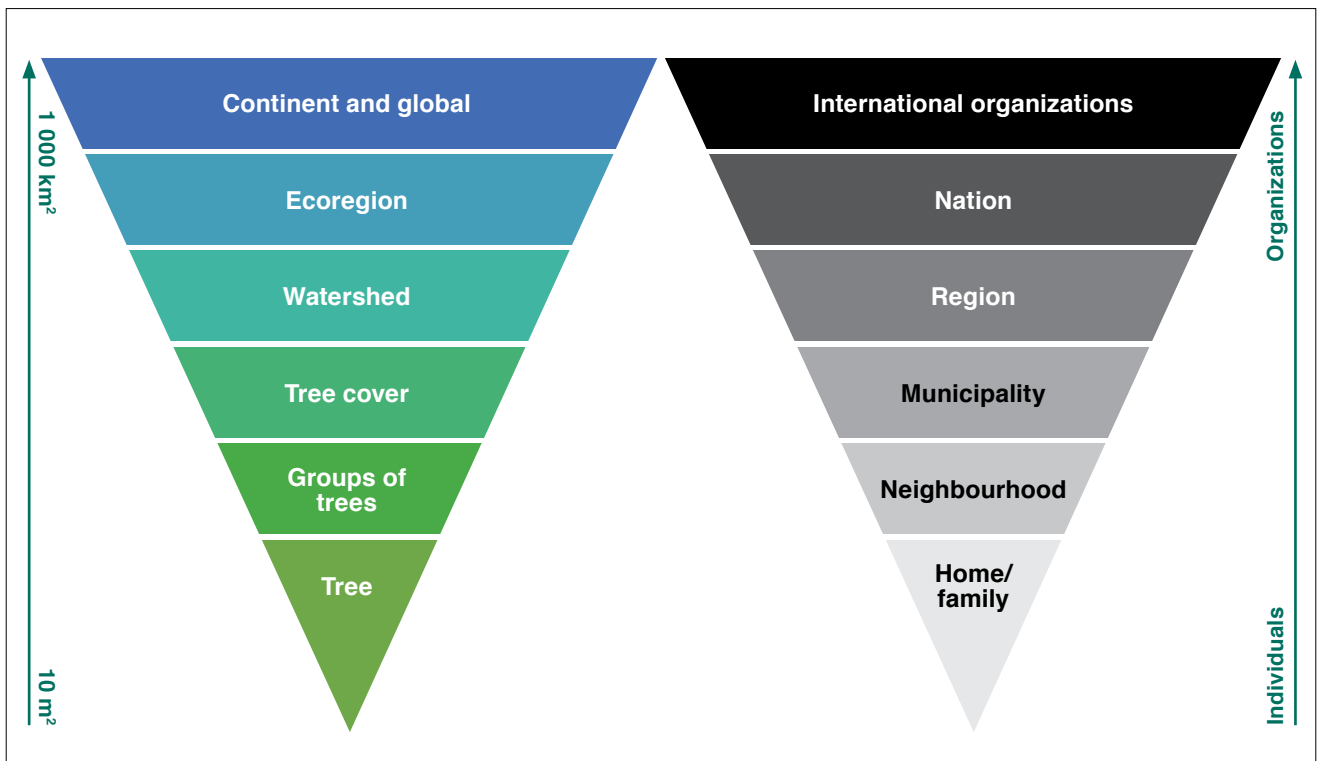
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Socio-ecological scales related to urban forests, their management and ecosystem services

Nevertheless, UPF science, practices and technologies need to continue to evolve (Livesley, Escobedo and Morgenroth, 2016). UPF is more than planting or pruning trees – urban and peri-urban forests are part of multiscalar socio-ecological ecosystems (Figure 1) that provide a range of benefits and incur costs. Therefore, ensuring that UPF makes an optimal contribution to the resilience and sustainability of modern cities requires long-term planning, knowledge of the biophysical, socio-ecological and socio-economic context, and participatory approaches (Livesley, Escobedo and Morgenroth, 2016).

Solving diverse problems
Australia and China – two countries with very different political systems – are both using UPF to solve problems. In Australian cities, participatory processes are taking place for the development of adaptive management plans and governance in order to integrate urban and peri-urban forests as essential components of city planning and management. China, through national decrees, has fostered large-scale urban reforestation to create green spaces for recreation and to mitigate air pollution and improve public health. Costa Rica and some Andean countries have developed tools such as payments for ecosystem services, which are helping improve the management of peri-urban forests to maintain water quality and conserve biodiversity. In Japan and Scandinavia, UPF is being used as a strategy for reducing stress and thereby improving public health. Chile recently implemented policies on urban and peri-urban forests as a way of offsetting industrial-sector greenhouse gas emissions.

Climate change
Climate change is expected to increase the incidence and severity of extreme weather events, such as drought, heat and heavy rains. Extreme heat events – such as those in France in 2003, 2006 and 2017 – can have major impacts on human health in cities. A heatwave in the United States of America in 1995 caused the deaths of more than 700 people, most of them elderly and disabled. The casualties of extreme heat events most commonly occur in neighbourhoods that lack social support for the most vulnerable people and where there is less access to human services and to shaded areas. UPF is increasingly being used to reduce the impacts of such extreme heat events in cities (Livesley, Escobedo and Morgenroth, 2016), including in tropical America and Asia. Urban and peri-urban forests can also mitigate other extreme weather events: in some parts of the Caribbean, the conservation of urban trees and mangroves seems to have reduced the damage caused by recent hurricanes (Escobedo *et al*., 2009). Many North American cities are implementing measures to incorporate green infrastructure as a way of increasing resilience.

Economic, social and environmental benefits

The science and practice of UPF have evolved as understanding of the benefits has increased and with the adoption of new technologies (Livesley, Escobedo and Morgenroth, 2016). For example, the measurement of energy savings due to the shading effects of trees has changed the public discussion on the costs and benefits of green infrastructure. Trees are not only aesthetic amenities, they are also strategies for economic investment and savings. Depending on the context, only relatively minor efforts are needed to determine and promote the social and environmental benefits of urban and peri-urban forests.

THE PUBLIC ADMINISTRATION OF URBAN AND PERI-URBAN FORESTRY

Most cities divide public spaces among, and deliver administration through, various agencies with differing objectives. Parks, water bodies, railway easements, roads, conservation areas and other spaces, which might all feature trees, may be managed in very different ways by different agencies. Many such agencies, especially those with no statutory conservation function (and therefore no budget for it), may completely ignore tree management. A key challenge for cities, therefore, is to increase coordination and collaboration among agencies to bring to bear a consistent approach to the management of urban and peri-urban forests. Such an intersectoral approach may produce better results than centralizing forest management in a single agency.

Multisectoral approach

In many places, urban and peri-urban forest management is still site-specific and fragmented, and the concept of achieving citywide functionality, therefore, is lacking. The lack of cohesion reduces the effectiveness of UPF in influencing city landscapes and the lives of residents. The challenge facing many cities is to create institutional structures that allow the comprehensive planning and management of the forest estate across a city. Most cities lack an agency able to regulate, monitor and coordinate the forest management actions of the various public agencies, and the lack of coordination among agencies also reduces the potential for the participation of private companies and civil society. One city that does feature such an institutional architecture is Bogotá, Colombia: the municipal

Bosque de Chapultepec, Mexico City, Mexico. A challenge facing many cities is to create institutional structures that allow the comprehensive planning and management of urban forests across land uses and tenure

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2
Institutional structure for urban tree management in Bogotá, Colombia

SECRETARÍA DISTRITAL DE AMBIENTE (Environmental Authority of Bogotá)	Determines the urban tree management policy Carries out urban silvicultural planning for Bogotá Monitors, evaluates and regulates the entities involved in urban tree management
Botanical Garden of Bogotá	Administers the georeferenced census of urban trees Advises other entities on tree-cover management Conducts research on urban trees
19 local mayorships	Carry out root-pruning on trees that are causing damage to platforms and sidewalks
Unidad Administrativa Especial de Servicios Públicos (Special Public Services Unit)	Carries out tree-pruning throughout the city following a pruning plan, by species, type of pruning and intervention cycle Maintains a census of urban trees
Instituto de Desarrollo Urbano (Institute of Urban Development – public)	Manages trees in the construction of public works
Empresa de Acueducto, Alcantarillado y Aseo de Bogotá (Water and Aqueduct Company of Bogotá)	Manages trees in and around the city's water system (i.e. rivers, streams and canals)
Agencia de Infraestructura Nacional (National Infrastructure Agency)	Manages urban trees in railway easements
Codensa and Grupo Energía de Bogotá (electricity supply companies)	Manage trees of potential risk to the electricity supply
Instituto de Recreación y Deporte (Institute for Recreation and Sports)	Manages trees in city parks
Firefighters and Instituto Distrital de Gestión de Riesgos y Cambio Climático (District Institute for Risk Management)	Manage trees of potential risk in fires and other disasters
District Treasury of Bogotá	Collects, in a separate account, funds paid for harvesting rights and fines paid for damaging urban forest resources
Fondo Distrital para la Gestión de Riesgo y Cambio Climático (District Fund for Risk Management and Climate Change)	Disburses funds to reduce the risks posed by urban trees

environmental authority there coordinates the management of 31 public agencies that, to a greater or lesser extent, have roles in UPF (Figure 2).

Master plans

A good starting point for a coordinated approach to UPF is to conduct a geo-referenced tree census to provide the basis for analysis and the development and implementation of an urban forest master plan. In general, the most sensitive issues in such plans are those associated with risk management, tree felling, and maintaining the existing forest stock. Underlying – but less visible – aspects are increasing the provision of goods and ecosystem services; species selection; biodiversity conservation; the connectivity of green spaces; and pest and disease management.

UPF generally attracts only small budgets; therefore, longevity is an important criterion in species selection in the establishment of urban and peri-urban forests. Maintenance costs are also important. In Bogotá, for example, the tree species caucho sabanero (*Ficus andicola*) is being planted less and less. This native species is resilient, well adapted to the area and well accepted by residents; it has proven prone to pests and diseases, however, meaning that maintenance costs are ten times higher than for other species.

Providing space for forests in new urban and peri-urban areas is often a significant challenge because of land scarcity and high land values. The urban growth model, which may be either low-density or high-density (or on a scale between these two extremes), is a major determinant of policies on the creation of public green space. Allocating large blocks of land in industrial or residential areas for ecological connectivity or recreation requires strong political effort and a clear justification, as established in the urban forest master plan. Such plans are essential tools, therefore, for enabling municipalities to plan new urban and peri-urban forests in the flux created by urban growth dynamics.

MULTISCALAR DESIGN: FROM INDIVIDUAL TREES TO COMPREHENSIVE STRATEGIES

The design of urban and peri-urban forests should consider various scales, from the individual tree to the citywide forest (FAO, 2016). It should also address the structural, functional, ecological, landscape, social and cultural requirements for ensuring multifunctionality.

Among structural aspects, the morphology of species (e.g. trees, bushes and grasses) and their distribution in the available space should be considered with a view to creating environments with

A London plane tree (Platanus spp.) in front of the Strausberger Platz, Berlin, Germany. The design of urban and peri-urban forests should consider various scales, from the individual tree to the citywide forest

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The publicly accessible Saxon ("Saski") Garden, Warsaw, Poland. Urban and peri-urban forests should be politically neutral places that enable environmental justice and the integration of social groups

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varying vertical structures. Species may be selected to favour certain ecosystem functions. Tree size, longevity and growth type are other elements to consider in design (Gustavsson, 2002); a diversity of species with different morphologies and functions occupying different ecological niches reduces the risk of widespread mortality in the face of a given threat and may also mean lower maintenance requirements.

Access and infrastructure are two of the most relevant functional aspects of urban and peri-urban forest design. All residents should have access to a diverse range of open spaces to meet their varying needs and expectations, regardless of age, ethnicity, culture or disability. The elimination of physical and legal barriers to urban and peri-urban forests is not only the best way of ensuring that all people have access to a healthy environment, it is a principle of environmental justice[2] that should be promoted by design and planning (Nilsson, Sangster and Konijnendijk, 2011).

The resilience of cities in the face of climate change and associated extreme weather events will depend on the maintenance of ecological processes. Ensuring urban and peri-urban connectivity is essential for maintaining ecological processes such as succession and transition.

Landscape design is important for conveying the "message" of UPF. For example, a lack of geometric lines in planting arrangements will help convey a sense of spontaneity and closeness to nature; geometric designs, in contrast, can convey closeness to urban design (Bell *et al*., 2005). The planting of individual trees should take the environment into account: for example, trees planted in historically important places should not disrupt the landscape but rather become a discreet part of it. On the other hand, the role of tree alignment zones in new areas is to strengthen architecture and

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[2] Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, colour, national origin or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies (United States Environmental Protection Agency, undated).

aesthetics and improve health. The general aim is to achieve a multisensory experience, producing views, sounds, smells and other stimuli that reinforce the sense of connection between humans and nature.

Finally, the sociocultural element should be a priority; urban and peri-urban forests should be politically neutral places that enable environmental justice and the integration of social groups (O'Brien *et al*., 2017). It is essential to consider the "forest culture" – that is, the way in which a community views and uses urban and peri-urban forests according to their diversity and biogeographical features. In northern Europe, for example, forest designs should take into account the need both for light and for contact with nature; in the Mediterranean, urban and peri-urban forest designs should provide cooling shade and be conducive to the prevailing outdoor lifestyle.

Table 1 summarizes a range of international approaches to urban and peri-urban forest planning to achieve various objectives.

TABLE 1. International experiences in urban and peri-urban forestry

Country	City	Name	Goal	Description
Germany	Berlin	Biotope Area Factor (1984)	To regulate new urban development with an ecological approach	Part of the area to be developed is to be used for green spaces in which the original vegetation is to be kept or new plant cover planted. Guidelines are provided for landscape planning and design, species protection, and conservation. One of the main advantages of the Biotope Area Factor is that it is flexible in the design of the urban forest and enables stakeholder participation. Since the Biotope Area Factor was introduced in the design and planning of green areas, the provision of vegetation in heavily populated areas has significantly reduced the impacts of climate change, such as heatwaves, flooding and storms
Sweden	Mälmo	Green Space Factor (2001)	To regulate urban development for new urbanization areas using an ecological approach	The approach is similar to the Biotope Area Factor, with various versions and biotopes
USA	Seattle	Urban Forest Stewardship Plan Seattle Green Factor	• To create an ethical model of urban forest management for all stakeholders • To make specific improvements with a view to achieving a net increase in the functions of urban forests and the associated economic, social and environmental benefits • To increase forest cover by 30 percent • To strengthen the health and longevity of urban forests, improve the quality of species and eliminate invasive species	The management plan is framed within the Trees for Seattle Strategy, which brings together all efforts on forests in the city. A section of the strategy focuses on the design and safety of street trees and their role as elements for reducing driving speeds, crime and domestic violence without reducing the important aesthetic values they provide. The Seattle Green Factor is an adaptation of the Mälmo Green Space Factor, which is being incorporated into other cities in the United States of America
Australia	Sydney	Greening Sydney Plan, 2012	• To protect and maintain existing urban forests • To increase canopy cover • To improve biodiversity • To increase knowledge and commitment in the community	Strategy aimed at developing and protecting urban and peri-urban forests
Sweden	Umeå	Young urban forests	To develop new urban forests	Young urban forests have been created by regenerating previous forests or by planting trees, the latter seeking to perform predetermined functions entailing specific forest treatments that need to be permanently maintained. An experimental study was carried out in Umeå on a 2.1-hectare plot that had been reforested 20 years before. In this forest, 12 small forest compartments were created using various thinning methods, with different functions and traditions, creating areas for relaxing and meditating in isolation; children's play areas; natural-looking spaces; areas subject to heavy management for aesthetic purposes; and various samples of local forest types
Norway	Akerselva (Oslo)		To create multisensory environments	A corridor was created along the Akerselva River to enable downtown residents to travel to nearby parks hosting 14 "quiet areas" for contemplation
USA	New York	Program PlaNYC: 2030	To ensure accessibility	The aim is for every inhabitant to have a green area within a 10-minute walking distance
Singapore			To provide opportunities to be outdoors and enjoy nature	The integration of 200 km of pathways through elevated runways to enable inhabitants in different parts of the city to access parks
Japan	Nagoya		To promote actions to actively support nature conservation	Conserve 10 percent of land next to the city boundaries as an unmanaged area and protect it as a nature reserve
USA	Phoenix		To encourage actions to actively support nature conservation	17 000 hectares of desert were purchased to avoid the negative effects of urban expansion, and this area was designated as a nature conservation site
USA	Portland		To invest in social infrastructure that helps urban dwellers understand nature	Investment of more than 5 percent of the annual city budget in biodiversity. The aim is to attain one of the highest tree-canopy covers among the nation's cities (29.9 percent)

TREE SPECIES SELECTION AND PLANTING DESIGN IN URBAN LANDSCAPES

Tree planting is an important tool for improving cities, but it needs to be done properly; often, trees are selected for use or planting with no technical criteria. Many strategies can be used for incorporating trees in cities. For example, FAO (2016) identifies five main types of urban and peri-urban forests: 1) peri-urban forests and woodlands; 2) city parks and urban forests (> 0.5 hectares); 3) pocket parks and gardens with trees (< 0.5 hectares); 4) trees on streets or in public squares; and 5) other green spaces with trees. All these are important resources for the spatial design and planning of an urban and peri-urban forest estate. Urban and peri-urban forest design should comply with basic landscape design principles addressing unity and structure, scale, proportion and balance, space division and definition, light and shade, colour, texture and shape.

Trees bring buildings closer to the human scale, and they enable the creation of spaces by providing a range of textures, light, shapes and seasonality (Arnold, 1980). Trees can be customized to suit almost any situation, thus addressing problems such as stormwater management and climate change and achieving specific aesthetic objectives.

Leaf area

Although, in general, the more trees in a city the better, the most important parameter is canopy cover because of the role that leaf area plays in the services provided by urban and peri-urban forests. The leaves of trees provide the most important ecosystem services of UPF – such as the maintenance of water quality; thermal regulation; the capture of volatile organic compounds and other air pollutants (e.g. sulphur dioxide, nitrogen oxides, ozone, and fine particulate matter such as soot, dust, pollen, and emissions from diesel vehicles); and oxygen production. Such services improve human health (e.g. asthma and related illnesses) and help reduce other complex air-quality problems (such as ground-level ozone, smog and the urban "heat island" effect). In Spain, one of the goals of Barcelona's recently published Urban Forest Master Plan 2017–2037, therefore, is to increase tree canopy cover by 5 percent of the land area, thus achieving a forest cover in the city of 30 percent.
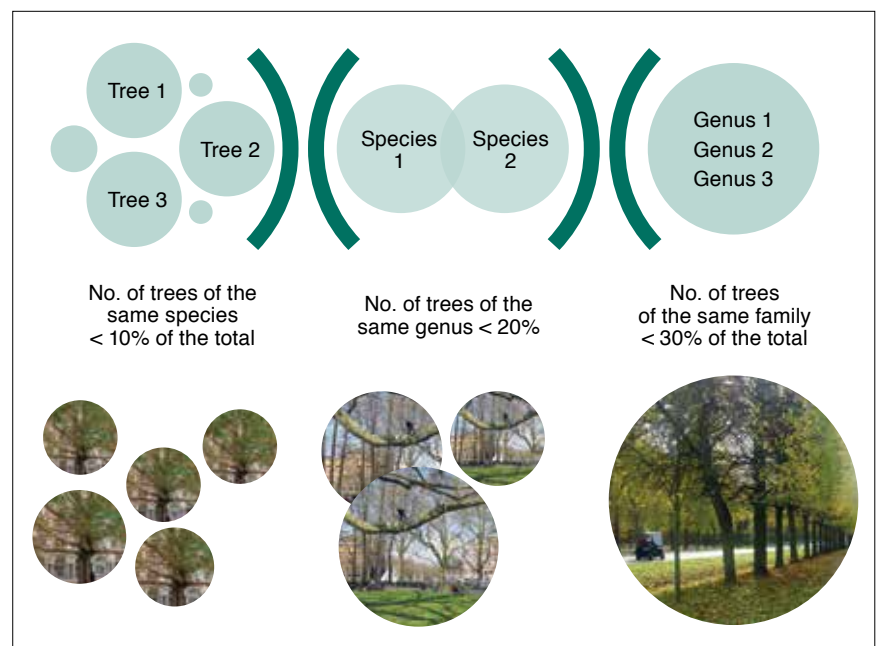
Big trees

Cities need big trees, and one of the aims of design, therefore, should be to maximize tree size. Large-stature trees deliver up to eight times the benefits compared with small trees (United States Forest Service, 2004); even at maturity, small-stature trees do not come close to providing the same magnitude of benefits. A strategically located large-stature tree can contribute significantly to mitigating the urban heat island effect and conserving energy. Choosing tree species that will be large at maturity, planting these on suitable sites, and managing them to ensure they grow strong and healthy will maximize carbon sequestration. The use of large-stature trees can multiply the bottom-line benefits of urban and peri-urban forests: in one theoretical study of trees at age 30 (projected to life expectancy), the annual benefits generated were USD 55 for large trees, USD 33 for medium-sized trees, and only USD 23 for small trees (McPherson *et al.*, 2003).

Diversity

The Santamour rule (sometimes called the "10 percent" rule) proposes maximum percentages for tree species, genera and families in a plantation (Figure 3). This rule, which was proposed by Frank Santamour (1990), a geneticist at the United States National Herbarium, states that no more than 10 percent of any one species, no more than 20 percent of any one genus, and no more than 30 percent of any one family should be planted; others have proposed a "5 percent" rule. The objective behind the rule is to maximize protection against pest outbreaks. Thus, another important goal of the Barcelona Urban Forest Master Plan is to achieve a tree diversity in which no species represents more than 15 percent of the total. Urban forest design should

3
The Santamour rule for biodiversity in forest plantations

No. of trees of the same species < 10% of the total

No. of trees of the same genus < 20%

No. of trees of the same family < 30% of the total

also aim for an adequate age distribution – that is, trees of a range of ages to enable planning for tree senescence and adequate and sequential removal and replacement of dead or dying trees.

Planting

Adequate tree-planting practices are essential for meeting urban and peri-urban forest objectives, and preparation of the planting site is also crucial: it is better to plant a tree that costs 1 euro in a hole that costs 50 euro than a 50-euro tree in a 1-euro hole. Several examples exist of planting systems customized to local needs; the City of Stockholm, Sweden, for example, employs a hybrid system for the sustainable management of stormwater (Box 1). Engineering approaches, such as the use of cells and floating soils, can help achieve consistent results in varying conditions (Urban, 2008; TDAG, 2014).

A study in the United States of America using the i-Tree model conducted a cost–benefit life-cycle analysis of 1 million trees over a 50-year period (MacDonagh, 2015). The two treatments were: 1) urban trees planted using a modern technique in which the pavement is suspended over adequate uncompacted soil volume, giving trees a lifespan of more than 50 years; and 2) urban trees planted with insufficient uncompacted soil volume, in which the trees have an estimated lifespan of only 13 years and therefore need to be replaced three times over the 50-year period and will die before they grow sufficiently large to provide significant ecological and financial benefits. The study projected that, after 50 years, the first treatment generated a net profit of USD 25 billion (i.e. USD 25 000 per tree; Kestrel Design Group, 2011), while the second resulted in a net cost of USD 3 billion (Table 2; MacDonagh, 2015). This finding is consistent with other research, such as that of Fowler (2011). Thus, although the initial cost of best-practice planting may be relatively high, the long-term benefits are immense. Planting many trees is good, but decisions on the methods used will

largely determine the long-term costs and benefits.

UPF knowledge and management techniques continue to improve, but major gaps remain and, in most countries, there is a lack of awareness and knowledge among urban designers. The best way to bridge such gaps in urban development and management is in multidisciplinary teams – because green infrastructure is multifunctional and cuts across all urban sectors.

Box 1
The Stockholm system for stormwater management

The City of Stockholm uses large stones ("large-stone skeleton soils") to provide a high-quality environment for tree roots that improves tree growth in urban environments and encourages stormwater infiltration and effective gas exchange. The technique involves forming a wide base of large (100–150 mm) angular stones covered with an aeration layer (washed granite stones 63–90 mm in size). A surface layer suitable for vehicles or pedestrians, and its subgrade, is installed over a geotextile layer placed on top of the aeration layer.

The Stockholm system prioritizes aboveground/belowground gas exchange and voids in the growing medium over the abundant provision of loam soil. It enables a high degree of water infiltration while enhancing the effectiveness of aeration (water expels any carbon dioxide built up in the voids, thereby avoiding the risk of root poisoning). Through condensation, the aeration layer offers better moisture retention in the warm season.

The Stockholm system continues to be studied; a recent development is the use of biochar as a filter for pollutants and to better retain nutrients and water.

Benefits of the Stockholm system
- The substrate has high load-bearing capacity, including resistance to lateral forces (e.g. heavy vehicular traffic).
- The system uses similar construction practices to those used in the industry, facilitating its incorporation in the construction sector.
- The system can be implemented for existing trees, including mature trees.
- Tree growth rates are very high – but the system needs more study because it has been in place for less than ten years.

Limitations of the Stockholm system
- Installation costs are high.
- Existing soil is not reused.
- The system is not technically complicated, but it requires rigorous implementation.

Source: City of Stockholm, 2009.

TABLE 2. Calculation of benefits and costs for tree life cycles, 1 million trees, with inadequate and adequate planting

	Inadequate planting	Adequate planting
Benefit after 50 years	USD 2.718 billion	USD 41.769 billion
Cost after 50 years	USD 5.812 billion	USD 16.342 billion
Life-cycle net benefit (cost) after 50 years	(USD 3.064 billion)	USD 25.427 billion
Investment return after 50 years	-47%	250%
Value after 50 years	USD 3.064 billion	USD 25.427 billion

Source: MacDonagh, 2015.

CONCLUSION

Urban and peri-urban forests are the most important components of green infrastructure, providing landscape solutions for several urban problems, including climate change. It is essential that UPF science, practice and technologies continue to develop. Multiscalar, multidisciplinary, long-term planning is key to optimizing the advantages and ecosystem services of UPF and for guaranteeing solutions that meet the specific needs of a given city and its social and demographic context, provide equitable access, and ensure environmental justice. It is imperative that tree species are selected to ensure adequate biodiversity, appropriately sized trees, the maintenance of ecosystem functions, and affordable maintenance. Planting systems should be used that guarantee and leverage ecosystem benefits throughout tree life cycles. Contemporary UPF approaches are being applied in various contexts worldwide, and regulatory frameworks have been developed to integrate and design urban and peri-urban forest experiences and achieve multiple purposes. Ultimately, UPF is a socially acceptable, politically effective, economically efficient and thus sustainable tool. ◆

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The benefits of urban and peri-urban forestry

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Forests in cities produce goods and generate ecosystem services that improve the well-being of citizens and increase the resilience of cities to shocks.

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Urbanization places pressure on adjacent natural resources in and around cities by competing for space and demanding products from them. Well managed, however, these natural resources can improve the lives of urban dwellers by providing ecosystem services.[1]

Urban and peri-urban forests comprise all the trees and associated vegetation found in and around cities. They occur in a range of settings, including in managed parks, natural areas (e.g. protected areas), residential areas and informal green spaces; along streets; and around wetlands and water bodies.

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[1] Here we define ecosystem services as the benefits derived from nature that are consumed or enjoyed by humans, increasing their well-being and exerting positive influences on human health (Coutts and Hahn, 2015).

Urban and peri-urban forests provide regulating, cultural and provisioning services that can be of both local and global importance. Regulating services include climate regulation (e.g. cooling), carbon storage, air pollution removal and flood regulation (Dobbs, Escobedo and Zipperer, 2011). Cultural services include natural heritage, recreation, aesthetics, knowledge transfer and "sense of place" (Dobbs, Escobedo and Zipperer, 2011). Provisioning services – which are especially relevant to city dwellers in developing countries – include products such as food, woodfuel, clean water and medicines (Shackleton *et al*., 2015). Urban and peri-urban forests

Above: Panoramic view of the ecological network of the Valle de Aburrá, northwestern subsector of Medellín, Colombia

also contribute to biodiversity in urban areas (Alvey, 2006) and help build cultural diversity, thereby increasing urban resilience to environmental shocks and stresses (Colding and Barthel, 2013). This article explores, through case studies, the benefits that urban and peri-urban forests can provide for citizens and discusses some of the challenges that urban forest planners and managers will need to accommodate in years to come.

THE BENEFITS OF URBAN AND PERI-URBAN FORESTS

Figure 1 provides a framework for the role of urban and peri-urban forests in the provision of ecosystem services, thereby shaping the well-being of urban dwellers. Preferences for certain ecosystem services affect policymaking and decision making and the value assigned to ecosystem services, ultimately affecting the structure and composition of the urban and peri-urban forest estate through management

1
Framework for the ecosystem services provided by urban and peri-urban forests
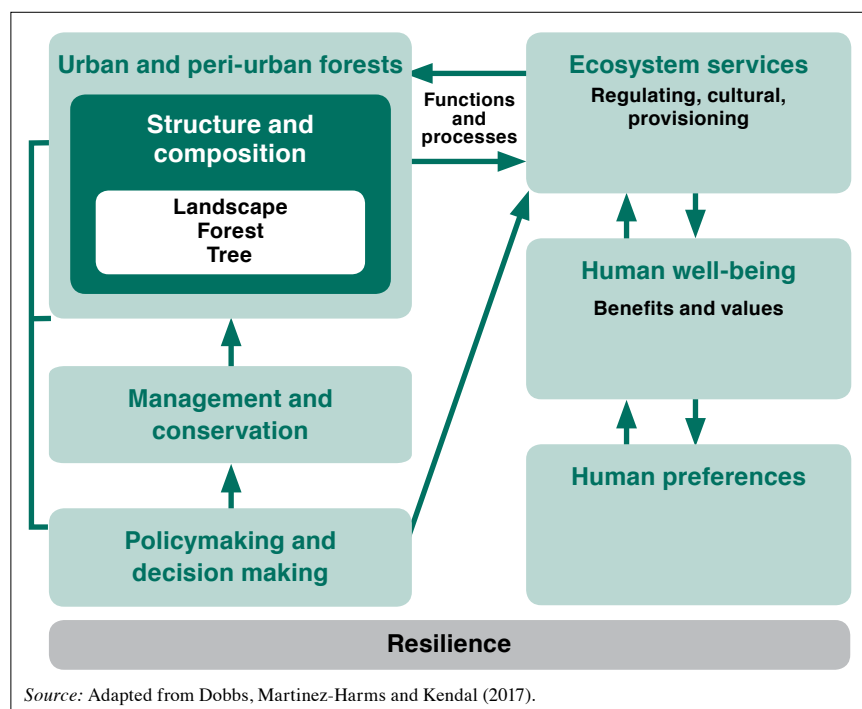
actions. All components of this framework can influence a city's resilience to social and environmental stresses and shocks (Dobbs, Martinez-Harms and Kendal, 2017).

Forest ecosystem services

Urban and peri-urban forests in good condition perform various ecosystem functions. Through shading and evapotranspiration, for example, they can reduce summer daytime temperatures by up to 6 °C (depending on the city's latitude; Skoulika *et al*., 2014). A large tree can intercept up to 190 litres of water in a rain event, thereby reducing water run-off and the risk of flooding and landslides. Urban and peri-urban forests filter air pollution, which is deposited on leaves, thereby acting as passive sinks for particulate matter (Nowak, 1994); particulate matter accumulation rates of 10–70 micrograms per cm^2 of leaf area have been recorded (Sæbø *et al*., 2017).

Forest products

Urban and peri-urban forests are important sources of wood for construction and fuel, especially for people in developing

countries, who still rely heavily on wood energy for cooking and heating. Urban dwellers can also make good use of the products of fruit trees and medicinal plants in private and community gardens, residential areas and streets (Fuwape and Onyekwelu, 2011). Jamun trees (*Syzygium cumini*) in public areas of New Delhi, India, for example, produce fruits that are sold to pedestrians and motorists (Singh, Pandey and Chaudry, 2010).

Urban agriculture

The planting and growing of trees in urban areas contributes to the economic strength and multifunctionality of urban agriculture (de Bon, Parrot and Moustier, 2010), providing sources of income and employment opportunities. Urban food production is not only beneficial as a service, it also increases food availability at the local scale, thus shortening supply chains for some products (e.g. leafy vegetables) and thereby reducing the negative impacts associated with long supply chains. Shorter supply chains also result in fairer product values and lower costs for consumers, therefore improving food security at many levels (de Bon, Parrot and Moustier, 2010) and contributing to community resilience (Salbitano, Borelli and Sanesi, 2015).

On the other hand, many cities worldwide are experiencing major shifts in property rights from public to privately owned lands and an associated lack of community access to public lands that can hinder the effectiveness of urban agriculture in the provision of ecosystem services (Colding and Barthel, 2013). Moreover, urban agricultural plots can serve as sinks (e.g. as receptacles of residential solid and organic waste) and sources of environmental pollution, including pesticides, herbicides and fertilizers (de Bon, Parrot and Moustier, 2010).

Social interactions, culture and well-being

People in urban communities can lose contact with nature (Maller *et al*., 2006). There is a trend towards people spending

Source: Adapted from Dobbs, Martinez-Harms and Kendal (2017).

less time in natural areas, parks and forests than in the past, with both adults and children adopting more sedentary and individualistic behaviours in preference to group activities that use open public spaces (Taylor and Kuo, 2006). Urban forests can foster cultural services such as a sense of community, place and satisfaction because they provide spaces in which people can come together and interact socially (de Vries *et al*., 2013). People become attached to places where they feel relaxed and comfortable, incorporating those places into self-identity (Stoner and Rapp, 2008). Additionally, by spending time outdoors, people tend to exert themselves more, boosting their physical health (Dinnie, Brown and Morris, 2013; Giles-Corti *et al*., 2013). Urban forests also have restorative effects and can lead to improved mental health. For example, attention fatigue can be ameliorated by spending time walking in green areas (Taylor and Kuo, 2006). Exposure to nature can reduce the symptoms of depression and the risk of developing mental disorders (Annerstedt *et al*., 2015).

Financial benefits
Urban and peri-urban forests can provide financial benefits. For example, the presence of mature trees can increase property values by 2–15 percent, and the presence of tree cover in a residential area can increase real estate prices by up to 9 percent (Wolf, 2017). Trees in commercial areas can boost shopping by providing a welcoming environment for retail stores and shaping consumer expectations (Wolf, 2017).

The demand for urban forest products and ecosystem services depends on their perceived importance to urban dwellers, which can vary according to socio-economic, cultural and political realities, psychological well-being, physical health, power inequities, and the biophysical location of the city (Ordóñez-Barona, 2017). Urban forest food and fuel production, for example, may be more important in developing countries, especially for some groups, than in developed countries.

Biodiversity
The role of urban and peri-urban forests in biodiversity conservation can be significant: data on bird presence compiled in 54 cities and on plants in 110 cities, for example, show that a large proportion of taxa are native, and some are endemic (Aronson *et al*., 2014). In Australia, hundreds of threatened native species occur in cities, many of them largely dependent on urban habitats (Ives *et al*., 2016).

Biodiversity can play an important role in increasing the resilience of urban forests to external shocks and stressors, such as climate change (Gomez-Baggethun *et al*., 2013). Diversity is needed at different taxonomic levels (Kendal, Dobbs and Lohr, 2014). For example:

- Genetic diversity contributes to resistance to pests and diseases.
- Species diversity ensures a variety of functions (to provide multiple ecosystem services) and functional redundancy (to minimize the risk of loss of particular services).
- Genus and family diversity can help reduce the incidence of particular pests and diseases (e.g. emerald ash borer and myrtle rust).
- Age diversity should be maintained in urban and peri-urban forests to maintain the provision of ecosystem services over time and to reduce the risk of uniform senescence of large areas of forest.
- Structural diversity (that is, the diversity of tree species, vegetation strata and density) is important for promoting fauna conservation in cities by increasing the number and complexity of habitats (Lindenmayer, Franklin and Fischer, 2006).

CASE STUDIES OF URBAN AND PERI-URBAN FORESTS
A growing body of evidence from North America, Europe, the Global South and elsewhere corroborates the contributions of urban and peri-urban forests to the well-being of urban dwellers. Local governments are increasingly including urban and peri-urban forests in their decision making, planning and regulations, both formally and informally. Here we provide examples of cities in which forestry is becoming a mainstream option for creating sustainable and resilient cities.

Providing ecosystem services in Colombia
Various Colombian cities have developed explicit greening actions in recent years, and studies have shown the benefits of urban and peri-urban forests. In the Aburrá metropolitan area, it was estimated that urban trees save 6 712 megagrams of carbon dioxide emissions per year ($MgCO_2$/yr) – equivalent to the yearly emissions of 1 428 average petrol-engine cars – by avoiding the emission of 5 090 $MgCO_2$/yr due to savings in electric cooling and sequestering 2 077 $MgCO_2$/yr (Reynolds *et al*., 2017). In Medellín, large urban and peri-urban trees represent only 1.33 percent of the total tree population but sequester more than 25 percent of carbon emitted annually in the city and remove almost 10 tonnes of particulate pollution (Restrepo *et al*., 2016). Research on the cultural and economic benefits of urban and peri-urban forests shows that 80 percent of residents in Bogotá, Cali and Pereira are interested in interacting with nature (Ordóñez-Barona and Duinker, 2014). Bogotá residents also perceive that urban forests provide other positive services, such as shading and temperature regulation (Rojas, 2013). Using spatial econometric techniques, Carriazo and Tovar (2016) found a significant positive relationship between the presence of urban forests and a reduction in theft, suggesting that psychological precursors of violent behaviours, such as mental fatigue, could be lower in urban populations with greater contact with nature (Kuo and Sullivan, 2001).

This accumulated knowledge and information has been incorporated into policies in Colombia. A partnership between the Humboldt Institute and the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y

An aerial view of El Poblado Park, Aburrá, Colombia, where urban trees store large amounts of carbon and provide residents with shade and other ecosystem services

Desarrollo Sostenible) has produced strategies and management tools to facilitate land planning, leading to an increase in social connectedness with urban and peri-urban forests and in the success of policy implementation (Montoya *et al*., 2017).

Tackling climate change with urban and peri-urban forests in Los Angeles
Los Angeles, in the United States of America, is highly vulnerable to the impacts of climate change, such as increases in the frequency and severity of flooding, drought and wildfire. People living under social constraints are most vulnerable to the consequences of such events. TreePeople,[2] a not-for-profit

organization, has developed a long-term programme called The Urban Forest Initiative with the aim of involving local communities in increasing canopy cover and building resilience to climate change. Actions include planting and caring for trees; supporting residential and neighbourhood strategies for rainwater collection; and restoring forests in depleted areas. The ten-year goal of the initiative is to increase canopy cover in the city by 25 percent, reduce inequities in forest distribution, and source at least 50 percent of the water supply locally. The initiative also intends to supply information and to work with all levels of government to create progressive policies for the use of urban and peri-urban forests, changing laws and regulations where necessary.

Recognizing the benefits: Open Tree Map
Recognizing the benefits of urban and peri-urban forests, a number of cities in the United States of America have made information on the location, species and care of urban trees available to the local and global communities using the Open Tree Map platform,[3] which can also be deployed to create future scenarios for tree populations. Several local governments are using Open Tree Map to manage and communicate information on their urban and peri-urban forests and as a decision-making tool to help deliver ecosystem services and create a pathway to sustainability.

[2] www.treepeople.org

[3] www.opentreemap.org

Increasing participation for integrated urban planning

In Foz do Iguaçu, Brazil, researchers at the Federal University of Latin American Integration (Universidade Federal da Integração Latino-Americana) have mapped urban and peri-urban forests as part of a federally supported regional initiative on the management and conservation of Atlantic forests. The framework generated by this initiative, the Atlantic Forest Municipal Plan, provides information on the state of urban natural areas. In addition to mapping, the plan includes environmental perception studies, risk assessment and scenario analysis; it also involves diverse stakeholders. The aims of the plan are to increase public participation in decision making and to establish strategies for integrating urban planning and environmental conservation.

Other university-supported projects have investigated other benefits of urban and peri-urban forests, such as their role in shaping children's perceptions of socio-ecological systems. In that project, children participate in field trips to urban gardens and natural areas within their neighbourhoods and interview elderly residents about local environmental history. These activities help the children develop social skills and increase their environmental awareness, and they expose children to local arrangements in the use and conservation of private and community green areas.

Planning with urban and peri-urban forests

The City of Melbourne, Australia, has changed its management of urban forests in line with the challenges it faces: climate change, population growth and increasing urban heat. Recognizing that a healthy forest is crucial for maintaining the well-being of people, the City developed an urban forest strategy aligned with its climate adaptation and open-space strategies (City of Melbourne, undated). The image below is a visualization of the City's urban forests of the future, in which trees are present in streets and parks and on rooftops. City planners used participatory methods – strong communication and engagement, including online visualization and a popular "email a tree" function – to involve residents and commuters in establishing a clear vision and goals for the City's urban forests. The strategy is being implemented through ten precinct plans,

A visualization of the future urban forests in the City of Melbourne, Australia

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which put the principles of the strategy into practice while integrating community views. Complementing this, and recognizing the importance of the community in generating and transferring knowledge, the City of Melbourne created the Citizen Forester Program, under which citizens are enlisted to collect data on, among other things, trees, tree genetics, habitats and pollinators. Recently, the City created the Urban Forest Fund, which, in partnership with the private sector, unlocks financial support to deliver more greening on private properties and therefore more benefits for the community.

FUTURE DIRECTIONS
Of the many challenges facing urban and peri-urban forests and their management, climate change, population growth and social inequalities are the most widespread and locally important.

Climate change
Climate change increases the risks to urban and peri-urban forests, which must be capable of surviving extended periods of severe drought and extreme heat and rain events. Urban forest plans must reduce the likelihood of catastrophic tree losses due to pests and diseases (Dobbs, Martinez-Harms and Kendal, 2017). Approaches to tree planting and landscape design based on ornamental features and historical performance will not necessarily work in the future; rather, species will need to be selected for the probable future climate. Creating a genetically and functionally diverse pool of species in cities will be crucial for ensuring resilience to climate change (Kendal, Dobbs and Lohr, 2014) and the maintenance of vital ecosystem services (Dobbs, Martinez-Harms and Kendal, 2017).

Population growth
It has been estimated that, globally, urban areas will have expanded by 185 percent by 2030 compared with circa 2000, especially in China, India and other Asian countries (Seto, Güneralp and Hutyra, 2012). Demand for food and other ecosystem services will increase worldwide as populations grow. Urban expansion will affect biodiversity hotspots, such as the Eastern Afromontane, the Guinean Forests of West Africa, and the Sri Lanka hotspots (Seto, Güneralp and Hutyra, 2012). Urban and peri-urban forests can be thought of as green networks that can connect rural and urban areas, parks and other natural areas in and around cities. Such forests can enable fauna mobility and increase people's connection with nature – requiring urban planning initiatives and policies that operate at several scales and involve diverse stakeholders. Planning needs to become a multidisciplinary process, involving not only a range of government institutions but also the communities who inhabit the cities.

Social inequalities
Social inequalities affect access to, and the distribution of, ecosystem services. This is especially relevant in cities in less-developed regions, such as Latin America. Therefore, management strategies and policy decisions that address only the ecological dimension of ecosystem services may increase socio-ecological vulnerability (Laterra *et al.*, 2016).

Creating institutional spaces to allow the blooming of local governance processes for urban and peri-urban forests, involving social networks of people of various ages, genders, ethnicities, socio-economic backgrounds, education and values, is essential for building resilient communities. Civic participation is likely to lead to innovative actions adjusted to local realities that create and sustain long-term linkages between cultural and biological diversity.

Understanding the socio-ecological context of urban forests
To develop sustainable and resilient cities, it is necessary to understand the contexts in which these urban dynamics occur. Urban and peri-urban forests will not succeed by simply copying what other cities are doing; plans and management must be adjusted according to the needs of individual cities, as determined by their biophysical contexts and the values and preferences of their communities. Planning urban and peri-urban forests that contribute to the sustainability and resilience of cities requires a multidisciplinary approach in which planners, urban designers, landscape architects, urban foresters, engineers, park managers and communities work together to develop effective policies, management regimes and regulations. The extent to which communities are involved in the policymaking process will be a determinant of the success of urban and peri-urban forest policies because community support is essential, in the long term, for successful implementation.

Access to data on the quality, quantity and distribution of urban and peri-urban forests is another prerequisite for successful planning and management. Policies must incorporate both scientific knowledge and people's preferences and values. Finally, a monitoring system is needed to evaluate the implementation of policies; citizen science programmes are a promising measure for obtaining ongoing information on the status of urban and peri-urban forests and for communicating with and educating citizens. ◆

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Improving city forests through assessment, modelling and monitoring

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Methods for estimating the costs and benefits of urban and peri-urban forests are increasingly accurate and easy to apply.

Urban and peri-urban forests produce numerous benefits for society. These include moderating the climate; reducing energy use in buildings; sequestering atmospheric carbon dioxide; improving air and water quality; mitigating rainfall run-off and flooding; providing an aesthetic environment and recreational opportunities; enhancing human health and social well-being; and lowering noise impacts (Dwyer *et al.*, 1992; Nowak and Dwyer, 2007; Dobbs, Martinez-Harms and Kendal, 2017). Inappropriate landscape design, tree selection and tree maintenance, however, can increase environmental costs (e.g. through pollen production and chemical emissions that contribute to air pollution), energy use in buildings, waste disposal, infrastructure repair, and water consumption. These potential costs must be weighed against the benefits when developing natural resource management programmes.

To sustain or enhance the benefits of urban and peri-urban forests for society, it is important to understand the existing forest structure, how this structure affects the magnitude of the benefits and costs, and how the forest structure and therefore benefits change over time. With such understanding, managers can guide forest structure to maximize benefits for society. Significant advances have been made in recent years on urban and peri-urban forest monitoring and assessment

Above: The monitoring and assessment of urban and peri-urban forests enables the development of management plans that optimize forest structure and the benefits such forests provide

and in quantifying the benefits and costs associated with the resource. Many of the benefits are not easily measured in the field, and modelling techniques must therefore be used to estimate their magnitude. This article provides an overview of a four-step process for easily assessing, modelling and monitoring urban and peri-urban forest structure and benefits. Through this process, local management plans can be developed that optimize forest structure to enhance the health and well-being of current and future generations.

STEP 1: ASSESSING FOREST STRUCTURE

Forest structure is a key variable because it is what managers manipulate to influence forest benefits and values. Structure represents the physical attributes of the forest, such as the abundance, size, species, health and location of trees. Managers often choose what species to plant, where and when to plant them, and what trees are removed from the landscape. These actions directly influence structure and consequently the benefits derived from the urban and peri-urban forest resource.

Bottom-up or top-down?
There are two basic ways of quantifying structure in urban and peri-urban forests: 1) top-down aerially based approaches; and 2) bottom-up ground-based assessments. Top-down assessments provide basic metrics on tree cover (e.g. percentage tree cover) and other cover types, and they can map the specific locations of such elements.

Tree cover can often be estimated by interpreting aerial photographs or by developing tree-cover maps using moderate-to-high-resolution imagery (e.g. Nowak, 2012a). If only the amount or percentage of tree cover is needed, photo interpretation provides a cost-effective and accurate means of assessing tree and other cover attributes; it lacks specific information on cover location, however.

If cover locations are needed, tree-cover maps can provide both tree-cover estimates and specific locations of cover elements (e.g. to be integrated into a geographic information system). Tree cover and distribution are important parameters of urban and peri-urban forest structure because they provide a simple way of conveying the magnitude and distribution of the forest resource. More detailed data on forest structure (e.g. species composition, the number of trees, tree size, tree condition, leaf area, leaf biomass and tree biomass) are often needed, however, to

Healthy tree leaves are crucial for the provision of many of the benefits of urban and peri-urban forests

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assess the benefits and costs and to guide management. Although various aerially based approaches are being researched and developed to derive specific tree information, the best existing approach for deriving many tree variables is field measurement.

Field data on urban and peri-urban forest structure can be obtained from inventories or by sampling. For large tree populations, field data in conjunction with aerially based assessments will likely provide the best and most cost-effective means for assessing urban and peri-urban structure. The most important parameters are species, diameter, crown dimensions, and tree condition. This information is helpful to managers for population management and in assessing risks to the resource, and it is also essential for estimating benefits and costs.

Attributes for modelling
For most benefits, the most important tree attribute is leaf area. Although not directly measured in the field, this variable can be modelled from information on species, crown size and crown condition,

while diameter measures are essential for estimating carbon storage. Leaf and tree biomass can be modelled from these core tree variables. Other important attributes for estimating urban and peri-urban forest benefits are crown competition (important for estimating tree growth and carbon sequestration) and location around buildings (important for estimating energy conservation). Numerous benefits of urban and peri-urban forests can be modelled from these tree variables, in conjunction with other local information (e.g. on weather, pollution and demographics).

There is interdependence between urban and peri-urban forest structure, benefits and economic valuation. Valuation is dependent on good estimates of the magnitude of the benefit provided, and benefit estimates require good estimates of forest structure and how it affects benefits. Benefits and values cannot be adequately quantified without good data on forest structure. Combining accurate data with sound procedures for quantifying benefits will produce reliable estimates of the magnitude of benefits provided by

urban and peri-urban forests. With these, the value of benefits can be estimated using valid economic estimates and procedures. Thus, three crucial elements are needed in sequence to value the benefits of urban and peri-urban forests and to aid their management: structure → benefits → values. Errors with precursor elements will lead to errors in subsequent estimates (e.g. errors in forest structure will lead to errors in estimating benefits and values).

STEP 2: MODELLING URBAN AND PERI-URBAN FOREST BENEFITS, COSTS AND VALUES
Information on forest structure can aid managers by revealing species composition, sizes, locations and potential forest risks (e.g. species composition can reveal potential risks posed by insects and disease infestations). Understanding the links between urban and peri-urban forest structure and the benefits those forests provide is essential for optimizing the benefits through management. Because many benefits cannot be measured easily in the field (e.g. air pollution removal),

A colour-enhanced aerial image of New York City, United States of America. The structure and benefits of urban and peri-urban forests vary across landscapes as forest cover and human populations vary

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models are used to estimate benefits, costs and values based in part on the measured data on forest structure. Once the benefits have been quantified, various methods of market and non-market valuation can be applied to characterize their monetary value (e.g. Hayden, 1989).

Various models exist for quantifying forest benefits; freely available models include InVEST (Natural Capital Project, undated), Biome-BGC (Numerical Terradynamic Simulation Group, undated) and numerous tools for assessing forest carbon (e.g. United States Forest Service, 2016a). Few models quantify urban and peri-urban forests, however. The most comprehensive model developed to date for quantifying urban and peri-urban forest structure, benefits and values is i-Tree,[1] a freely available suite of tools developed by the United States Forest Service through a public–private partnership. i-Tree is based on peer-reviewed science and can be used globally, and it has more than 180000 users in 130 countries; it was designed to accurately assess local forest structure and its impacts on benefits, costs and values (Table 1). Model results have been validated against field measurements (e.g. Morani et al., 2014) to provide sound estimates of the benefits of urban and peri-urban forests. The model focuses on estimating forest structure and the magnitude of services received (e.g. tonnes of carbon removed). It then relies on economic valuation (e.g. dollars per tonne removed) to estimate the value of a given service. The model uses various economic estimates; users can adjust many of these if local economic values are available.

i-Tree Eco
The core programme of the i-Tree suite is i-Tree Eco. This model, which can be used globally, uses sample or inventory data and local environmental data to assess and forecast forest structure, benefits, threats and values for any tree population (Nowak et al., 2008). i-Tree Eco includes plot

selection tools; mobile data entry applications; tabular and graphic reporting and exporting; and automatic report generation. Assessments of urban and peri-urban forests have been conducted using this model in numerous cities globally, including Barcelona, Spain; Calles, Mexico; Chicago, United States of America; London, United Kingdom of Great Britain and Northern Ireland; Medellín, Colombia; Milan, Italy; New York, United States of America; Perth, Australia; Porto, Portugal; Santiago, Chile; Seoul, Republic of Korea; Strasbourg, France; and Toronto, Canada (Chaparro and Terradas, 2009; Escobedo

et al., 2006; Graca et al., 2017; Nowak et al., 2007, 2010, 2013; Rogers et al., 2015; Selmi et al., 2016).

The other tools in i-Tree are:
- **i-Tree Species** – selects the most appropriate tree species based on desired environmental functions and geographic area;
- **i-Tree Hydro** – simulates the effects of changes in tree cover and impervious cover on run-off, stream flow and water quality;
- **i-Tree Canopy*** – allows users to easily photo-interpret Google aerial images to produce statistical estimates

TABLE 1. Benefits and costs of trees currently quantified and in development in i-Tree

Ecosystem effect	Attribute	Quantified	Valued
Atmosphere	Air temperature	○	○
	Avoided emissions	●	●
	Building energy use	●	●
	Carbon sequestration	●	●
	Carbon storage	●	●
	Human comfort	○	
	Pollen	○	
	Pollution removal	●	●
	Transpiration	●	
	Ultraviolet radiation	●	○
	Volatile organic compound emissions	●	
Community/social	Aesthetics/property value	○	○
	Food/medicine	○	
	Health index[1]	○	
	Forest products[2]	○	○
	Underserved areas	●	
Terrestrial	Biodiversity	○	
	Invasive plants	●	
	Nutrient cycling	○	
	Wildlife habitat	●	
Water	Avoided run-off	●	●
	Flooding	○	○
	Rainfall interception	●	
	Water quality	●	○

Notes: ● = attribute currently quantified or valued in i-Tree; ○ = attribute in development in i-Tree; 1 = developing a health index based on mapping of green viewing ("forest bathing"); 2 = estimating product potential based on forest structure (e.g. timber, wood pellets, ethanol).
Source: Nowak (2017).

[1] www.itreetools.org

A tree-lined street in Honolulu, Hawaii, United States of America. The design of urban and peri-urban forests is important for minimizing potential negative effects, such as trapping pollutants near roadways

of land-cover types. Historical imagery in Google Earth can also be used in analysing changes in land-cover types;

- **i-Tree Design** – links to Google Maps and enables users to quantify the current and future benefits of trees on their properties;
- **MyTree** – easily assesses the benefits of one to a few trees using a phone via a mobile web browser; and
- **i-Tree Landscape** – allows users to explore tree canopy, land cover, tree benefits, forest and health risks, and basic demographic information anywhere in the United States of America and to prioritize areas for tree planting and protection.

i-Tree is being developed through a collaborative effort among numerous partners to better understand and quantify how changes in forest structure will affect benefits and values and to aid in urban and

peri-urban forest management and planning. Many new forest benefits and costs are being added to the model (Table 1).

Assessments and modelling in the United States of America indicate that there are an estimated 5.5 billion trees (39.4 percent tree cover) in urban areas nationally, containing 51.5 million hectares of leaf area and 40 million tonnes of dry-weight leaf biomass. Annually, these trees produce a total of USD 18.3 billion in value, comprising air pollution removal (USD 5.4 billion), reduced building energy use (USD 5.4 billion), carbon sequestration (USD 4.8 billion) and avoided pollutant emissions (USD 2.7 billion) (Nowak and Greenfield, in press).

STEP 3: DEVELOPING MANAGEMENT PLANS
Urban and peri-urban forests change constantly, and the goal of management

is to guide such forests towards desirable outcomes that maximize benefits for present and future generations. A crucial step towards achieving this goal is to develop an urban and peri-urban forest management plan that optimizes forest structure over time. Data from local assessments and modelling, in conjunction with inputs from residents, can be used to develop plans to sustain or enhance urban and peri-urban forest structure and benefits. These plans can be as simple as detailing the means (e.g. funding) for attaining desired tree-cover goals at specific locations, or they can provide detailed information on planting rates by species and location.

Urban tree cover is on the decline in the United States of America (Nowak and Greenfield, 2012). Management plans need to consider various forces that are likely to alter forest structure over time, including forces that decrease tree cover (e.g. development, storms, insects and diseases, and old age) and increase tree cover (e.g. tree planting, natural regeneration and invasive species). In the United States of America, it is estimated that two-thirds of the existing urban forest is from natural regeneration (Nowak, 2012b). The influence of tree planting tends to increase in cities in grassland and desert areas, in more densely populated cities, and on land uses that are highly managed in relation to trees (e.g. residential lands). Planning for both human- and nature-driven changes in urban and peri-urban forests will facilitate better management plans that can sustain forest structure and benefits over time.

STEP 4: MONITORING CHANGE IN URBAN AND PERI-URBAN FORESTS

The last step in the assessment process is to remeasure the forest periodically (i.e. monitoring) to determine how it is changing and whether management goals are being met. This step is a remeasurement of the forest structure, as conducted in step 1, thereby restarting the cycle of modelling benefits and evaluating or updating management plans (Figure 1). The evaluation cycle (e.g. every 5–10 years) can ensure that the structure of the urban and peri-urban forest is progressing in the desired fashion to sustain benefits and values for society.

An increasing number of cities globally are assessing their urban and peri-urban forests so as to better understand the benefits and costs. The United States Forest Service Forest Inventory and Analysis programme, in partnership with states and cities, is undertaking long-term urban forest monitoring in the United States of America. This programme collects urban forest data annually to assess forest structure, benefits and values and changes in these over time. The first city to complete a baseline assessment was Austin, Texas (Nowak *et al.*,

1
Cycle of urban and peri-urban forest assessments and monitoring for sustaining forest benefits over time
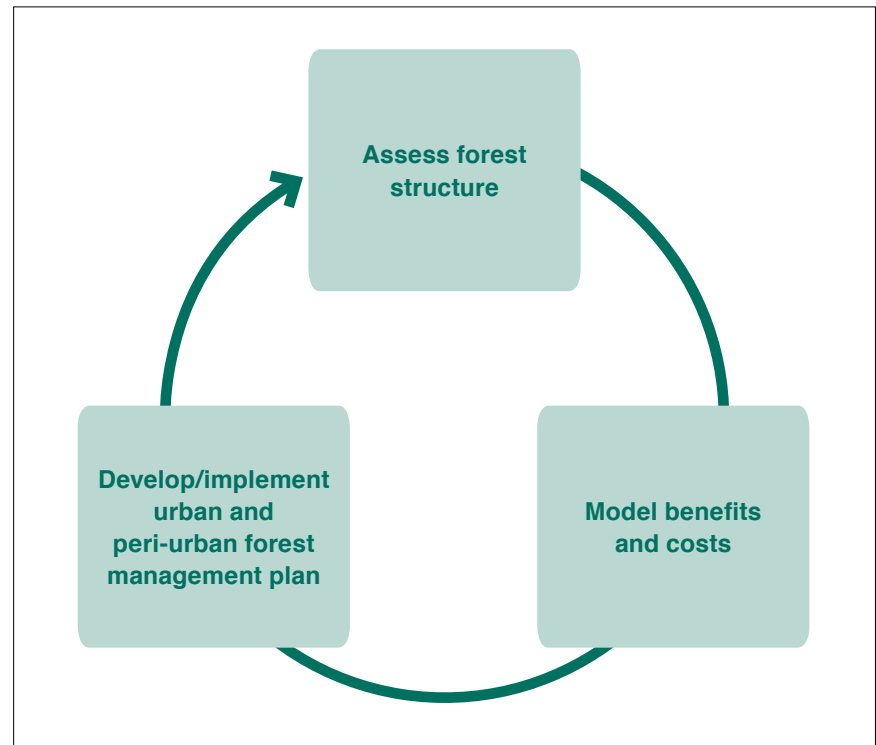
2016); 26 cities were monitored in 2017, and new cities will be added to the monitoring programme over the next few years (United States Forest Service, 2016b).

KEY FINDINGS

The main points made in this article can be summarized as follows:

- Understanding and accounting for the benefits provided by urban and peri-urban forests enables better planning, design and economic decisions for using those forests to improve environmental quality and human health and well-being.
- Data on urban and peri-urban forest structure (e.g. species composition and tree locations), and how that structure affects benefits and values, are crucial for such improvement.
- i-Tree is a simple and freely available set of tools for assessing and valuing the impact of trees and forests – from the scale of local forest parcels to regional landscapes – on environmental quality and human health and well-being.

- Monitoring urban and peri-urban forests is crucial for assessing change and evaluating management plans. The United States of America has recently begun a national urban forest monitoring programme in several cities and states.
- Future assessments, monitoring and management plans can help lower costs and sustain the benefits of urban and peri-urban forests. ◆

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The changing governance of urban forests

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Demand for forests and other green spaces is leading to new models of urban governance.

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Trees, woodlands and other vegetation make crucial contributions to the health, well-being and resilience of urban communities. A body of evidence has accumulated in recent years on, for example, the roles of urban forests in mitigating the impacts of climate change and urban "heat islands" (Roy and Byrne, 2014; Dobbs, Martinez-Harms and Kendal, 2017), and the case has also become strong for urban forests and other green spaces as important contributors to public health (e.g. van den Bosch, 2017). Urban forests are often under pressure, however, from development and urban densification, poor management and their low political status (Haaland and Konijnendijk van den Bosch, 2015).

Better urban and peri-urban forestry (UPF) programmes are needed in communities worldwide. The interdisciplinary field of UPF operates in a complex context, with rapidly changing conditions, drivers and "storylines" (such as biodiversity loss, and the need to adapt cities to climate change and to enhance public health), and many issues compete for the attention of decision makers and local communities (Sheppard *et al.*, 2017).

Local action organized by The Greening of Detroit in Michigan, with seed funding from the federal and state governments, is a governance model that has built a constituency for city forest management across the United States of America

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An expanding global urban forestry community, and increasing networking and knowledge exchange supported by organizations such as FAO, has resulted in greater knowledge and acceptance of good practices in urban forest design, planning and management. To date, however, only limited attention has been given to the way in which decisions on urban forests are made at the strategic level. Who is involved in such decisions, and who is left out? What are the main storylines? How is decision making organized, and who takes the lead? All these questions need attention.

From education to governance
Traditionally, UPF professionals have focused efforts on educating politicians and raising citizen awareness about the importance of urban trees and woodlands. We have come to realize, however, that UPF needs to move beyond this to find ways of including a wider set of stakeholders in decision making and management (Sheppard *et al.*, 2017).

In forestry in general, there is growing interest in emerging, often complex multi-actor decision making – processes captured in the concept of "governance". Previously, public actors such as state forest authorities tended to dominate forest policy, planning and management, but this is less the case today. In UPF, municipal forestry and parks (or planning and engineering) departments still play leading roles, but increasingly they must involve other actors. Thus, we can see a movement from governance by government to governance with (and sometimes even without) government (Konijnendijk van den Bosch, 2014).

Definitions of governance vary widely. All recognize, however, a strategic shift in which a range of government actors share (or transfer) decision making and rule setting with (or to) civil society and businesses (Lawrence *et al.*, 2013; Sheppard *et al.*, 2017). Governance involves decisions, negotiation and a range of power relations among stakeholders to determine who gets what, when and how (UNDP, 2009).

Knowledge of urban and peri-urban forest governance and the different shapes and models it can take is still limited. Therefore, we need to study examples of governance models across the world and draw lessons from them. There is an emerging body of research on urban forest governance (e.g. Bentsen, Lindholst and Konijnendijk, 2010; Lawrence *et al.*, 2013; Buizer *et al.*, 2015; Sheppard *et al.*, 2017), but much more work is needed, involving, for example, more cases from developing countries. In this article, we illustrate the diversity of urban forest governance using three promising examples. The first introduces a well-established, public-sector-led UPF programme in the United States of America. The second presents a case of emerging urban forest governance in a difficult developing-country context in Bolivia (Plurinational State of). The third examines an innovative governance approach in Tokyo, Japan, involving public–private partnerships.

PUBLIC-SECTOR LEADERSHIP AND CIVIL-SOCIETY PARTNERSHIP IN MICHIGAN
The United States Forest Service has a unique programme across all states and territories of the United States of America to support state and local governments in improving the extent and condition of their urban and peri-urban forests. Authorized in 1978 and expanded in 1990 with the help of non-governmental partners, the programme builds capacity and strengthens local action to plant and protect trees and forests for the economic, social, environmental and psychological benefits they provide (United States Forest Service, 2017).

The national programme has focused on local governance since its inception. Although tree planting is recognized as an important entry-level activity that engages people and organizations, the real target has been local tree inventories and management planning and the creation and nurturing of sustainable local programmes and institutions that protect existing tree cover across all lands. Delivered in partnership with state forestry agencies, the programme supports a network of state coordinators and technicians in every state and reaches more than 7 800 cities, towns and villages serving 200 million residents nationwide. These communities have local laws protecting trees, and nearly 70 percent employ professional staff and have management plans in place.

One model partnership is between the United States Forest Service and the Michigan Department of Natural Resources (DNR). The state of Michigan lies within the Great Lakes basin, surrounded by the world's largest freshwater lake system, and the majority of the state's nearly 10 million residents live on roughly 11 000 km^2 (13 percent of the land area). The state concentrates its urban work in 300 communities, with an average 21 percent tree canopy.

The provision of federal funds (USD 344 000 in 2017) to the state through the urban forest programme is driven by a DNR forest action plan developed in collaboration with a statewide advisory (governing) council. The programme's focus is to:
- reduce threats from invasive pests;
- build local community capacity to manage urban forest resources;
- maintain community quality of life and economic resilience; and
- reforest urban and peri-urban areas.

The funding supports state technical assistance and non-governmental partnerships that help deliver services and engage a growing network of professional and volunteer leaders. More than 50 percent of funds are allocated in grants to local government to build public- and private-sector capacity in tree planting, tree inventory, management planning and education and training.

Detroit (population 711 000), in Michigan, provides an example of how the federal programme is delivered locally. The city has a storied history

Unplanned urban development is causing the deterioration of environmental quality in Cochabamba, Bolivia (Plurinational State of). Pressure from a citizens' group has led to the development of an urban forest strategy in the city

of local park and tree investment dating back to its founding in 1701, and it boasts 1 986 hectares of parkland in a total area of 360 km². In the mid-twentieth century at the height of its population (1.8 million people), the city reportedly had 250 000 street trees; by 1990, however, it had lost half its tree canopy to Dutch elm disease, and thousands more trees were subsequently lost to the emerald ash borer. Since 2000, with DNR leadership, the United States Forest Service has supported The Greening of Detroit, a non-governmental organization, to engage residents in restoration planting and tree maintenance. In 2010, the Forest Service and DNR funded a multiyear, citywide street-tree inventory that identified the species and condition of 175 000 public trees. Using i-Tree tools,[1] the inventory collectively valued the city's street trees at USD 29 million; this convinced city leaders to fund and implement a management plan to address dead and dangerous trees,

diversify its tree population, and rebuild its forestry division to conduct regular maintenance. With a strong constituency for trees in Detroit, the future looks bright.

The pattern is similar in other Forest Service and state work in cities across the country. Sustaining long-term relationships, leveraging local capacity and investing in credible, science-based approaches are key to creating governance and building local commitment for successful city forest management.

COCHABAMBA: A COMMUNITY CALLS FOR BETTER GOVERNANCE

With 630 000 residents, Cochabamba is the fourth-largest city in Bolivia (Plurinational State of), and it is situated at the centre of a larger metropolitan area with 1.2 million residents. Cochabamba's urban population is growing by almost 2.5 percent per year. Located at 2 500 m above sea level on an inter-Andean plateau, the city has a mild climate compared with elsewhere in the region. Because of this, it is also known as the "Garden City" and the "City of Eternal Spring". Conditions in the city have

changed dramatically in the last decade, however, due to poor urban governance and planning, which transformed the Garden City into a chaotic urban complex with severe socio-environmental problems. Many of these problems are strongly associated with a substantial decrease in tree and vegetation cover in both established urban settings and new urban development zones. The city's environment has been under pressure from rapid and unplanned urban expansion. Pervious soils traditionally covered by vegetation and trees have been converted to impervious surfaces. The few native trees remaining on public roads, sidewalks and parks have been replaced with exotic ones because of the latter's allegedly more rapid growth. The exotic trees are declining, however, and are not being replaced, and the loss of tree cover has accelerated.

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[1] www.itreetools.org; see also article on page 30 of this issue.

Members of the grassroots collective "No to the Felling of Trees" march in Plaza 14 de Septiembre, Cochabamba, in May 2016

Faced with deteriorating environmental quality, Cochabamba residents began expressing concern about what was happening to the city environment as well as with the municipal administration and its management choices. Before the approval of the Municipal Tree Law in 2017, the management of public green spaces was based on a 1998 tree ordinance and on a regulation for the protection and control of green spaces dating from 2003. Both these documents lacked clear legal and administrative procedures as well as technical support for their implementation. The weak municipal structure has been unable to develop effective tree care and forest management.

Facing this critical situation, in 2016 the municipal administration promoted the preparation of an urban forest master plan as a planning tool with a comprehensive vision for addressing prevailing problems and finding solutions. The plan defines strategic, technical, administrative, normative and institutional guidelines and criteria and sets the course for a new model of urban forest management and planning.

Local citizens played a crucial role in the development of this plan by stressing the need for better protection of existing trees and for afforestation initiatives. Community involvement was encouraged through a process of active tree citizenship. The grassroots collective No to the Felling of Trees (No a la tala de árboles – "the collective"), was created in March 2016 to defend the city's trees. Sarah Jiménez Villarpando, an urban forester, participated in it from the beginning, and it soon gained popularity in social media, reaching nationwide attention within a few weeks and inspiring similar spontaneous actions in other cities. The collective made public announcements about the mistreatment of trees. Although apolitical, it could be considered radical, and it was highly critical of the mayor and especially of EMAVRA, the company responsible for managing the city's trees and green spaces. Initially, the collective was opposed to any intervention that would harm the city's trees and did not want to negotiate with the mayor's office. Many members of the collective, although passionate about trees, had only basic knowledge about the need for the proper management of urban trees and forests. To address this, Sarah Jiménez and a few of her urban-forestry colleagues conducted a long process of education within the group.

The collective initially rejected the proposed municipal urban forest master plan, and the negotiation expanded to include other interested parties. The process was long and delicate, and the collective's strategy was to put pressure on the municipal authorities while maintaining the technical content of the plan. Eventually, the collective accepted a modified plan and the Municipal Tree Law that followed.

The strong commitment of the citizens and public institutions, and the common recognition of the importance of urban trees to the city's future, encouraged the

various municipal bodies to finally collaborate with civil society. The Municipal Tree Law was adopted on 3 October 2017, in tribute to the National Day of the Tree (traditionally held on 1 October).

PUBLIC–PRIVATE PARTNERSHIPS FOR NEW URBAN FORESTS IN TOKYO
Increasing green open spaces has been a major challenge for many Japanese cities, and Tokyo is no exception. Although the western third of Tokyo is mountainous and covered mainly by forests, only 3 percent of the land area in the core of the city is dedicated to green spaces. The Tokyo Metropolitan Government and local municipalities in Tokyo have worked persistently to increase public green spaces, especially parks, but increases have mainly been in the suburbs and there has been no major improvement in the central area. Although the shortage of green spaces in central Tokyo is a major public concern, further

investment by the Tokyo Metropolitan Government and local municipalities in creating public green spaces cannot be expected because of the stagnant financial condition of those bodies.

Meanwhile, a growing concern for environmental conservation has led real estate developers and enterprises to contribute to the improvement of the urban environment as part of their corporate social responsibility policies. To encourage the private sector to participate actively in the creation of green spaces, which can help conserve biodiversity, improve the urban climate and provide recreational opportunities, the Government of Japan approved several new regulations on building design and urban planning. The "overall design system", established in the Building Standards Act, is a good example. The aim is to improve the quality of development projects by providing bonus volume- or height-control allowances to buildings on project sites

that fulfil environmental-quality criteria set by the government. One of the criteria is the creation of a substantial area of green space that is permanently open to the public. The application of this system has enabled the development of more than 700 green spaces in central Tokyo, including the headquarters of Mitsui Sumitomo Marine Insurance, which has 4 700 m² of green space at its base that is open to the public.

Another prominent regulation under the Urban Green Space Conservation Act establishes a system for certifying the public accessibility of privately owned green spaces. This system encourages the creation of green spaces for public use on privately owned vacant lands by providing landowners with financial incentives such as tax concessions. The Kashiniwa project, established in 2012 in Kashiwa City (near Tokyo), was used as a model for the system: it brings together the owners of

The headquarters of Mitsui Sumitomo Marine Insurance in Tokyo has 4 700 m² of publicly accessible green space at its base. A new model of public–private partnership is helping create new green space in this densely populated city

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vacant land and citizens who want to create green spaces for public use and supports such matches by providing landowners with financial incentives.

In the history of open green spaces in Japanese cities, there used to be a robust "wall" between the public and private realms. Public open spaces such as parks were created only by the public sector on publicly owned lands, and the private sector had no interest in contributing to the creation of publicly available green spaces. As corporate social responsibility policies have become more integral to the activities of private enterprises, however, and in light of the United Nations Sustainable Development Goals, this is no longer the case. The private sector is actively seeking opportunities to play substantial roles in the "public" domain. The future of open green spaces in central Tokyo relies on such successful public–private partnerships.

TAILOR-MADE GOVERNANCE FOR SUCCESSFUL URBAN FORESTRY
The three cases described in this article illustrate the wide variety of urban forest governance approaches in place across the world. No single model will work everywhere: each city and urban forest will need its own, tailor-made approach. In Cochabamba, where good governance was absent, it took a bottom-up initiative by a group of concerned citizens to move towards better urban forest governance and laws. Many cities in the developing world face similar conditions and lack basic governance and urban forest programmes. When resources are limited, the involvement of local communities and non-profit-making organizations is essential. Nevertheless, municipal authorities will continue to play crucial roles, too, because they usually have formal responsibility for public street trees, parks and woodlands and for city master planning. At the other end of the spectrum, in the United States of America, a federal government initiative to support urban forestry in states and cities has been in place since 1978. The programme has evolved to leverage effort

and funds by means of partnerships with states, cities and non-profit-making organizations, as the case of The Greening of Detroit illustrates. Ultimately, a top-down governance structure has become blended in a co-governance model in which local communities play leading roles.

The case of Tokyo presents a third approach to governance. There, businesses are becoming drivers of urban forest establishment and even governance. In dynamic, densely populated cities such as Tokyo, land comes at premium prices, and retrofitting the urban core with urban forests or other green components is very difficult for local authorities. A new avenue towards greening can be created, however, if businesses see benefits in greening their properties, encouraged by co-governance in the form of public–private partnerships.

Faced with the challenge of creating healthy living environments for their citizens, cities across the world are increasingly recognizing urban and peri-urban forests as key components. Good governance is required to make urban forest programmes effective while also ensuring that the benefits are shared equitably. Learning from the successes and failures of existing governance approaches and models is an important part of the process of developing better urban forest governance. ◆

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Forests as nature-based solutions for ensuring urban water security

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Increasing international attention is an opportunity to deploy smart, green, cost-effective water management policies in towns and cities and their hinterlands.

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The era of globalization is giving rise to unprecedented trends and patterns in the flows of humans and natural capital. Most prominently, the speed and magnitude of the shift from rural to urban living are having direct impacts on water demand and supply. Cities might occupy only a small proportion (roughly 2 percent) of the world land area but they account for 60 percent of total world energy consumption and 70 percent of greenhouse gas emissions (BP, 2017). In 2014, about 54 percent of the global population was urban; this is projected to increase to 60 percent by 2030 and to 66 percent by 2050 (when the total population is projected to reach 9.55 billion) (UNDESA, 2014). Minimizing the resultant stress on urban areas and natural capital and ensuring water security will require increased attention and smart planning.

Water security is "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable-quality water for sustaining livelihoods, human well-being, and socio-economic

Visakhapatnam, Andhra Pradesh, India, an urban centre of more than 5 million people, is preparing to become a smart, green city. The need for nature-based solutions to address urban water insecurity is increasingly apparent, here and worldwide

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Recreational fishing in Windsor, Ontario, Canada. Fishing is a common urban activity requiring unpolluted water and healthy ecosystems

development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water, 2013). Economic water scarcity, the deterioration and destruction of water infrastructure, unsustainable development and ecological degradation are putting pressure on water-supply systems. High population densities and large industries mean that addressing urban water security is a key priority.

Water security in both urban and rural landscapes is affected by hydro-climate dynamics (and climate change), migration flows, demography and supply-based water management practices. Water is at the core of urban planning and is crucial for socio-economic development and healthy ecosystems; its links to the health, welfare and productivity of populations are made clear in many recent research and development reports, including the UN-Water (2013) synthesis report. Scientists suggest that only about 200 000 km³ of the water supply – less than 1 percent of the total available fresh water – is allocated for ecosystems in supply-oriented water management planning (Boberg, 2005). On the other hand, water demand for human consumption has almost doubled in the last century, and the world is projected to face a 40 percent global water deficit under a business-as-usual scenario (WWAP, 2015). Ensuring a sustainable water supply is crucial for the survival and sustainable development of urban areas, and it looms as a major global challenge in coming years.

Nature-based solutions
Nature-based solutions are "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing

human well-being and biodiversity benefits" (Cohen-Shacham *et al*., 2016). The nature-based solutions approach is founded on the concept that ecosystems innately have various mechanisms that produce services, which, in turn, provide social and ecological co-benefits for communities. For example, forests and trees provide ecosystem services such as erosion control and water regulation that help protect water resources, manage stormwater, ensure domestic water supplies, build resilience to climate change and reduce the risk of disasters. Development agencies, including the World Bank, are promoting

nature-based solutions approaches to protect, sustainably manage and restore natural and managed systems and address societal challenges, human well-being and ecosystem services in an efficient and adaptable manner (MacKinnon, Sobrevila and Hickey, 2008). Nature-based solutions involve the use of green and blue infrastructure in its original form or designed according to ecological principles to supply ecological services.

This article addresses the roles of urban and peri-urban forests – including forested watersheds in the hinterlands of cities – as nature-based solutions for increasing water

security. Because the focus of this article is on forested landscapes, the terms "nature-based solutions" and "green infrastructure" are used synonymously.

CITIES NEED TO BE WATER-SMART
The need for nature-based solutions to address water insecurity is increasingly apparent. Traditionally, urban managers have focused on increasing water supply rather than managing demand. This has led to a heavy reliance on large-scale grey-infrastructure schemes such as large dams and massive embankments along rivers and coastal zones, which have proven expensive – with high environmental, social and political costs – but have failed to address excessive water use. The outcome of this myopic approach has been the further deepening of water demands and the exacerbation of water crises in urban and peri-urban areas.

Water management in towns, cities and municipalities needs to evolve from conventional approaches towards innovative management strategies that combine natural (or "green") and grey infrastructure and include other multifaceted dimensions, such as good governance, microfinancing for community-scale interventions, water-related conflict management, pricing policies, and strategies for disaster risk reduction and community resilience. Box 1 (see page 46) provides examples of recent moves in this direction.

The UN Water for Life Decade (2005–2015) brought together development actors, agents and institutions to address water security. Among other things, it gave rise to the conceptual framework for water security shown in Figure 1, which is designed to guide efforts to address the cross-cutting, multidimensional aspects of water-related decision making (Mehta and Nagabhatla, 2017), including urban water management. Increasingly, the global academic community and development agencies

are prioritizing the water-security agenda and recognizing the need for innovative, cross-cutting approaches that integrate grey and green infrastructure; there is an urgent need to create "water-smart" and "climate-resilient" cities (Nagabhatla and Metcalfe, 2017).

Global demand for water is projected to exceed supply in coming decades, but many cities are already facing water crises as a result of urbanization, aging infrastructure and hydro-climatic variability. In October 2017, the World Water Council, with the support of the Government of Morocco and the United Nations Framework Convention on Climate Change (UNFCCC), convened an international meeting aimed at maintaining water as an important element of climate talks and to focus on water for food and urban resilience. It has been
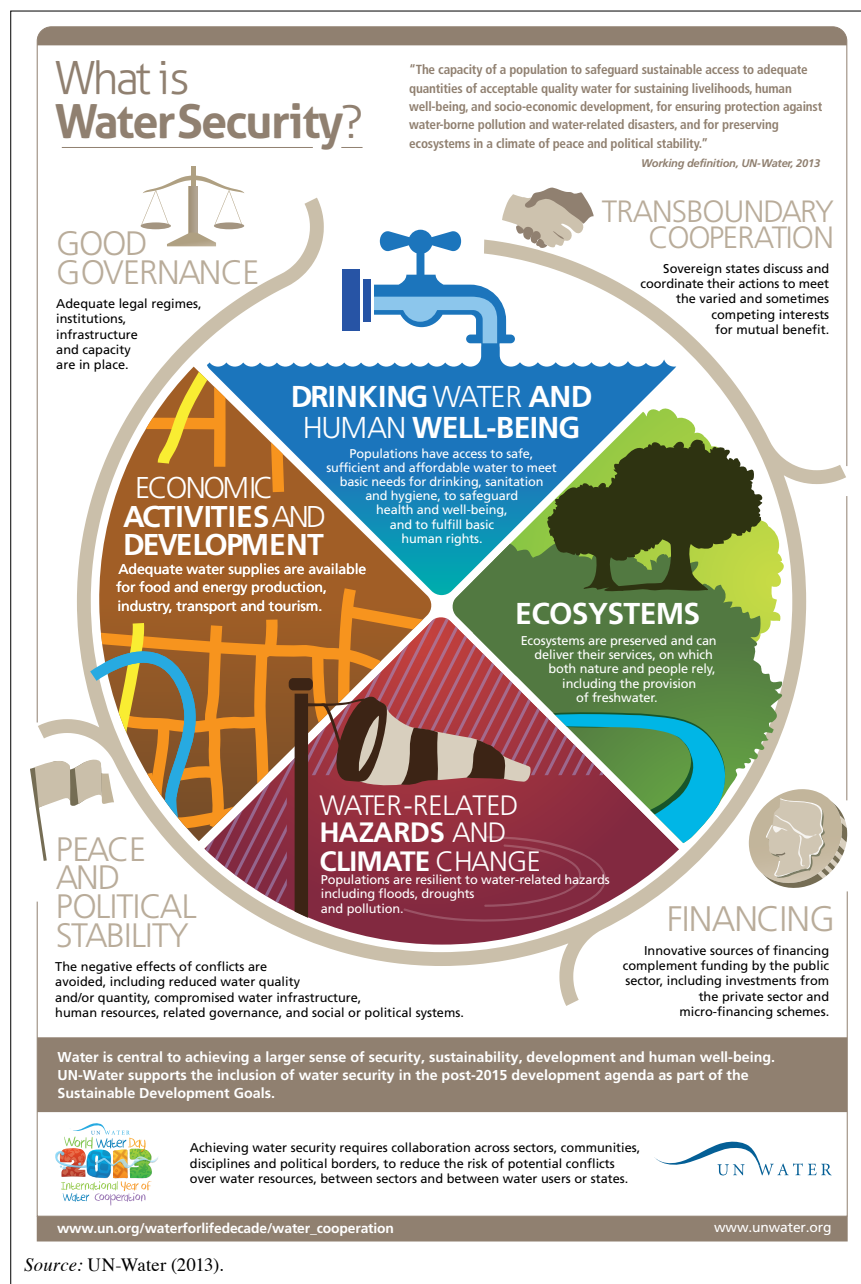
1
The water-security conceptual framework

Source: UN-Water (2013).

Box 1
Nature-based solutions, urban development and community resilience

Recent examples of nature-based solutions to water insecurity in an urban development context include the following:

- The European Union's Connecting Nature project is being implemented in 11 European cities, one of seven European projects seeking nature-based solutions for smart cities and climate change. The total investment of the suite of projects is EUR 150 million; the aim is to help the transition to more sustainable and resilient cities (Thompson, 2017).
- China is investing heavily in innovative green infrastructure such as green roofs on buildings and urban wetlands, with the central goals of flood control, water conservation and increasing the resilience of city inhabitants (Zweynert, 2017). Shenzhen, an emerging smart city in Guangdong Province, is becoming an icon of international environmental leadership by adoption a "green city" agenda. It is incorporating the concepts of green energy, resilient communities and intelligent city infrastructure in its planning as part of a nature-based solutions approach (Kam Ng, 2017).
- Architects and urban planners in the Syrian Arab Republic are considering "people-centred" housing strategies using local resources and approaches to infrastructure development in an effort to create resilient cities (Zekavat, 2017).
- Taking note of intense weather, devastating hurricanes and frequent flooding episodes in urban spaces, architects in the United States of America are proposing green solutions that will embed and deploy ecological services and the benefits of forested and aquatic landscapes in the management of urban development (Lee, 2017).

estimated that protecting water sources, including forests and trees on agricultural land, could improve water quality for more than 1.7 billion people living in cities globally – over half the world's urban population (Abell *et al.*, 2017).

FORESTS AND WATER

It has been estimated that forested watersheds supply approximately 75 percent of the world's accessible freshwater resources (Millennium Ecosystem Assessment, 2005). Forests increase soil infiltration, soil water-holding capacity and groundwater recharge; regulate flows; reduce soil erosion and sedimentation; and contribute to cloud cover and precipitation through evapotranspiration (Ellison *et al.*, 2017). Some forest ecosystems, particularly tropical montane cloud forests and dryland forests, increase net water flow by condensing water from moist air on their leaves, which then drips to the ground. Forests also help reduce flooding and the associated risks to property and human safety.

The maintenance of coastal vegetation and forest fringes in Shenzhen, China, is a nature-based solution to urban problems and part of creating a smart, green city

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Healthy natural forests generally provide higher-quality, purer water than most other land uses. An estimated 1.4 billion people benefit from forests due to reductions in sediments and nutrients in water supplies (Abell *et al.*, 2017). According to Dudley and Stolton (2003), one-third of the world's 105 largest cities (selected by geographical area) receive a significant proportion of their drinking water from forested protected areas such as national parks and wilderness areas. Investing in the protection and sustainable management of forested water catchments can reduce costs associated with water treatment (Ernst, 2004; WWAP, 2015). Maintaining high water quality by investing in green infrastructure may reduce the capital costs of conventional treatments such as coagulation, flocculation and sedimentation and more advanced treatment processes like membrane filtration and activated carbon. It is estimated that the protection of forests as green infrastructure for water can cost less than USD 2 per person per year, which would be fully offset by savings from reduced water treatment (World Bank, 2012; Abell *et al.*, 2017).

FAO (2015) reported that approximately 25 percent of forests globally are managed for soil and water protection, a proportion that rose steadily from 1990 to 2015. Although the global forest average has increased, however, the area of tropical and subtropical forests managed for soil and water protection has declined, due mainly to deforestation and conversion to other land uses in Africa and Latin America. Tropical and subtropical forests may be disproportionately important for water availability because of their contributions to regional precipitation through high rates of evapotranspiration and water recycling; mass deforestation and conversion, on the other hand, has been associated with reduced precipitation downwind (Ellison *et al.*, 2017). For example, recent droughts and water scarcity affecting São Paulo, Brazil, and its 21.3 million inhabitants have been linked to deforestation in the Amazon (Fearnside, 2005; Nobre, 2014; Watts, 2017).

Box 2
Addressing water security through greening infrastructure in Lima

Lima, Peru, is the second-largest desert city in the world after Cairo, Egypt, and its 10 million inhabitants put immense pressure on the surrounding environment and its natural resources, including water and forests. Lima is in the Pacific Coast Basin, which has lost approximately 75 percent of its historical tree cover (Qin *et al.*, 2016), and this vegetation loss has been associated with changes in the region's natural dry and wet seasons and an increased incidence of droughts, floods and landslides (Barrett, 2017). The Pacific Coast Basin now supplies only about 2 percent of the city's water.[*]

The balance between water supply and demand is strained, with a high risk of water scarcity; for example, water demand exceeded the renewable water supply in the dry season in 2015. With Lima projected to grow by 1.4 percent per year, the scenario of demand exceeding supply is likely to become more frequent. Foreseeing this situation, the Peruvian Government adopted the Law on the Mechanism for Ecosystem Service Compensation (2015) to guide and oversee the process of introducing green infrastructure nationally. The law was based on research by Gammie and de Bievre (2015), which showed that integrating existing grey infrastructure with green infrastructure in the watersheds supplying Lima's water could reduce the dry-season deficit by 90 percent, and this would be achieved at a lower cost than by adding grey infrastructure alone. The new law is an opportunity for the water sector to harmonize nature-based solutions with ongoing grey infrastructure projects.

Nature-based solutions such as reforestation, pastoral reforms and wetland restoration, as well as other low-impact approaches such as the rehabilitation of *amunas*,[#] have been planned and are being implemented. Funding for the work will be provided by Lima's water utility authority, Servicio de Agua Potable y Alcantarillado de Lima (SEDAPAL), which has agreed to earmark almost 5 percent of its water tariff (estimated at USD 110 million between 2015 and 2020) to address water management; 3.8 percent of the tariff will be invested in climate-change adaptation and disaster risk reduction, and 1 percent will be spent on green infrastructure projects to close the gap between Lima's water demand and supply. SEDAPAL is developing a novel green infrastructure master plan to enhance and complement grey infrastructure (SEDAPAL, 2016). Lima, therefore, is pioneering a new generation of integrated water and landscape management, providing an example for other municipalities and countries to follow.

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[*] Most of the city's water supply comes from the Rímac, Chillón and Lurín watersheds in the Andes and the Alto Mantaro watershed on the Amazonian side of the Andes.

[#] *Amunas* are stone canals built in the Andes by the Wari culture between 600 and 1000 CE, before the rise of the Incas. Before modern times, *amunas* captured water from rivers in the mountains during the rainy season and took it to places where it could infiltrate rocks that fed year-round springs further down the mountains, so maintaining river flow during the dry season (Pearce, 2015).

Nature-based solutions in cities
The notion of conserving and managing forests for water supply is not new, and many nature-based solutions to water supply are working effectively worldwide today. Some are using payment schemes for ecosystem services ("PES schemes"), whereby individuals or communities are incentivized to protect and sustainably manage forests through a fee paid by downstream water companies and other users benefiting from the improved management. In Quito, Ecuador, and Costa Rica, for example, PES schemes are in place to maintain green infrastructure for the vital water-related ecosystem services it provides; similar schemes are being implemented in other parts of Latin America, such as Lima, Peru (Box 2).

Lake Ontario and forest near the industrialized "steel" city of Hamilton, Ontario, Canada. The city is encouraging nature-based solutions to help achieve environmental sustainability

A comparable PES scheme is working successfully in Viet Nam, bringing money and other incentives to forest conservation and providing local communities with powerful stakes in success. Cities in China are using forest restoration to help manage flooding, and local forest restoration has also reduced flooding in Malaga, Spain.[1]

Discussions on "smart" and "climate-resilient" cities are underway in some countries, such as Australia, the United Kingdom of Great Britain and Northern Ireland, and the United States of America, where national agencies provide spatially distributed, easily accessible and often-free data and information. The United States Geological Survey, for example, has a network of 1.5 million hydrometric sites for gathering data on water.[2] Other countries are in the process of developing information bases. Some countries are using innovative economic and financial instruments to tackle urban water management, such as pollution taxes for managing costs related to decontamination and for generating operational revenues (OECD, 2012).

In other places, however, conditions appear to have moved backwards. Jakarta, Indonesia, receives a large fraction of its water from two national parks, both of which face serious problems of illegal deforestation. In Africa, the rapidly growing port of Mombasa, Kenya, receives clear and plentiful water from the Chillu Hills, a protected area, but the forests there are being illegally cut and degraded. The fate of the forest that has supplied clean water to Istanbul, Turkey, for thousands of years remains uncertain because it has no formal protection (Aydin *et al.*, 2013).

Some tropical cities, especially coastal cities with mangrove ecosystems, are making conscious efforts to review their urban and peri-urban forest management strategies using a disaster risk reduction "lens". Mangrove ecosystems act as protective shields against the effects of wind and wave erosion, storm surges and other coastal hazards that affect people and infrastructure (FAO, 2007). In addition, coastal vegetation, especially mangrove forests, can treat wastewater and remove chemical contaminants (mainly total suspended solids and heavy metals such

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[1] Large, frequent or exceptional precipitation events can overwhelm both natural and engineered defences – but forests can mitigate a significant proportion of minor to moderate flooding events.

[2] In contrast, Water Survey Canada's Hydrometric Program operates just a few thousand such sites, which are particularly sparse in the north (Bakker, 2009).

as phosphorous, zinc, cadmium, lead and nickel) (Tam and Wong, 1997; Boonsong, Piyatiratitivorakul and Patanaponpaiboon, 2003), thereby mitigating coastal pollution (Spalding *et al.*, 2014). Other studies have shown that mangrove forests can improve water quality, especially in areas with intensive aquaculture (Peng *et al.*, 2009).

Urbanization is leading to the rapid proliferation of medium-sized cities (1 million inhabitants or more) in developing countries, where water supply is often poorly or optimistically planned and where there is a low level of understanding about the benefits of maintaining tree cover in catchments. It is projected that, by 2025, 800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's people could be under water-stress conditions (UNESCO, 2006). Decisions to address water security have generally already been made in the world's major cities, but there are opportunities to adopt nature-based solutions in rapidly emerging cities in Africa and Asia.

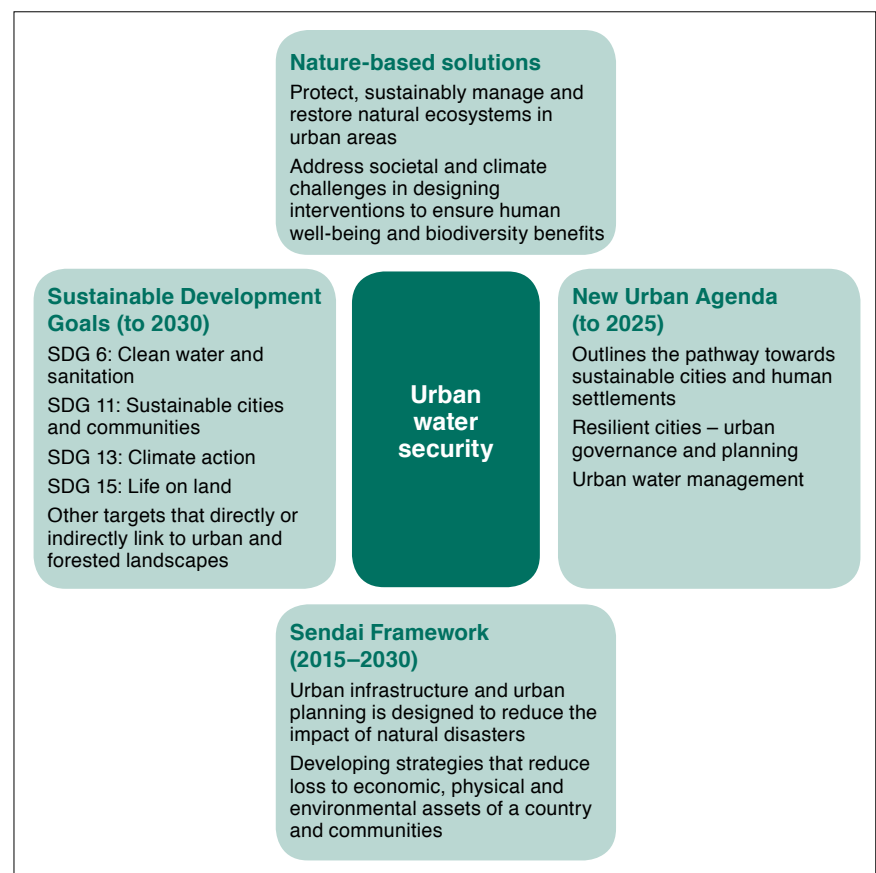## WATER SECURITY AND SUSTAINABLE DEVELOPMENT

Water security is attracting increasing policy attention. International deliberations from the 1970s onwards (e.g. Habitat I in 1976, Habitat II in 1996 and Habitat III in 2016), the Earth Summit, Rio+20, climate-change discussions at the UNFCCC, the Millennium Development Goals (2000–2010) and, most recently, the Sustainable Development Goals (SDGs), as set out in the 2030 Agenda for Sustainable Development (United Nations, 2015), along with global agreements such as the New Urban Agenda and the Sendai Framework (Figure 2), have all taken note of urban issues, sometimes explicitly and at other times as embedded objectives, goals and targets.

The cross-cutting nature of the SDGs, and the high level of commitment among countries to implement them, gives impetus to the recognition of the links between forests and urban water security, including in the monitoring and reporting of progress towards a more sustainable world. Especially relevant SDGs are SDG 6 (clean water and sanitation), SDG 11 (sustainable cities and communities), SDG 13 (climate action), and SDG 15 (life on land). The links between forests and water are explicitly mentioned in SDG targets 6.6 and 15.1 and implied in SDG target 11.a, which calls for the support of "positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning".

Although the links between forests and water are recognized, however, they are not adequately accounted for in the indicators used for monitoring. Indicator 6.6.1, for example, includes only swamp forests, mangroves, and forests temporarily or permanently inundated by water (UN-Water, 2017). These forests undoubtedly have a role in disaster risk reduction, but other forests with potentially significant value for water-related ecosystem services are unrecognized, such as forests managed for water supply and other forest types known to have strong roles in hydrological cycles (e.g. riparian and cloud forests). Indicator 15.1.2 focuses only on protection for biodiversity and not other functions, such as water-related ecosystem services. None of the SDG targets considers the spatial distribution or health of forests.

Thus, although the SDGs provide important backing for nature-based solutions as means for ensuring water security, they could be greatly strengthened by the inclusion of a wider set of goals relating to forests and water supply. For example, it would be useful to have an indicator for

2
Global agreements with goals or targets related to urban water security

Nature-based solutions
Protect, sustainably manage and restore natural ecosystems in urban areas
Address societal and climate challenges in designing interventions to ensure human well-being and biodiversity benefits

Sustainable Development Goals (to 2030)
SDG 6: Clean water and sanitation
SDG 11: Sustainable cities and communities
SDG 13: Climate action
SDG 15: Life on land
Other targets that directly or indirectly link to urban and forested landscapes

Urban water security

New Urban Agenda (to 2025)
Outlines the pathway towards sustainable cities and human settlements
Resilient cities – urban governance and planning
Urban water management

Sendai Framework (2015–2030)
Urban infrastructure and urban planning is designed to reduce the impact of natural disasters
Developing strategies that reduce loss to economic, physical and environmental assets of a country and communities

SDG 6.5 (on integrated water resource management) addressing the health of forested watersheds that are sources of urban water. Existing data, such as FAO's global forest resources assessments (e.g. FAO, 2015) and the World Resources Institute's Global Forest Watch–Aqueduct Tool, could be incorporated in the measurement of existing indicators to recognize the interconnection of forests and water, improve the analysis of progress towards the SDGs, and better inform management decisions at the national and local levels.

The goals and targets of the 2030 Agenda for Sustainable Development, along with other global agreements, require countries to look for innovative, smart, collaborative and sustainable solutions to urban issues. For example, the recently convened Water Desalination Symposium Africa 2017 featured discussions between government, industry, academics and traders on ways of tackling the water shortage in Cape Town, South Africa, using a multistakeholder approach. Similarly, a recent water crisis in Bangalore, India, raised the alarm on the need to make urban water security

a priority. In both cases, it is clear that smart, strategic approaches are required to manage water demand, including nature-based solutions.

CONCLUSION

Water is a multisectoral issue. Ensuring water security in urban, peri-urban and rural contexts, therefore, requires a common framework and understanding and a coherent policy approach among the water, forest, land, urban, climate-change, energy and other sectors. The acknowledgment of urbanization as an issue in global sustainable development frameworks is encouraging for the future of urban centres and their associated landscapes. The recognition of integrated grey–green approaches for addressing water security and the conceptual framework proposed by UN-Water (Figure 1) should be of interest, therefore, to many stakeholders – such as urban and regional planners, water managers and policymakers, international companies and organizations with large water "footprints", not-for-profit institutions steering change, and communities.

Urban communities are just as vulnerable as rural communities to natural hazards. It is important, therefore, that they build their capacity, evaluate their vulnerability, and participate in designing and implementing resiliency approaches, including nature-based solutions, in the face of the risks posed by environmental and climate variability. Designing and planning for water security requires collaboration among stakeholders at the local to global scales. Increasing green cover is also part of the equation: smart, sustainable, forest landscape protection strategies and investment plans will emphasize the security and protection of urban and peri-urban forests as green infrastructure for water. In many cases, such strategies and plans will require a better understanding of the interconnections between urban ecosystem services and sustainable urban development planning and interventions.

Future innovations to improve urban water security will likely involve the integrated design of urban spaces to include, for example, constructed wetlands, green roofs and retention ponds. Overall, the

The forested landscape surrounding densely urban Hong Kong, China, is a source of water and other ecological benefits for city dwellers

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increasing acknowledgment, in global sustainable development frameworks, of the importance of urbanization is an opportunity to address water security in cities through innovative, long-term nature-based solutions. ◆

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The role of urban and peri-urban forests in reducing risks and managing disasters

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There is a pressing need to take forests fully into account in city risk reduction and disaster management plans.

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The unplanned urbanization process that many cities have undergone in recent decades to accommodate population growth has contributed to the daily exposure of urban communities to environmental risks that threaten their health and well-being. In addition to the poor living conditions in many cities, residents face the risks posed by extreme natural hazards such as storms, floods, fire and drought, which climate change is exacerbating. Most regions of the world are exposed to natural hazards that cause significant economic damage and the loss of human lives. The risks posed by natural hazards may be amplified in urban areas by human interventions, potentially leading to situations of accumulated risk and permanent vulnerability (Figure 1). All sectors of urban populations are exposed to these risks, but the poor are especially vulnerable.

There is a need, therefore, for policies and measures that reduce or eliminate long-term risks to people and property due to hazards and which strengthen the resilience of cities and their structural elements in the face of increasingly extreme stressors. The creation of UN-Habitat in 2002 led to the development of strategies for achieving and increasing urban resilience to natural or human crises. The United Nations Plan of Action on Disaster Risk Reduction for Resilience, developed in 2013, identifies measures to strengthen support for countries and communities in managing disaster risk, including the

Above: Urban trees can dramatically reduce the radiant surface temperature of paved areas and moderate the thermal stress experienced by pedestrians (note that blue and purple in the thermal image indicate relatively cool areas)
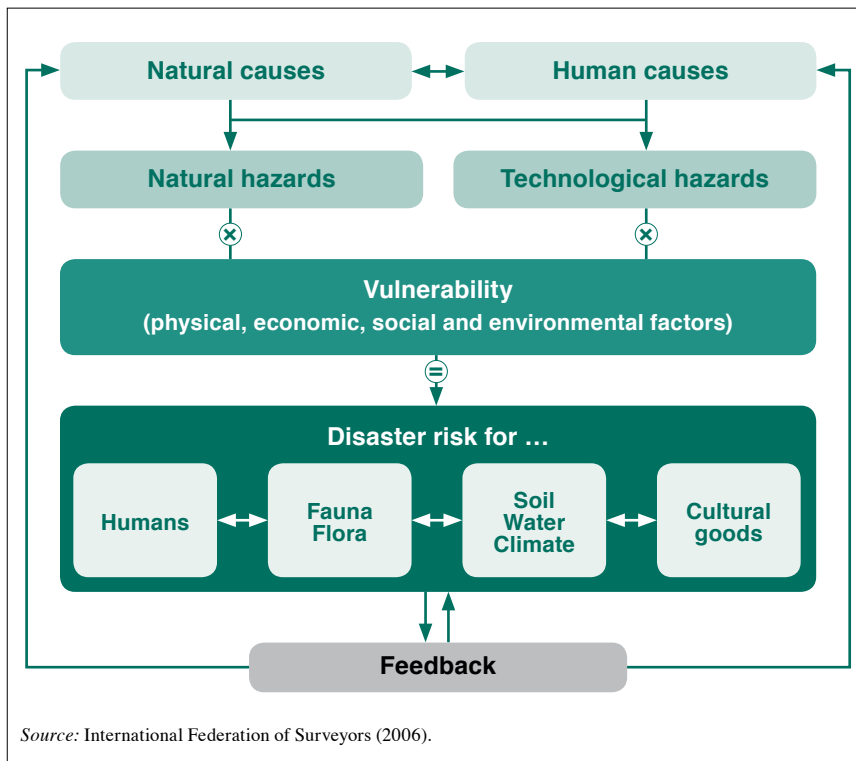
1
Disaster risk as the product of hazard and vulnerability

implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030. Among the priority lines of action in the Sendai Framework are enhancing disaster preparedness for effective responses and "building back better" in recovery, rehabilitation and reconstruction. This means not only promoting resilience in new and existing infrastructure but also identifying areas that are safe for human settlements and preserving ecosystem functions (UNISDR, 2009).

One of the key measures for increasing resilience in urban settings is the reinforcement of urban ecosystems to ensure they have the capacity to reduce risks and manage disasters. Urban green infrastructure, of which urban and peri-urban forests are the backbone, can boost resilience to disasters and help minimize the intensity of associated impacts. The establishment of urban green infrastructure adheres to the basic principles of proactive resilience – efficiency, diversity, interdependence, strength, flexibility, autonomy, planning and adaptability (Table 1) (Bell, 2002).

This article presents examples of the role of urban and peri-urban forests in reducing the impact of hazards, both natural and those caused by human interventions. It also looks at how hazards presented by urban and peri-urban forests can be managed, thereby increasing urban resilience in light of the challenges to be faced in coming decades.

URBAN HAZARDS ASSOCIATED WITH CLIMATE CHANGE
Climate change is often considered synonymous with global warming, but we are living in an era of climatic uncertainty – with localized events that have usually been considered extreme becoming increasingly frequent (Meir and Pearlmutter, 2010). Communities around the world are experiencing upsurges in catastrophic storms, flooding, heatwaves and droughts, and these disruptive events will likely become more pronounced in the future.

TABLE 1. Urban hazards and the role of urban and peri-urban forests in risk reduction

Hazard	Role of urban and peri-urban forests
Natural	
Strong winds (e.g. cyclones, hurricanes)	Act as barriers; reduce wind speed; work as protection screens
Flooding and drought	Reduce stormwater volumes and flood risk; increase precipitation interception; increase water infiltration and groundwater recharge
Landslides	Increase stability of steep slopes by reducing surface run-off and erosion
Soil loss	Prevent soil erosion; reduce impact of raindrops on soil surfaces; improve soil-water retention
Extreme heat and cold events, urban "heat island" effect	Cool by shading, evapotranspiration, etc.; protect from hot and cold winds
Wildfires	Reduce fire intensity, flammability and spread when properly designed and managed
Biodiversity loss	Conserve species and habitats; limit spread of invasive species
Pests and diseases	Limit spread and impacts
Anthropogenic	
Air pollution	Sequester carbon; reduce ozone formation; capture particulate and gaseous pollutants; reduce emission of allergens
Pests and diseases	Provide buffer against invasive species
Reduced physical and mental health	Provide pleasant spaces that increase well-being, social cohesion and interaction, and leisure activities, etc.

Urban heat island effect

The urban "heat island" effect is a commonly observed example of local climate change, which is intensified by a city's size, density and material composition. One of the main catalysts of urban heat islands is the replacement of vegetated terrain with "dry" urban landscapes, thereby reducing the cooling achieved through evapotranspiration (Pearlmutter, Krüger and Berliner, 2009) and – most importantly for human thermal stress – by the shading of pedestrians. Heat stress is intensified by unshaded urban surfaces, which absorb solar energy and re-radiate heat and reflect solar energy directly onto the bodies of pedestrians.

The most effective general strategy for mitigating the urban heat island effect is the cultivation of trees in and around cities. The magnitude of the "park cool island" effect – that is, the reduction of air temperature in urban green spaces relative to their built-up surroundings – is typically in the range of 3–5 °C but can reach nearly 10 °C (Hiemstra *et al*., 2017). Tree canopies are especially beneficial for shading when they are broad and dense and their leaves are transpiring freely (Shashua-Bar and Hoffman, 2004); a lack of water in urban areas is often a constraint, however.

In the United Kingdom of Great Britain and Northern Ireland, London is likely to face increasingly frequent heat events in coming years, with potentially significant effects on public health and the associated risk of hundreds of deaths in heatwaves. The city established a climate-change adaptation strategy in 2010 that identifies the risks to public health posed by climate change and sets out the actions needed to manage them. An action now underway is to leverage the benefits of urban forests by increasing the number of green roofs and street trees and the quantity and quality of green spaces. The objective is to increase tree cover in Greater London by 10 percent and achieve a total green cover of 50 percent by 2050 (Mayor of London, 2017).

Floods and storms

Overwhelming stormwater volumes and flooding in urbanizing cities associated with deteriorating drinking-water quality have become major health, environmental and financial concerns globally. Increased urbanization alters the hydrology of an area, reducing the infiltration capacity of soils and increasing both surface-water run-off and peak discharges (Vilhar, 2017).

The increased incidence of flooding in cities demonstrates that the existing grey infrastructure for conveying stormwater to wastewater treatment facilities or into surface waters was not designed for current rainfall intensities. In most urbanized watersheds, too, the area of impervious surfaces is increasing. Urban and peri-urban forests have great potential to reduce stormwater run-off by increasing evapotranspiration and water infiltration into the soil (Gregory *et al*., 2006) and by the interception of precipitation by tree crowns (Kermavnar and Vilhar, 2017). Tree roots and leaf litter stabilize soil and reduce erosion (Seitz and Escobedo, 2008).

Floods are the most frequent disasters in many areas of Asia and the Pacific. Ten of the countries most exposed to flood risks in the region (Afghanistan,

Flooding after heavy rain in Ljubljana, Slovenia. Tree roots are helping protect the soil from erosion

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Bangladesh, Cambodia, China, India, Indonesia, Myanmar, Pakistan, Thailand and Viet Nam) are riparian, and transboundary floods occur frequently, causing large-scale impacts (Luo *et al*., 2015). In Bangladesh, practices under implementation to reduce the impacts of flooding include the development of advanced simulated weather forecasting to enable the evacuation of large numbers of people several days in advance of flooding events, the planting of flood-resistant trees, and stronger regional cooperation to coordinate response measures (Basak, Basak and Rahman, 2015).

Hurricanes and windstorms
Hurricanes and other windstorms are predicted to occur at an increased frequency and severity due to global warming (e.g. in the Atlantic: Bender *et al*., 2010). Like other kinds of infrastructure, trees can be damaged by high winds and storms, but they can also contribute to hurricane-resistant landscapes. Duryea, Kampf and Littell (2007) studied ten recent hurricanes and their impacts on more than 150 urban tree species to assess the factors that make trees wind-resistant. Trees best able to survive storms are compact and have a major taproot and well-developed secondary roots, a well-tapered trunk, a low centre of gravity, and open, flexible and short branches. Trees in groups of five or more are also more likely than individual trees to survive high winds. Only 3 percent of more than 14 000 historic trees in New Orleans, United States of America, were lost during Hurricane Katrina in 2005; most of the survivors were oaks, with many of the characteristics listed above. The lessons learned from the study by Duryea, Kampf and Littell (2007) and others are being put to use in areas devastated by the successive hurricanes that hit the Caribbean and the Gulf of Mexico in 2017.

Risk mitigation and disaster management plans developed by the local government of Kathmandu, Nepal, after the earthquake in 2015 include the development of urban forests and open spaces as measures to reduce earthquake impacts and provide community gathering points and temporary shelter (Saxena, 2016).

Forest fires in the Mediterranean
Forest fires, especially at the wildland–urban interface, pose an increasing threat to cities in the face of climate change. People cause more than 90 percent of forest fires in the Mediterranean region, where, on average, more than 800 000 hectares burn each year. Droughts have lengthened in recent decades, leading to an increase in the number, extent and recurrence of fires and the scale of human and economic losses (Gonçalves and Sousa, 2017). Martínez, Vega-García and Chuvieco (2009) found that the main factors associated with high forest fire risk in Spain were landscape fragmentation, agricultural abandonment and development processes. On the other hand, policies to encourage the afforestation of abandoned agricultural land had little effect on fire occurrence.

Portugal has experienced high recent losses due to fire: there were more than 500 fires in the summer of 2017, for example, and more than 100 fatalities. Since 2005, the country has been implementing the Portuguese National Plan for Prevention and Protection Against Fires (Oliveira, 2005), which is intended as the main approach for addressing one of the country's chief threats. Among the measures indicated in the plan is the progressive replacement of eucalypt forests: the country has more than 900 000 hectares of plantations of these trees, the leaves and bark of which are highly flammable. The abandonment of agricultural lands and the expansion of urban centres have brought eucalypt forests closer to the peri-urban fringe, increasing the risk of fire at the urban–rural interface.

Threats to biodiversity
Tree pests and diseases have spread globally and are causing considerable damage. For example, Dutch elm disease (*Ophiostoma ulmi* and *O. novo-ulmi*) was transported from Asia to the Americas

Urban trees can pose hazards: this tree has fallen on a children's playground, although fortunately no one was hurt

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and Europe during the twentieth century by means of infected logs, resulting in a pandemic in the Northern Hemisphere. In the United Kingdom of Great Britain and Northern Ireland alone, Dutch elm disease caused the deaths of about 28 million mature elms in 1970–1990, many of them in urban and peri-urban areas, and the subsequent death of about 20 million young elms (Brasier, 2008).

Many cities are adopting policies to ensure sufficient tree species diversity in cities to reduce the impacts of pests, diseases and other factors that might otherwise cause the decimation of urban trees. In Canada, one of the objectives of the City of Kelowna Sustainable Urban Forest Strategy is to increase species diversity across the city to avoid the catastrophic loss of trees through pests, diseases and climate change. The strategy calls for the diversification of the species used as street trees so that ten or more species are represented at 10 percent or less of the total street-tree population. Ornamental species compatible with the city's climatic conditions are being introduced (Blackwell and Associates, 2011).

Urban areas can contain relatively high levels of biodiversity (Alvey, 2006). Cities are adopting management practices to conserve and promote such diversity, including as a means to increase resilience in the face of environmental change.

HUMAN HEALTH RISKS AND BENEFITS

Modern urban living can have negative impacts on public health and the quality of life of citizens. According to the World Health Organization, an estimated 12.6 million deaths each year are attributable to unhealthy urban environments (Prüss-Ustün *et al.*, 2016), with air, water and soil pollution, chemical exposure and climate change linked to more than 100 types of ailment; cardiovascular and respiratory diseases are among the top ten causes of environment-related deaths. Urban and peri-urban forests pose risks to human health but can also have a wide range of health benefits.

Risks

Vegetal substances can be toxic to humans, and trees and other plants can emit volatile organic compounds and particulate material that can adversely affect human health (Cariñanos *et al.*, 2017). Some of the most frequently used species in urban and peri-urban forests worldwide have been identified as the main causative agents of human pollen allergies (Cariñanos and Casares-Porcel, 2011).

People are also at risk of being hurt or killed by falling trees. For example, a 200-year-old oak fell on a crowd of people on the island of Madeira, Portugal, in August 2017, killing 13 and injuring nearly 50 (Minder and Stevens, 2017).

The risks posed by urban and peri-urban forests can be managed by implementing an urban tree hazards plan (Calaza Martínez and Iglesias Díaz, 2016). For example, the Master Plan for the Trees of the Jardines del Buen Retiro in Madrid, Spain, includes a tree risk management plan that, among other things, establishes a risk management protocol for the park.

Benefits

Numerous studies have highlighted the role of green infrastructure in general, and urban and peri-urban forests in particular, in promoting human health. Many initiatives have been launched – some supported by national health services and the World Health Organization – aimed at encouraging the use of urban and peri-urban forests for physical activities and other forms of outdoor recreation to improve human health (World Health Organization, 2010).

Green spaces, including urban and peri-urban forests, can provide a form of natural therapy that helps people recover from traumatic events, such as disasters. Activities with potentially therapeutic benefits include planting gardens for peace and reconciliation and caring for surviving trees or planting new trees in areas affected by war, terrorist attacks or natural disasters (Tidball *et al.*, 2010).

CONCLUSION

In an era in which extreme natural events are becoming more frequent, there is a pressing need to develop and implement risk reduction and disaster management plans in cities to reduce vulnerability and exposure to risks and improve adaptive capacity. Urban and peri-urban forests are key components of such plans, both to minimize the impacts of disasters and the damage they cause and to restore, rebuild and rehabilitate urban ecosystems in the aftermath. The multifunctionality of urban and peri-urban forests, their effectiveness in mitigating flooding, extreme heat events and strong winds, and the hazards they themselves pose, make it imperative that they are taken into consideration in action plans for disaster risk reduction.

The increasing risk to human health and welfare posed by human activities such as air, water and soil pollution also indicates the need to install and manage urban green infrastructure, especially urban and peri-urban forests, as a measure to protect people, built infrastructure and habitats. Finally, given the transnational character of some of the impacts of disasters, transboundary and regional cooperation is crucial for developing policies and strategies for risk preparedness and disaster impact mitigation and coordinating response measures. ◆

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"Edible" urban forests as part of inclusive, sustainable cities

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Urban and peri-urban forests can produce a range of foods to supplement local diets and provide a focus for community activity.

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Feeding an increasingly urban population and ensuring the economic and social well-being of urban dwellers will be the primary challenge for cities in coming decades. The impacts of climate change are expected to slow down urban economic growth, exacerbate environmental degradation, increase poverty and erode urban food security. Many cities are on a quest for more sustainable urbanization pathways that will enable effective responses to the increasing socio-economic and environmental challenges they face.

In the search to "make cities and human settlements inclusive, safe, resilient and sustainable" (Sustainable Development Goal 11 in the United Nations Sustainable Development Agenda 2030), interest is increasing in growing local food. Edible green infrastructure, mainly in the form of urban food forests and trees (referred to here generally as urban food forests and also sometimes as tree-based edible landscaping), can help address a range of problems caused by rapid and unplanned urbanization, such as food scarcity, poverty, the deterioration of human health and well-being, air pollution, and biodiversity loss (FAO, 2016).

The use of edible plants in urban and peri-urban forestry varies among cities and is influenced by historical, cultural and socio-economic factors. Overall, it has tended to be neglected in modern cities.

Above: The pomegranate (Punica granatum) – "granada" in Spanish – is the heraldic symbol of the city of Granada, Spain, where it appears on streets throughout the town. It produces a highly nutritious fruit

This article explores the potential of urban and peri-urban forests as sources of food and the role that urban food forests can play in fostering sustainable cities.

WHAT ARE URBAN FOOD FORESTS?

Clark and Nicholas (2013) defined urban food forests and trees as "the intentional and strategic use of woody perennial food-producing species in edible urban landscapes to improve the sustainability and resilience of urban communities". As an "edible landscaping" practice, urban food forestry involves a combination of agriculture, forestry and agroforestry in urban areas to supply cities with food. It may involve various species of fruit and nut trees, berry bushes, vegetables, herbs, edible flowers and other ornamental plants.

The integration of urban food forests into the infrastructure of a city can provide urban dwellers with many benefits. There is evidence that urban food forests can motivate stewardship practices and give inhabitants opportunities to interact with nature and each other (McLain *et al.*, 2012); enable the development of more resilient food systems and promote social and environmental sustainability (Yates, 2014); improve social cohesion and well-being and strengthen local communities (Lwasa *et al.*, 2015); enhance biodiversity (Dennis and James, 2016); and provide economic benefits for both municipalities and citizens (Lafontaine-Messier, Gélinas and Olivier, 2016).

Tree-based edible landscaping in urban areas has been practised since ancient times. Ancient Egyptian and Persian gardens combined fruit trees with flowers, ponds, pot plants, vine-clad pergolas and places to sit in winter sun or summer shade. Classical ornamental gardens had water channels, pools, fountains and cascades cooling the air, flowers producing scents, and fruit trees providing food and shade. Medieval monastic gardens produced fresh fruit and vegetables, as well as flowers and medicinal herbs. Renaissance estates had plots and terracotta pots for growing flowers and producing fruit, vegetables and

herbs that were sold locally to raise funds for maintenance.

In the Industrial Revolution in the nineteenth century, however, the edible elements of urban landscapes tended to be replaced by ornamental vegetation. Today, most cityscapes are largely devoid of edible components and instead feature traditional shade trees, lawns and other soil-cover plantings.

Urban food forest typologies are influenced by city histories. In Central America, for example, native gardens of multistrata agroforestry systems coexist with colonial cityscapes featuring large trees and exotic plants (González-García and Gómez-Sal, 2008). Socio-economic circumstances may also play a role: in Berlin, Germany, the estimated fruit-tree density is still significantly higher in the eastern part of the city than in the west (8.6 trees/ha versus 1.6 trees/ha) (Larondelle and Strohbach, 2016).

EFFORTS TO APPLY URBAN FOOD FORESTRY WORLDWIDE

The applicability of urban food forestry and its efficacy in addressing social and environmental challenges depend on a range of social, environmental and other local factors. Only a few examples exist of modern efforts to encourage urban food forestry, and these are mostly limited to relatively small urban settings.

In Todmorden, West Yorkshire, in the United Kingdom of Great Britain and Northern Ireland, volunteers grow fruit, herbs and vegetables for everyone to share; they do so without paid staff, buildings or funding from statutory organizations. The volunteers also run events to help strengthen the local community; income is generated through donations and fees for talks and tours (Incredible Edible Todmorden, undated). In Copenhagen, Denmark, in contrast, citizens do not collect fruit from urban forests because it is widely perceived that doing so would break social norms (Yates, 2014).

United States of America

Among examples of urban food forestry in the United States of America, Seattle's

urban food forest (McLain *et al.*, 2012) is probably the best-studied. Seattle Public Utilities owns the Beacon Food Forest, but the forest's fruit trees were planted by community volunteers, many of whom continue to work in the forest and maintain the orchards. Ongoing participation gives community members a sense of stewardship and pride in the space.

Lemon Grove – a municipality of 26 000 inhabitants in California – is preparing to grow public orchards in city parks as part of efforts to preserve the city's history and small-town charm. Issues to be addressed in selecting sites for fruit trees include proximity to roadways and sidewalks; accessibility for mobility-impaired individuals; access for maintenance; and input from community members and garden experts (Federman, 2017).

The San Francisco Urban Orchard Project provides ongoing resources for the planting and maintenance of publicly accessible fruit trees. The programme partners with local not-for-profit organizations to plant fruit- and nut-tree orchards and to assist community-based groups in their roles as local stewards of green spaces (SF Environment, undated).

Barnum is one of eight city parks in Denver, Colorado, with urban orchards. It is in what used to be one of the city's least desirable neighbourhoods, but things took a turn for the better when Denver Urban Gardens – a not-for-profit organization that supports community gardens in the city – purchased a vacant lot. This is now a community orchard that grows red currants, raspberries, grapes and winter squash among fruit trees (Extreme Community Makeover, 2016).

Developing countries

Rapid urbanization in many developing countries is leading to increased urban poverty and pressure on green spaces. Edible landscaping is often in the form of small-scale subsistence agriculture, and such gardens represent significant proportions of urban green infrastructure. Even in inner-city areas, residents cultivate

roadsides and riverbanks, along railroads, on vacant private lands and in parks, based on minimal user rights such as informal rents, leases and inheritances. In Taipei, Taiwan Province of China, however, the law forbids the planting of fruit trees and vegetables in parks and public spaces (Chang *et al*., 2016).

Disputes arise about who can plant, harvest or otherwise use urban forests when laws or ordinances do not specify rights for the use of common areas (Rana, 2008). Fear of eviction is a strong disincentive for people to introduce food trees and shrubs. In illegal settlements in Kathmandu and Lalitpur, Nepal, people grow seasonal food crops but do not care for "doubt tenure" trees. In South Africa, homestead fruit and nut trees are important sources of food, especially in informal settlements, where the poorest people live. Residents of new low-cost housing make especially extensive use of urban tree products harvested in public urban spaces because they have fewer homestead trees than residents in informal areas and townships (Kaoma and Shackleton, 2014).

Urban food forestry is not widely implemented in Asia and the Pacific, but innovative urban forestry practices are evolving in the region (Kuchelmeister, 1998). In China, residents can harvest fruit in many parks; in Queensland, Australia, residents and schools maintain edible public parks, producing fruit, herbs, flowers and vegetables (Kuchelmeister, 1998).

Africa
Agroforestry gardens are probably the most significant type of urban green space in West African countries (Fuwape and Onyekwelu, 2011). In arid and semiarid areas, it is common practice to establish windbreaks to protect urban areas and enhance soil productivity (Kuchelmeister, 1998). Urban forest practices that contribute to food security include collecting wild edible plants, planting fruit-bearing street trees, and establishing medicinal public parks. Fruit trees are planted in many residential compounds, especially those on urban fringes and in new urban settlements.

Despite the marked differences in the sociospatial and environmental settings of Botswana, Cameroon, Côte d'Ivoire, South Africa and the United Republic of Tanzania, wild food trees are integral to most urban and peri-urban households in small and mid-sized cities in those countries. This applies not only to poor families lacking access to productive soils

An educational initiative in Chinandega, Nicaragua, is designed to help protect urban fruit trees, such as this large mango tree (Mangifera indica). *Fruit trees are common in indigenous neighbourhoods in Central America*

In public areas of impoverished districts in Cabo Verde, people plant, care for and protect fruit trees in preference to ornamental trees

but also to those with a higher standard of living (Schlesinger, Drescher and Shackleton, 2015). A study in Senegal nearly three decades ago (Brun, Reynaud and Chevassus-Agnes, 1989) found that urban food forests did not make a significant contribution to food consumption and nutrition but were instrumental in improving the income and social status of women and increasing their awareness of evolving food habits in urban areas.

In Cabo Verde, the extent of urban food forestry varies according to the actors involved. Trees planted and managed by municipalities are mostly ornamental, while those planted and cared for by residents are usually fruit trees (e.g. *Carica papaya*, *Mangifera indica* and *Terminalia catappa*).

ISSUES FACING URBAN FOOD FORESTS AND TREES

Research and literature on urban food forestry are scarce, despite the long history of growing forest foods in urban areas. Most existing studies report specific cases of local food production from urban food forests, and there have been few attempts to explore the adaptation and application of local practices in other contexts or to scale them up. The lack of research probably reflects the general bias of studies on urban ecosystem services in western Europe and North America, where cities today depend mostly on outside sources of food (Larondelle and Strohbach, 2016). Although edible urban landscapes were widely used for centuries in the European Mediterranean, the contributions of such landscapes to the livelihoods of modern urban communities are far from fully explored. Of existing experiments, none has explicitly addressed the food-provisioning aspects of urban trees (Valette, Perrin and Soulard, 2012). A recent review of urban food forestry collected information on 37 initiatives worldwide (Clark and Nicholas, 2013): it evaluated 30 urban forest master plans in various cities and found that human food security was a primary objective in only four of them.

Russo *et al.* (2017) analysed more than 80 peer-reviewed publications focusing on urban ecosystem services and disservices. They identified eight typologies of edible green infrastructure, including edible forest gardens and edible urban forests, which were addressed in 38 percent of the publications. Some publications showed urban food forestry to be a multifunctional urban landscape practice combining an extended range of ecosystem services efficiently in cities and integrating the provision of food with environmental, sanitary, social, cultural and economic co-benefits. Evidence of the trade-offs between the supporting, provisioning, regulating and cultural services of urban food forests is lacking, however.

Also lacking is a conceptual framework that would enable the synthesis and analysis of existing knowledge on urban food forestry. Such a framework is needed to integrate the relevant aspects of urban food forestry into urban planning, such as the area required, species, knowledge,

management, governance, and financial and human resources. As to the area needed, Richardson and Moskal (2016) calculated that a 58-km buffer around Seattle would be required to meet 100 percent of the city's food needs.

In most countries, the actual and potential contribution of urban food forestry to sustainable and resilient urban development models is unknown. Although research into, and the practice of, urban agriculture is growing, urban food forestry has been implemented systematically in only a few countries, and its practices are little explored.

Risks of urban food forestry
Certain risks are associated with the implementation of urban food forestry. Poe *et al.* (2013), for example, pointed out that the toxicological profiles of urban soils should be investigated before

they are used for urban food forestry to avoid health risks posed by the uptake by plants of pollutants such as heavy metals. Species selection and cultural techniques can also help prevent the accumulation of pollutants in the edible parts of plants: the translocation of pollutants absorbed by roots to edible parts, as well as the amount of airborne pollutants penetrating the fruit epicarp, has been shown to differ widely by species (von Hoffen and Säumel, 2014).

Vegetables from urban and peri-urban farming may contain unacceptable quantities of trace elements (Nabulo *et al.*, 2012; Samsøe-Petersen *et al.*, 2002; Säumel *et al.*, 2012); on the other hand, some studies have found it possible to produce healthy food from fruit trees grown along streets in large cities (von Hoffen and Säumel, 2014). The apparent discrepancy between studies on the health risks of urban food

forestry may be due to soil characteristics and the plant species used.

Another health risk that can occur from the consumption of raw fruit produced in urban food forests is an allergic reaction known as oral allergy syndrome. This can occur in sensitized individuals due to cross-reactions between aeroallergens and food allergens – such as between pollen produced by species in the Cupressaceae family and the fruit of *Prunus persica*, giving rise to "cypress–peach syndrome" (Popescu, 2015).

Unharvested fruit can be hazardous and unsightly when they drop from trees, and they can also attract vermin and pests. Highly perishable crops require quick processing, such as canning, freezing or drying, or sufficient people to quickly consume surplus supplies (Brown, 2016).

Most widely used fruit tree species belong to only a few families or genera

Orange trees planted as part of a new urban development in Porto, Portugal. Urban food forestry involves a combination of urban agriculture, forestry and agroforestry techniques and strategies

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(e.g. Rosaceae in temperate environments). But the use of a small number of species may challenge the 30–20–10 biodiversity rule proposed by Santamour (1990) to maximize protection against pest out-breaks.[1] Many commonly grown fruit trees are indeed very sensitive to pests and pathogens, but this can be managed through wise, inventory-based species selection. New releases and the restoration of ancient resistant cultivars of widely used species, as well as the use of minor, neglected species with edible uses, might help improve the tolerance of urban food forests to pests and diseases.

Urban food forestry strategies
The development of an urban food forestry strategy requires a broad range of expertise to ensure a comprehensive approach. It involves the integration of knowledge from social and environmental sciences and disciplines such as urban forestry and arboriculture, urban agriculture, urban ecology, landscape and urban architecture, economics, policy and governance. Effective, efficient collaboration among experts, policymakers, local governments, the private sector and citizens is essential to ensure effective urban food forestry.

CONCLUSION
The examples in this article show that urban food forestry can be applied in diverse contexts and to meet various objectives. Urban food forests and trees are located mostly on formal and informal public land, and implementing an urban food forest approach depends on ownership, local rules, norms, policies, and an effective governance model. Comparative studies and lessons learned are needed to understand the most effective approaches in different contexts.

The consideration of urban food forests and trees and their integration into regional, national and local urban policies

can provide a pathway towards sustainable urban development. Developed countries have started to rediscover urban tree-based edible landscaping but, in most cases, food production is still not the primary objective of urban and peri-urban forestry. In developing countries, knowledge gaps need to be identified to stimulate research on strategies to consolidate traditional models of tree-based edible landscaping and to foster new approaches.

The potential of urban food forests is still far from adequately exploited, and there is a need to develop modelling tools, advanced design principles, and efficient management and governance strategies. Initiatives are needed to gather knowledge on existing efforts and to fully assess issues associated with food safety, such as the risks posed by soil, water and air pollution.

Further research is needed to identify the species, compositions and configurations that will maximize the benefits of urban food forests for local communities and minimize the risks to human health. Cultivars and genotypes are needed that are adapted to harsh urban environments, especially in the context of climate change.

Collaboration – subnationally, nationally and internationally – among scientists, citizens, policymakers and city managers is crucial for establishing a robust conceptual framework for urban food forests. It is also desirable to compile traditional tree-based edible landscaping practices to guide the design of projects in which food production is the central objective. Urban food forests are potentially a valuable multifunctional component of the broader green infrastructure of the cities of the future and can help achieve the Sustainable Development Goals. ◆

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[1] Under this rule, no more than 30 percent of trees in the same family, 20 percent of trees in the same genus, and 10 percent of the same species should be planted. See also the article on page 11.

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Protecting heritage trees in urban and peri-urban environments

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Some individual trees perform especially important cultural functions, and strong community involvement is crucial for their conservation and management in urban settings.

People have held trees in high esteem and awe since antiquity. Primitive peoples recognized that trees were notably bigger, stronger, more majestic and longer-lived than most other organisms. Intimate interactions with nature have increased human awareness of trees progressively; over time, particular trees have instilled in people a sense of fraternity, fear, generosity, providence, ubiquity, immortality, eternity and divinity.

As benevolent providers and protectors of humans, certain trees have acquired special status. Beginning with admiration and respect, attitudes evolved to adoration and reverence and then to veneration and worship (Taylor, 1979; Dafni, 2006). Traversing geographical, temporal and cultural divides, tree worship is common in many ancient polytheistic belief systems. Many mythologies, legends and folklores are associated with beloved or feared trees, indicating a continued and widespread human deference to them. Many indigenous cultures have bestowed a sacred standing on individual trees and groves, seeing them as deities or the abodes of certain spirits.

The pragmatic contributions of trees to farming communities in soil and water conservation and microclimatic amelioration are well recognized. In East Asia, such contributions have been practised systematically as feng shui or geomancy (Han, 2001; Coggins *et al.*, 2012). Such

Above: Traditional villages in southern China are protected by upslope feng shui (geomancy) groves. This photo shows the well-preserved tradition in the village of Lai Chi Wo, Hong Kong

indigenous knowledge reflects the traditional wisdom of learning from and mimicking nature to create a harmonious and healthy milieu for humans and to tackle the capriciousness and harshness of nature. Translated into adaptive practices, feng shui has provided a collective community-based and holistic resource-management system (Gadgil, Berkes and Folke, 1993) that has fostered the persistence of agrarian cultures for millennia.

In modern societies, systematic forest management by governments or other agents sometimes recognizes and protects sacred trees. Associated with human settlements, such trees may be subsumed in urban and peri-urban forestry, but local customs may also continue to defend them in unwritten codes. Superstitious traditions include taboos, the infringement of which could incur the wrath of deities and bring dire consequences (Laird, 2004). For centuries, the fear of supernatural retribution has protected many precious trees. The attendant cultural internalization and social regulation, expressed as village sanctions, including punitive measures, have strengthened local enforcement (Berkes, Colding and Folke, 2000).

In managing urban forests, outstanding trees – whether or not associated with traditional sanctity – are often given special care. Among dozens of epithets used in the literature, such trees have been labelled as champion, monumental and heritage trees (Jim, 2017a). There are clear indications of the continued reverence attached to trees, but the dilution of traditional taboos in cities calls for substitute protection based on statutory and administrative measures.

The impacts of urbanization on heritage trees

Increasing urbanization by intensification and sprawl has the potential to threaten urban forests (FAO, 2016) and to decimate the tiny but vital cohort of iconic heritage trees. For example, subterranean tree habitat is widely neglected. Heritage trees in urban and peri-urban environments often suffer from the ill treatment

TABLE 1. Designation criteria for the evaluation of heritage trees

	Criterion	Rating score		
		1	2	3
1	Tree height (m)	< 15	15–30	> 30
2	Crown spread (m)	< 15	15–30	> 30
3	Diameter at breast height (m)	< 1	1–2	> 2
4	Tree age (yrs)	< 100	100–300	> 300
5	Tree performance	Low	Medium	High
6	Ecological function	Low	Medium	High
7	Scenic/landscape dominance	Low	Medium	High
8	Personality/event association	Low	Medium	High
9	Natural/cultural bequest	Low	Medium	High
10	Spiritual/mythical connotation	Low	Medium	High

of soils, which could be inadvertent due to misconceptions (Jim, 2005). Original natural soils are commonly compacted, added to, removed or polluted, and the most valuable topsoil horizons – with high organic matter content and nutrient stock – are often degraded or lost. Surface sealing and associated soil compaction can harm and restrict root growth. Iconic trees attract many visitors, who may damage soil structure and cause the compaction or loss of topsoil; such trees sometimes have literally been loved to decline and demise. In dense cities, the routine response to heavy foot traffic is to install impermeable concrete, asphalt or other paving materials, which causes additional damage. Awareness needs to be raised that soil problems have contributed significantly to poor tree health and long-term deterioration.

Urban forest managers, as the modern custodians of this natural-cum-cultural heritage, are charged with ensuring the long-term welfare of heritage trees in urban and peri-urban environments. By sharing research and practices, tailor-made measures can be developed to ensure the continued robustness and survival of heritage trees. This article, which draws on literature and extensive field studies, focuses on such trees in cities and their fringes with a view to improving their conservation worldwide. It evaluates designation yardsticks, surveys
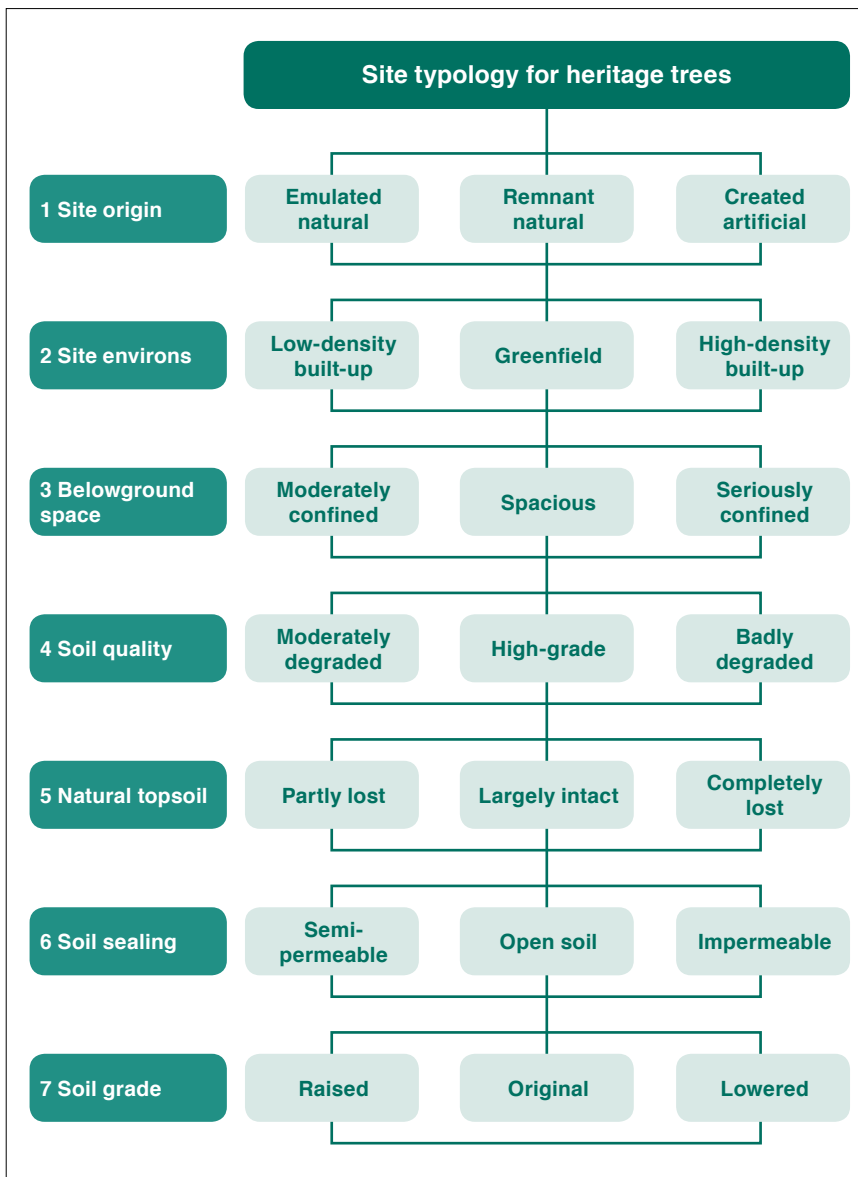
notable management practices and certain activities of citizens, and concludes with lessons learned.

DESIGNATION AND TYPOLOGY

Table 1 shows the ten physical and cultural criteria adopted in various jurisdictions for the identification of heritage trees, with three levels of significance. The key physical tree dimensions are height, crown spread and diameter at breast height (American Forestry Association, undated), which are measured in the field using accurate instruments such as laser hypsometers. Trees that have crown spreads wider than 30 m, are above 30 m in height, or have diameters greater than 2 m at breast height are generally regarded as landscape giants. There is a preference for trees older than 100 years, and those exceeding 300 years are widely rated as exceptional.

Other criteria recognize crucial attributes such as tree performance,[1] ecological function and scenic or landscape dominance. Some trees vividly demonstrate the outstanding traits of a species in form, structural integrity or vigour. Veteran trees accommodate assorted microhabitats, offering complex micro-ecosystems inhabited by diverse flora and fauna (Read, 2000). Cultural dimensions are expressed

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[1] "Tree performance" refers to general tree health and structural integrity.

1
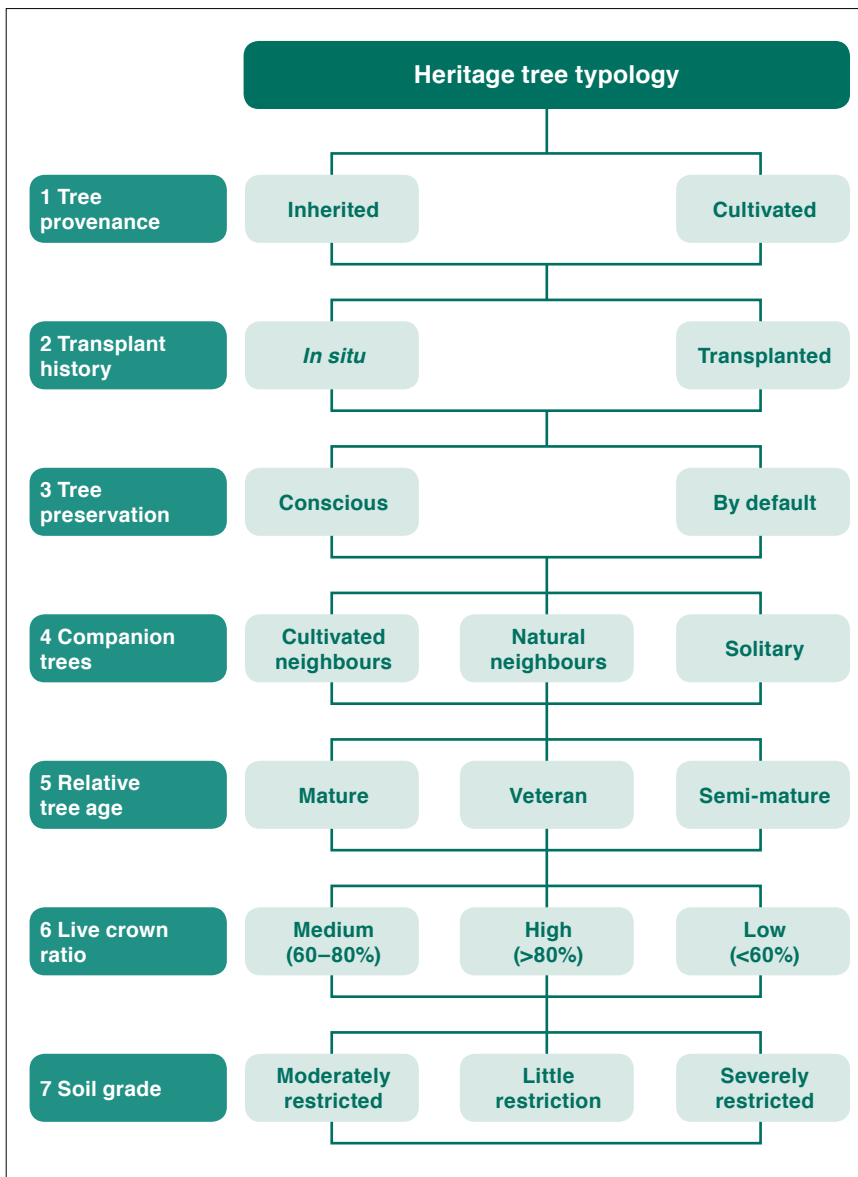*Site typology for heritage trees in urban and peri-urban settings*

Figure 1 provides a typology of heritage trees (figure reference).

Figure 1 content (Site typology for heritage trees)

Criterion			
1 Site origin	Emulated natural	Remnant natural	Created artificial
2 Site environs	Low-density built-up	Greenfield	High-density built-up
3 Belowground space	Moderately confined	Spacious	Seriously confined
4 Soil quality	Moderately degraded	High-grade	Badly degraded
5 Natural topsoil	Partly lost	Largely intact	Completely lost
6 Soil sealing	Semi-permeable	Open soil	Impermeable
7 Soil grade	Raised	Original	Lowered

ecologically and culturally significant (Jim, 2013).

Heritage trees can be classified based on site and tree characteristics to facilitate understanding, management and conservation. Figure 1 provides a typology of tree sites based on seven criteria, each with three states, that influence habitat quality and hence the past growth of a given heritage tree and its prognosis. Site origin may be remnant natural, emulated natural or created artificial, reflecting the degree of naturalness and habitat quality. Site environs are characterized by building density, which may impose microclimatic stresses such as heat load and shading. Within a site, the size of the belowground space affects crown development. Soils may be high-quality or degraded due to human disturbance. The extent to which the natural topsoil has been retained affects tree growth. The site surface may be open, or it may be sealed by impermeable materials (e.g. concrete), affecting root development. Grade change – either by burying existing soil with added soil or by removing the original soil – is injurious to roots (Jim, 2017b).

Figure 2 provides a typology of heritage trees based on seven key attributes (the photo on page 70 gives an indicative typology for a tree in the Meiji Shrine in Tokyo, Japan). Provenance is about whether a tree is inherited from pre-urbanization vegetation or planted after urban development (or it could have been transplanted). The decision to preserve a tree may have been made consciously, with an accompanying protection and management plan, or the tree may have survived by default. The presence of companion trees could indicate better habitat conditions than those pertaining to solitary specimens. Determining the relative age of trees can help in identifying those veterans in need of special care (Fay, 2002). The biomass

in the criteria "personality/event associations" tied to local history; "natural/cultural bequest"; and "spiritual/mythical connotation". For example, trees associated with personalities might be those planted on the occasion of the coronation of a king. Trees associated with events could be those planted or designated to commemorate an important event, such as a battleground victory. Trees associated with local beliefs might be those considered the abodes of spirits or deities with mystical or religious connections. Some

trees are intimately linked to landmark historical events or notable persons, thereby bestowing social–cultural values (Blicharska and Mikusinski, 2014). Trees planted by dignitaries on important dates have commemorative significance. Others may be actively worshipped, as evidenced by shrines, altars or associated paraphernalia. Some trees grow spontaneously on artificial structures such as old buildings and masonry retaining walls and in archaeological ruins. Specimens of unusual size and form are likely to be

2
Tree typology for heritage trees in urban and peri-urban settings

form, together with the selection criteria used. The information contained in such registers varies from the bare minimum (e.g. species and location) to detailed survey and assessment data, digital maps and access guidelines (e.g. City of New York, undated; Jim, 1994).

In some jurisdictions, trees in private lands are excluded from the administrative ambit and therefore may not benefit from systematic assessment, care and protection. In cities experiencing rapid expansion and redevelopment, such neglected trees are prone to damage or felling – and residents may not know what has been lost. Trees on the grounds of private institutions, especially religious establishments, usually receive a certain level of care, despite a lack of official input. For religious reasons or because of taboos associated with the harming of sacred trees, such trees are less likely to be damaged by owners, managers and visitors than trees on other forms of non-public land. Because religious grounds tend to persist in urban landscapes, they are often valuable sites for heritage trees. Their low-density, low-rise built form and freedom from construction works are conducive to tree preservation. In contrast, residential and commercial land uses are subject to urban renewal, *in situ* intensification and infilling, all of which can degrade site quality and cause tree damage or removal.

Some cities have established comprehensive heritage-tree databases, tree laws and management agents to improve management and conservation; such databases, if continually updated, facilitate the timely formulation of action plans. Some administrations assign sufficient resources and well-trained professional and technical staff to ensure appropriate tree care, and some have active publicity and public-education programmes that present information in accessible forms. Such programmes,

structure can be evaluated as a function of the live crown ratio (that is, the ratio of the height of the crown containing live foliage to the height of the tree) and soil–root integrity,[2] indicating the net outcome of site history and contemporary factors. The structural integrity of stems and roots may have been compromised by natural or human impacts.

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[2] That is, field evidence showing that the soil in the area embodying the tree roots has not been disturbed or cut away.

EXEMPLARY MANAGEMENT PRACTICES
People have been protecting and caring for heritage trees since ancient times and continue to do so today, often with little or no government input. In cities, however, heritage trees are usually managed by urban forest administrations. The management practices reviewed here are derived from diverse sources (for the sake of brevity, they are mostly unreferenced).

Some cities have established official registers of heritage trees in printed or digital

including public lectures and guided field tours, disseminate relevant knowledge and messages, raise awareness among citizens, and increase public support for heritage-tree maintenance and conservation.

Succinct, attractive information plaques are installed at tree sites to convey conservation messages. In addition to providing basic information on the species, plaques may include statements about the cultural-historical background of a tree or site, its association with local events and personalities, and interesting ecological and ethnobotanical functions. Information on connections with traditions, deities and other supernatural objects is sometimes included, together with problems affecting tree health, arboricultural treatments, and potential threats. In some jurisdictions, QR codes are provided to direct interested people to further web-based information.

Some cities have developed techniques to arrest the decline of old or degraded heritage trees. These focus on relieving problems of soil compaction and the degradation of soil structure, composition and properties and on increasing the moisture-holding capacity of soils and nutrient supply. Soil treatments are restricted to only a portion of sites to avoid shocking the trees. Often, the site soil is loosened to a prescribed depth by various means, such as the use of air spades,[3] drilling inclined bore holes, and opening narrow radial trenches (Beijing District Standard, 2009). The poor site soil is replaced with a soil mix enriched with mature compost. Research is needed on soil improvement techniques to arrest tree decline and boost growth (Layman et al., 2016).

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[3] Air spades are field tools that use compressed air to generate a supersonic air jet that can blow away soil particles while retaining most of the roots.

Heritage trees require a high standard of arboricultural care, and inexperienced or ill-informed tree management can have detrimental impacts. Common mistreatments include excessive or frequent branch pruning, improper branch tipping, the preferential removal of lower branches, and aggressive crown reduction and thinning. For veteran trees, an inadequate understanding of the multiple microhabitats they provide for a diverse assemblage of flora and fauna has led to overzealous sanitization treatments (Woodland Trust, 2008).

This old camphor tree (Cinnamomum camphora) *in the grounds of the Meiji Shrine in Tokyo is venerated as a wishing tree. Note the open wooden frames installed below the tree canopy for hanging wooden placards, on which wishes are written. The approximate typology of this tree, as per Figure 2, would be: 1) cultivated; 2)* in situ*; 3) conscious; 4) cultivated neighbours; 5) mature; 6) high; 7) little restriction*

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The proper management of heritage trees requires knowledge of a wide range of aspects – such as the tree's ecology, growth habits, microclimate, soil science, and cultural significance, and the threats posed by the urban environment – and specialized skills. To mitigate risks at sites with above-average pedestrian traffic, a compromise needs to be found between ecology and safety (English Nature, 2000).

Outstanding trees affected by development can sometimes be retained, given sympathetic urban design. For example, building footprints and road alignments can be reconfigured or shifted to avoid impacts on protected trees. Construction activities near preserved trees can be adjusted to minimize impacts, and precautionary measures can be taken to protect roots and stems. Future site conditions should be designed to enable sustained tree health, with sufficient good-quality space to accommodate crown and root expansions. Roadside heritage trees can be protected from trenching damage by diverting excavation alignments or by adopting trenchless or no-dig techniques (Jim, 2003).

Where circumstances do not allow *in situ* preservation, transplanting may be considered as a last resort. Transplanting a large tree demands multidisciplinary collaboration between tree experts and engineers (Jim, 1995). Phased root pruning is conducted well in advance. The root ball should be large enough to accommodate sufficient roots and strong and rigid enough to prevent deformation by the moving and lifting operations. The recipient site should be chosen or prepared to match as closely as possible the donor site in terms of above-ground and soil conditions.

Advocates of trees in urban spaces have tended to emphasize the environmental and ecological benefits but, increasingly,

the economic and social contributions of trees are attracting research and community attention (Becker and Freeman, 2009). Recent studies have combined tree evaluation and economic valuation to link tree value more intimately with inherent tree attributes (Jim, 2006). It is important that the findings of such studies are made publicly available in accessible language

to increase community awareness of the diverse roles played by heritage trees and interest in their protection. Strong public support for heritage trees will increase the willingness of policymakers to assign adequate funding and staff. In this way, iconic heritage trees can play crucial roles in rallying attention and support for urban and peri-urban forestry.

This old Japanese cedar (Cryptomeria japonica), situated next to a path leading to shrines in the Takao Mountains in western Tokyo, is protected and worshipped as a sacred tree

© C.Y. JIM

This century-old Chinese banyan (Ficus microcarpa) was originally designated as the sacred ("deity of the earth") tree protecting its Hong Kong village from harm but was subsequently used as a wishing tree. The tree received thousands of paper offerings, which were tied to oranges and thrown by visitors to hang on the branches, causing considerable damage. This mass vandalism was stopped only after a large branch fell, injuring several people

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Citizen endeavours

Many people living in urban environments have considerable respect for trees due to both tradition and modern environmental education (Zhang *et al*., 2007), and this can be harnessed to boost tree protection efforts. Self-initiated citizens' green groups have played pivotal roles in protecting heritage trees by engaging communities and raising public awareness and knowledge (FAO, 2016). In such groups, members are coached in tree assessment techniques to become "citizen tree wardens" to participate in basic tree care. Most importantly, they monitor site conditions to prevent degradation and guard against harm to heritage trees. Citizen tree wardens and green groups play important roles in many cities by alerting governments, non-governmental organizations and the media to risks posed to heritage trees and have launched many concerted tree-saving

operations. Good examples of such groups include Big Trees in Bangkok, Thailand, and the Conservancy Association in Hong Kong, China, which alert citizens to threats to urban trees and help prevent their damage or removal. Overall, with well-organized involvement, participation, education and engagement, citizens can be effective tree guardians and also partners with governments in promoting green urban spaces and nature conservation.

THE PROS AND CONS OF WISHING TREES

In some places, there is a belief that the deities or spirits residing in certain heritage trees will respond benevolently to people's requests, and such trees have been designated as wishing trees. This practice is probably a residual expression of ancient polytheistic beliefs and associated paganism and idolatry. Wishers seek good

fortune for themselves and their loved ones in all sorts of personal and interpersonal domains, such as romantic love, family relationships, friendship, health, work and study. Votive or token offerings are transmitted to wishing trees in various modes. Burning paper incense, candles and joss sticks is a common ritual in East Asia. Some cultures treat certain trees as living temples and like to pray, sing and meditate near them and to ambulate around them. In Japan and the Republic of Korea, a common passive and non-intrusive approach is to write wishes on small wooden placards that are hung on racks near heritage trees (see photo page 70). The placards are usually removed each day to provide space for new ones. At some sites, visitors pay to keep their placards in weatherproof glass cabinets for longer periods.

Sometimes, intrusive or even damaging actions are adopted to convey wishes

from people to trees. In Western countries, such actions include hammering nails, pins or coins into tree trunks. Less injurious methods are also used, such as tying cloth or ribbons to branches, and irrigating trees with alcoholic libations. Some people hang material offerings on trees, such as apples, meat, candy and cigars. These practices are seldom adopted in Asia. In East Asia, and especially on mainland China, people write their wishes on pieces of paper which are folded and tied onto small branches.

A more aggressive method of conveying wishes to trees was invented in the 1990s in a village in Hong Kong. Apparently trying to boost sales, hawkers used string to tie wish papers to oranges, and these projectiles were thrown at a century-old Chinese banyan (*Ficus microcarpa*) tree in an attempt to lodge the "wishes" on it. In the early 2000s, the tree was assaulted daily with hundreds of oranges (with wishes attached), and the official tourism organization promoted the practice to local and overseas visitors. Many small branches were broken. In removing the tokens so that the tree could receive a fresh barrage each day, the entwined strings were forcibly pulled away, causing extensive damage to foliage and branches and creating numerous wounds open to pest and fungal invasion. The daily cycles of attack and dislodgement over several years seriously enfeebled the tree. Eventually, in 2005, a large branch fell and hurt several throwers, whereupon the authorities stopped the practice (Leisure and Cultural Services Department, 2005). Unfortunately, the practice has been mimicked in other cities and religious establishments on mainland China, damaging many heritage trees (Huitu.com, 2017). Inexplicably, such collective vandalism is often endorsed or condoned by authorities.

LESSONS LEARNED
If a city can take excellent care of the cream of its tree stock, its heritage trees, it can inspire confidence in its capacity to care for all its urban and peri-urban forests. The extent of care shown for heritage trees

also speaks volumes about the attitudes of the community to nature and about citizen welfare. From the above analysis, the following recommendations can be proposed to management authorities to mitigate existing problems and improve professional practice:

- Heritage trees are a crucial part of urban forests, and their in-depth assessment, regular monitoring, and high-order and specialized care is warranted.
- Local capacity to manage heritage trees can be nurtured through the education of high-level urban forest managers and arborists.
- A dedicated urban and peri-urban forestry unit could be established in government to ensure the implementation of recommended actions in a timely and professional manner.
- Statutory measures are essential for supplementing administrative approaches and ensuring sufficient safeguards against the destruction of heritage trees.
- A well-maintained, detailed database of heritage trees, and a regular and systematic monitoring programme, will enable the timely prognosis of threats posed to heritage trees and effective preventive care.
- It may be possible to save declining heritage trees and prolong their safe service life with dedicated rejuvenation plans.
- For long-term tree health, the quality of aboveground and belowground habitats must be assiduously ensured and acute and chronic stresses abated.
- The neglect of tree risk assessment, which is particularly important for the management of veteran heritage trees in compact urban areas, requires urgent attention.
- Heritage trees should be transplanted only as a last resort. It is technically feasible, however, to move large heritage trees without causing undue harm or jeopardizing long-term performance.

- The special skills of heritage-tree care, including pruning and the treatment of veteran trees, must be mastered to deliver high-calibre results.
- Practices and activities that are harmful to heritage trees must be averted at the earliest possible stage, which requires vigilance (for example through well-informed citizens' groups).
- Ongoing, adequately funded research is needed to study locally specific issues affecting heritage trees and to inform mechanisms for the effective transfer of knowledge from research to practice.
- The economic valuation of heritage trees can help raise awareness of the benefits such trees generate for society and to muster support for urban forestry.
- Green non-governmental organizations can develop partnerships and synergies with government and private bodies to further the cause of heritage trees. ◆

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Cities worldwide are increasingly aware that trees and forests make cities greener, cooler and healthier

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Greener, cooler, healthier cities

The need for greener and healthier cities was highlighted in two major regional meetings on urban forestry – Asia and the Pacific, and Latin America – in 2017. The two events explored the benefits of urban trees and forests for the millions of people living in cities and megacities in the two regions and their role in mitigating climate change.

Asia-Pacific Urban Forestry Meeting

The second Asia-Pacific Urban Forestry Meeting, co-organized by FAO, discussed and endorsed an action plan to help countries in the region develop sound urban and peri-urban forest practices. The meeting, which was held in Seoul, the Republic of Korea, on 13–15 September 2017, followed up on the first Asia-Pacific Urban Forestry Meeting, held in Zhuhai, China, in 2016. The first meeting culminated in the Zhuhai Declaration, a declaration of intent to increase trees and forests in cities and to make cities greener, cooler and healthier. The regional plan of action launched at the second meeting builds on the Zhuhai Declaration. It includes a set of robust urban forestry actions to be implemented by countries to increase the sustainability and resilience of urban development in the region.

More information: *www.fao.org/asiapacific/news/detail-events/ en/c/1036873*

Latin American and Caribbean Forum on Urban Forestry

The Latin American and Caribbean Forum on Urban Forestry, Silviculture and Landscape Restoration for Urban Forests and Green Areas, organized by FAO in collaboration with the Latin American Development Bank, was held in Lima, Peru, on 7–9 June 2017.

Its purpose was to discuss how best to make cities in the region greener, healthier and more sustainable and resilient in the face of climate change.

More information: *www.fao.org/peru/noticias/detail-events/es/c/ 892705*

To complement these regional initiatives, FAO is organizing, with partners, the World Forum on Urban Forests, to take place in Mantova, Italy, on 28 November–1 December 2018 (see the article on page 3 and the announcement on the inside front cover).

Sustainable wood for a sustainable world

Sustainable wood value chains that are environmentally friendly, socially responsible and economically sound are an integral part of sustainable landscapes and key to making progress towards the Sustainable Development Goals (SDGs), according to the experts who met at the Sustainable Wood for a Sustainable World global meeting at FAO headquarters in Rome on 31 October–1 November 2017.

The meeting, which was attended by more than 100 delegates from 40 countries, was organized by FAO and its Advisory Committee on Sustainable Forest-based Industries in collaboration with the Center for International Forestry Research, the Finance Alliance for Sustainable Trade, the International Tropical Timber Organization, the World Bank and the World Wildlife Fund.

Sustainable wood value chains and products are especially relevant to SDG 8 (decent work and economic growth), SDG 12 (responsible

consumption and production), SDG 13 (climate action) and SDG 15 (life on land). Meeting participants agreed that, to enhance local livelihoods, there is a need to connect global, regional and local value chains and to diversify forest products beyond wood to make effective use of "baskets of value chains". Sustainable forest management was repeatedly cited as a significant component of sustainable landscape management.

The meeting emphasized the crucial role of sustainable wood value chains in mitigating climate change through carbon storage in standing forests and harvested wood products and the substitution of fossil-based raw materials and products. The contribution of wood to climate-change mitigation in the construction sector was also highlighted.

Increasing investments to promote sustainable wood value chains requires the assessment of investment barriers and opportunities along value chains and the securitization and monetization of the full range of forest products and services. The creation of a virtual multistakeholder investment promotion facility would help tailor finance to support sustainable wood value chains.

The global meeting constituted the start of an initiative by FAO and partners to strengthen the role of sustainable wood value chains in sustainable development.

FAO's regional forestry commissions

Established by the FAO Conference between 1947 and 1959, the six regional forestry commissions represent FAO's institutional presence in forestry at the macro-regional level worldwide. The commissions convene every two years to bring together heads of forestry and experts in the six major regions worldwide to address policy and technical issues in their respective areas of influence.

In reporting their inputs and recommendations to the FAO Committee of Forestry (COFO), which is the biennial global forum for all forestry issues, and to the United Nations Forum on Forests (UNFF), the regional forestry commissions function as important liaison institutions between country-level and global issues. They also help identify regional trends, needs and specific areas of intervention that should be considered in a well-designed global plan of action for forestry.

The regional forestry commissions contribute to dialogues with other regional forestry institutions and organizations, and most have technical working groups or subregional chapters, which, among other things, implement projects that benefit from collaboration among countries in the region.

Of the most recent round of regional forestry commission meetings, five had taken place by February 2018 (with the sixth planned for March 2018). It has addressed the following items:

- a study on sustainable forestry for food security and nutrition conducted by the Committee on World Food Security High-level Panel of Experts;
- input for the upcoming Global Forest Resources Assessment 2020 and streamlining forestry reporting;
- outcomes of the 22nd Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change, COP 13 of the Convention on Biological Diversity, the 12th meeting of the UNFF, and other institutional global fora; and
- a new strategic document for FAO in forestry, as well as input to FAO governance.

Other important issues discussed at one or more commission meetings included gender; social protection; community-based forestry and farmer organizations; communication in forestry; urban forestry; forests in landscape restoration; and initiatives to combat desertification.

Regional inputs on these and other issues are essential for adapting strategies, policies and projects to the characteristics and needs of each region.

The official reports of the regional forestry commission meetings will be presented at the 24th Session of COFO, scheduled to take place at FAO headquarters in Rome in July 2018.

An officer inspects rough-sawn boards at Dakar port, Senegal. Sustainable wood value chains that are environmentally friendly, socially responsible and economically sound are crucial for making progress towards the Sustainable Development Goals

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WORLD OF FORESTRY

United Nations adopts Strategic Plan for Forests

The first-ever United Nations (UN) Strategic Plan for Forests, adopted by the UN General Assembly on 27 April 2017, provides an ambitious vision for global forests in 2030. The plan features a set of six Global Forest Goals and 26 associated voluntary, universal targets to be reached by 2030. It is designed to serve as a reference framework for the forest-related work of the UN system and to foster enhanced coherence, collaboration and synergies among UN bodies and partners. The plan also serves as a framework to enhance the coherence and guide and focus the work of the International Arrangement on Forests and its components. The six Global Forest Goals are:

1. Reverse the loss of forest cover worldwide through sustainable forest management, including protection, restoration, afforestation and reforestation, and increase efforts to prevent forest degradation and contribute to the global effort of addressing climate change.

2. Enhance forest-based economic, social and environmental benefits, including by improving the livelihoods of forest-dependent people.

3. Increase significantly the area of protected forests worldwide and other areas of sustainably managed forests, as well as the proportion of forest products from sustainably managed forests.

4. Mobilize significantly increased, new and additional financial resources from all sources for the implementation of sustainable forest management and strengthen scientific and technical cooperation and partnerships.

5. Promote governance frameworks to implement sustainable forest management, including through the UN Forest Instrument, and enhance the contribution of forests to the 2030 Agenda for Sustainable Development.

6. Enhance cooperation, coordination, coherence and synergies on forest-related issues at all levels, including within the UN system and across member organizations of the Collaborative Partnership on Forests, as well as across sectors and relevant stakeholders.

One of the targets in the plan is to increase forest area by 3 percent worldwide by 2030, which would be an increase of 120 million hectares. The plan builds on the vision of the 2030 Agenda for Sustainable Development and recognizes that real change requires decisive, collective action, within and beyond the UN system.

Co-Chairs Mohammad Ali Zarie Zare, Iran (Islamic Republic of), and Hans Hoogeveen, the Netherlands, shake hands at the end of the UNFF Working Group and Special Session. The session was held on 16–20 January 2017 at UN headquarters in New York, USA, to, among other things, develop a proposal for a UN strategic plan on forests for 2017–2030

Reducing Inequality in a Turbulent World: Scaling-up Strategies to Secure Indigenous, Community, and Women's Land Rights

More than 300 people from 58 countries gathered in Stockholm, Sweden, on 4–5 October 2017 to raise awareness of community land rights as a prerequisite for decreasing inequality and delivering on global goals; assess the status of promising instruments to secure community rights; and encourage greater action, support and commitment from key stakeholders. Participants hailed from indigenous and community organizations, the private sector, civil society and governments. The conference was co-organized by the Rights and Resources Initiative, Sida, the Stockholm Environment Institute, the Swedish International Agriculture Network Initiative, and the International Foundation for Science.

This conference was the third in a series, following similar meetings in Interlaken and Bern, Switzerland, in 2013 and 2015. The series is designed to take stock of the global state of indigenous, community and rural women's land rights, raise awareness of the importance of these rights, catalyse new partnerships, and develop a shared path forward for scaling up the recognition of rights.

Research launched on the eve of the Stockholm conference found that 61 percent of land-based conflicts between companies and communities since 2001 are unresolved. Securing community and indigenous land rights is vital for mitigating and preventing these devastating conflicts, achieving the Sustainable Development Goals and the commitments of the Paris Agreement, and ensuring peace and justice.

Three strategy sessions at the conference (on rural and indigenous women's rights and leadership in collective lands; strategies and mechanisms to scale up implementation from the local to the national level; and connecting and leveraging international support structures to advance indigenous and community land rights) developed action plans to increase recognition of community land rights. All sessions included speakers from the private sector, whose recommendations were highlighted in a plenary session on the second day of the conference.

For the first time, the conference included an "innovation zone", which highlighted the use of technology and other innovative strategies to secure rights.

There is growing recognition of the importance of community land rights, both as a matter of human rights and as a crucial solution to global problems, including inequality and climate change. There is also unprecedented momentum and growing commitment from all sectors to secure and respect these rights. Conference participants identified ways to connect and leverage global and grassroots efforts to drive change.

BOOKS
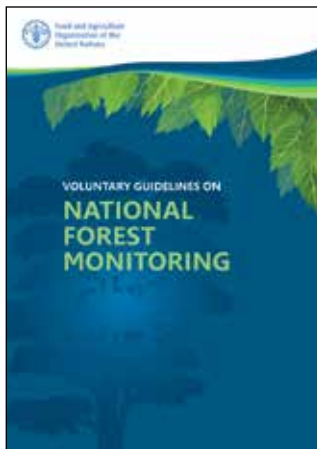
Helping countries assess their standing forests

Voluntary guidelines on national forest monitoring. FAO. 2017. Rome.
ISBN 978-92-5-109619-2.

Establishing and running a national forest monitoring system (NFMS) is a complex scientific-technical process and an organizational and institutional challenge. An NFMS exercise has a direct link to policy because it informs management and decision makers about the sustainable use of forest resources and the efficient protection and conservation of forest ecosystems. Accordingly, an NFMS supports governments in fulfilling their obligations to continually develop, monitor and report on forest resources, which may include trees outside forests as well as other land-cover classes. The aim of these voluntary guidelines is to assist in the creation and operation of NFMSs. They include good-practice principles, guidelines and a general framework. The document also incorporates a set of decision-support tools for planning and implementing a multipurpose NFMS grounded in nationally appropriate and scientifically sound practice, taking into consideration domestic information needs and reporting requirements.

Available online: *www.fao.org/3/a-i6767e.pdf*

Also available online in:

Arabic – *www.fao.org/3/a-i6767a.pdf*
Chinese – *www.fao.org/3/a-i6767c.pdf*
French – *www.fao.org/3/a-i6767f.pdf*
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Spanish – *www.fao.org/3/a-i6767s.pdf*
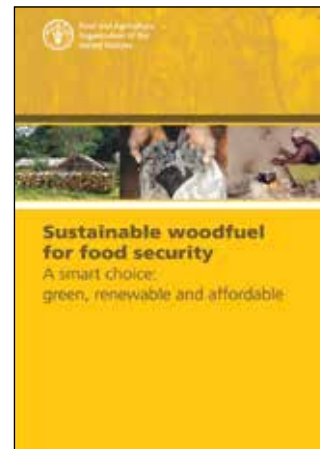
Increasing food security with sustainable woodfuel

Sustainable woodfuel for food security. A smart choice: green, renewable and affordable. FAO. 2017. Rome. ISBN 978-92-5-109962-9.

Food insecurity and a high dependence on woodfuel as a primary cooking fuel are characteristics common to vulnerable groups of people in developing regions worldwide. With adequate policy and legal frameworks in place, however, woodfuel production and harvesting can be sustainable and a main source of green energy. Moreover, the widespread availability of woodfuel, and the enormous market for it, presents opportunities for employment and sustainable value chains, providing additional reasons for promoting this energy source. This paper explains how sustainable woodfuel is linked closely to food security and provides insights into how the linkages could be strengthened at all stages of woodfuel production, trade and use.

Available online: *www.fao.org/3/a-i7917e.pdf*
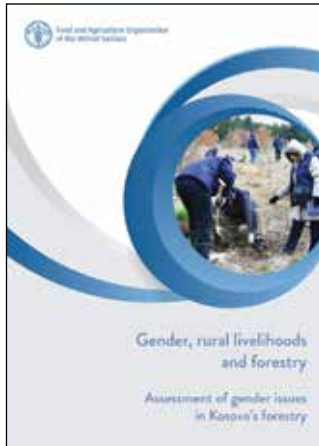
Mainstreaming gender in forest policies in Kosovo

Gender, rural livelihoods and forestry: assessment of gender issues in Kosovo's forestry. FAO. 2017. Rome. ISBN 978-92-5-109797-7.

The main purpose of the research reported in this publication is to identify and analyse the role of women and men in the forest sector in Kosovo and their ownership and use of forests. The report also analyses gender issues within the institutional, policy and legal framework that governs forest management in Kosovo and makes recommendations on how to mainstream gender in forest policies.

The research is part of a project titled, "Support to implementation of the forest policy and strategy in Kosovo" (GCP/KOS/005/FIN), funded by the Government of Finland, which aims to increase the forest sector's contribution to the national economy through the sustainable use of forest resources, taking into account multipurpose forestry, the economic, social and environmental benefits of forests, and the sector's contributions to the mitigation of climate change. The study shows that women have limited access to decision making and information compared with men. Rural communities – especially women – identify high unemployment as the main obstacle they face.

The report demonstrates the interests of rural women in improving their skills in the collection, processing and marketing of non-wood forest products. Consequently, the report shows the importance of improving women's access to information, capacity development and decision making. It concludes by emphasizing that non-wood forest products have strong potential for reducing food insecurity and poverty in the study regions, particularly when both women and men are supported effectively.

Available online: *www.fao.org/3/a-i7421e.pdf*

Also available online in:

   Albanian – www.fao.org/3/i7421sq/I7421SQ.pdf

   Serbian – www.fao.org/3/i7421sr/I7421SR.pdf

What do zero-deforestation commitments mean for forestry?

Potential implications for the forest industry of corporate zero-deforestation commitments. Discussion paper prepared for the 58th Session of the FAO Advisory Committee on Sustainable Forest-based Industries. 2017. FAO. Rome.

This paper analyses the implications for the forest industry of zero-deforestation commitments made by consumer-goods customers and financiers and the benefits that could arise, and it makes recommendations to enable the forest industry to take advantage of the benefits and minimize the risks. The paper, which addresses recommendations made by the FAO Advisory Committee on Sustainable Forest-based Industries, provides background information on the zero-deforestation movement, building on earlier work by the Advisory Committee and FAO.

Available online: *www.fao.org/3/a-i8042e.pdf*
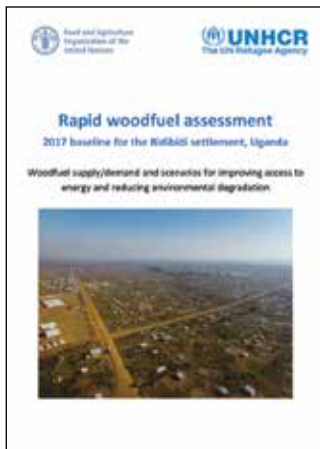
Improving energy access for displaced people in Uganda

Rapid woodfuel assessment: 2017 baseline for the Bidibidi settlement, Uganda.
2017. FAO & United Nations High Commissioner for Refugees (UNHCR). 2017.
Rome and Geneva, Switzerland. ISBN 978-92-5-109947-6 (FAO).

Uganda is host to more than 1 million refugees who have fled famine, conflict and insecurity in the neighbouring countries of Burundi, the Democratic Republic of the Congo and South Sudan. The recent influx of refugees from South Sudan prompted one of Uganda's most severe humanitarian emergencies and led to the establishment of the Bidibidi settlement in Yumbe District in August 2016. The settlement is now the world's largest refugee-hosting area, with 272 206 refugees settled on a land area of approximately 250 km^2 in a total assigned area of 798 km^2; the settlement constitutes more than half the population of the host district. The settlement has increased pressure on the environment due to tree felling for settlement establishment and to meet ongoing household demand for woodfuel for cooking and heating.

FAO and UNHCR initiated a joint rapid woodfuel assessment in March 2017 to determine woodfuel supply and demand in the area. The assessment had three components: 1) an assessment of woodfuel demand; 2) an assessment of woodfuel supply; and 3) the identification of interlinkages, gaps, opportunities and alternative scenarios. Data and information were obtained through a desk review of existing documents, field surveys and remote-sensing analysis. Among other findings, the report estimates that 12–15 percent of the total land area of the Bidibidi settlement would need to be planted with fast-growing species to provide a sustainable woodfuel supply. Each household would need to dedicate a minimum woodlot area of 50 m × 50 m exclusively to growing wood for energy.

Available online: *www.fao.org/3/a-i7849e.pdf*

## The potential of agroforestry for landscape restoration

*Agroforestry for landscape restoration: exploring the potential of agroforestry
to enhance the sustainability and resilience of degraded landscapes.* 2017.
A. Hillbrand, S. Borelli, M. Conigliaro & A. Olivier. Rome, FAO.

Agroforestry has considerable potential for restoring degraded forests and agricultural lands and thereby contributing to landscape restoration, but constraints limit its adoption. This brief makes the following key points:

- Agroforestry can provide many ecosystem services. It is a suitable tool for landscape restoration because it can enhance physical, chemical and biological soil characteristics, thereby increasing soil fertility, controlling erosion and improving water availability.
- Agroforestry systems that provide permanent tree cover can be valuable forest and landscape restoration options, especially in initiatives in which neither natural forest restoration nor full sun crops are viable.
- Agroforestry can enhance livelihoods in rural communities by providing a variety of food, fodder and tree products, which increase food and nutrition security, generate income and alleviate poverty.
- The restoration of degraded landscapes using agroforestry can increase the resilience of communities to shocks, including drought and food shortages, and help mitigate climate change.
- The widespread uptake of agroforestry requires an enabling legal and policy environment that guarantees rights to – and ownership of – trees and land, provides farmers with incentives, promotes investment, and facilitates the marketing of agroforestry products.

Available online: *www.fao.org/3/b-i7374e.pdf*

Also available online in Spanish: *www.fao.org/3/b-i7374s.pdf*
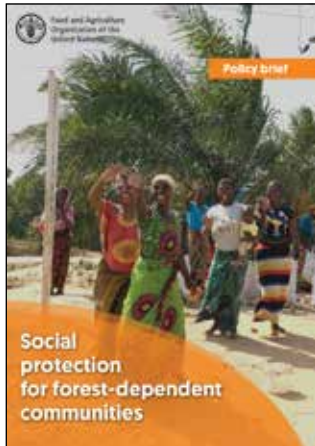
Protecting forest-dependent communities

Social protection for forest-dependent communities. Policy brief. 2017. N. Tirivaye, O. Rodriguez, T. Juvenal & Qiang Ma. Rome, FAO.

Forest-dependent communities are usually located in remote rural areas characterized by low levels of market development and poor access to public goods and social services. They must deal constantly with the consequences of market failure and are particularly exposed to risks and repeated shocks. A wide range of environmental, economic, health-related, demographic, social and political factors are key sources of vulnerability in these communities.

Since the implementation of FAO's five new Strategic Objectives, social protection has become an important area of focus for the Organization. This policy brief, developed by FAO in collaboration with the United Nations University–Maastricht Economic and Social Research Institute on Innovation and Technology, uses a global literature review and country case studies in Burkina Faso, China and Uganda to explore the need for more social protection for forest-dependent communities. Among other things, the brief recommends the inclusion of environmental and poverty-alleviation objectives in social protection and forestry interventions and raising awareness of the potential synergies between them.

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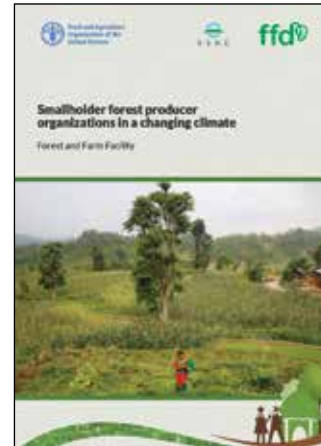
## The role of smallholder forest organizations in climate-change mitigation and adaptation

Smallholder forest producer organizations in a changing climate. 2017. Forest and Farm Facility. Rome, FAO.

National organizations and networks of smallholder forest producers play important roles in climate-change mitigation and adaptation, spanning political and practical action. Innovative and successful climate action builds on the strengths of each organization and harnesses the support of the membership base and organizational alliances in multi-actor networks.

This publication summarizes the findings of a review of the innovative ways in which smallholder forest producer organizations in developing countries are contributing to climate-change mitigation and adaptation. The review was carried out by the Finnish Agri-Agency for Food and Forest Development and the Finnish Environment Institute in collaboration with the Forest and Farm Facility.

The Forest and Farm Facility is a partnership between FAO, the International Institute for Environment and Development, the International Union for Conservation of Nature, and AgriCord.

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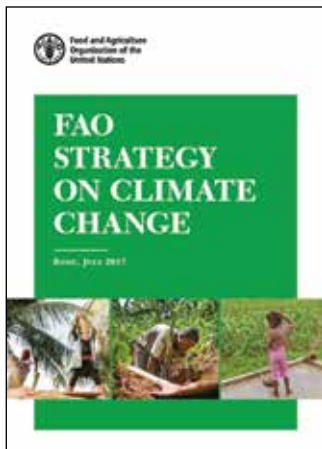
FAO's approach to climate change

FAO strategy on climate change. 2017. Rome, FAO.

Three outcomes frame FAO's strategy on climate change:

1. Enhanced capacities of Member Nations on climate change through FAO leadership as a provider of technical knowledge and expertise.
2. Improved integration of food security, agriculture, forestry and fisheries in the international agenda on climate change through reinforced FAO engagement.
3. Strengthened coordination and delivery of FAO's work on climate change.

The strategy on climate change sets FAO on a path to deliver on the Sustainable Development Goals (SDGs), particularly SDGs 1, 2 and 13. In operational terms, it is an integral part of FAO's Strategic Framework, Medium Term Plan, and Programme of Work and Budget.

The strategy will be implemented through a plan of action designed to strengthen FAO's existing capacities, especially in decentralized offices, and it sets out the results to be delivered by FAO through its Strategic Programmes.

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Investing in trees to improve health

Funding trees for health: an analysis of finance and policy actions to enable tree planting for public health. R. McDonald, L. Aljabar, C. Aubuchon, H.G. Birnbaum, C. Chandler, B. Toomey & J. Daley, *et al.* 2017. Arlington, USA, The Nature Conservancy.

Every year, up to 4 million people die worldwide as a result of air pollution, which has lifelong impacts on people's health through ailments such as asthma, cardiac disease and stroke. Each summer, thousands of unnecessary deaths result from heatwaves in urban areas. Studies have shown that trees are a cost-effective solution for both these challenges, but investment in urban forestry is perpetually underfunded.

This report examines the link between trees and public health, which recent science has shown is robust and economically significant. One way to overcome the funding barrier for urban forestry, say the authors, is to more closely link the goals and funding of the health sector with the goals and funding of urban forestry agencies. The authors urge all cities to explore ways of creating links between the health sector and urban forestry agencies, using one of the potential models discussed in the report.

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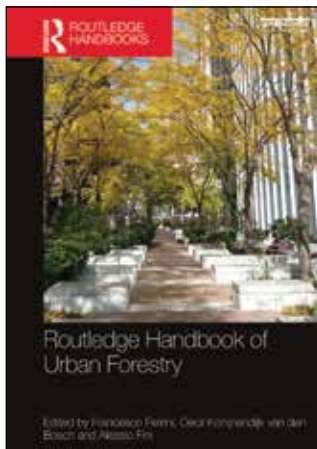
Creating sustainable urban environments

Routledge handbook of urban forestry. 2017. F. Ferrini,

C.C. Konijnendijk van den Bosch & A. Fini. Abingdon, UK, Routledge.

ISBN: 9781138647282 (hardback); 9781315627106 (ebook)

More than half the world's population now lives in cities. Creating sustainable, healthy and aesthetic urban environments is therefore a major policy goal and research agenda. This comprehensive handbook provides a global overview of the state of the art and science of urban forestry. It describes the multiple roles and benefits of urban green areas in general and the specific role of trees; reviews the various stresses experienced by trees in cities and tolerance mechanisms, as well as cultural techniques for either preconditioning or alleviating stress after planting; and outlines the sound planning, design, species selection, establishment and management of urban trees. The handbook shows that the close involvement of local urban communities who benefit from trees is key to success.

Available for purchase at: *www.routledge.com/Routledge-Handbook-of-Urban-Forestry/Ferrini-Konijnendijk-van-den-Bosch-Fini/p/book/9781138647282*

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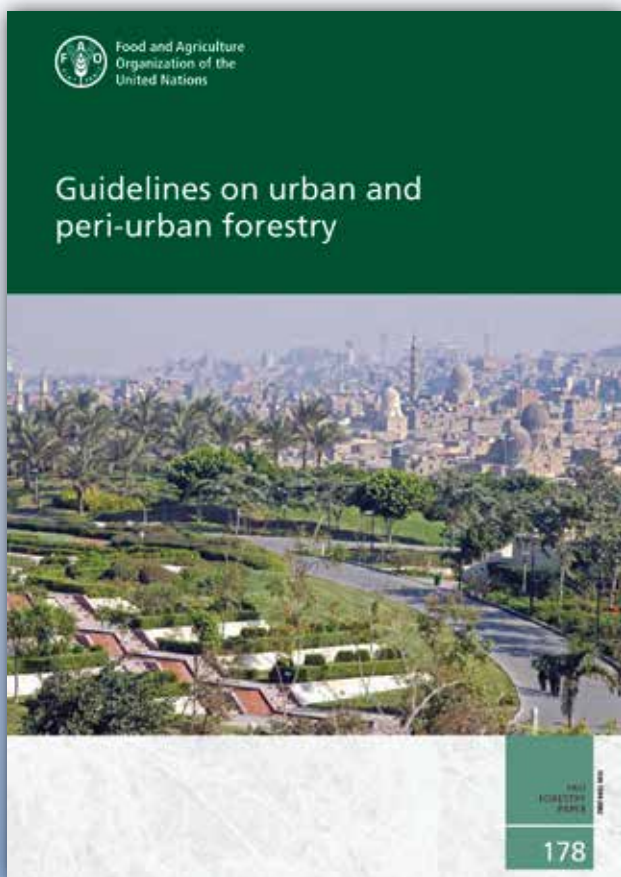
Guidelines on urban and peri-urban forestry

A globally applicable guide to developing forests that will meet the present and future needs of cities for forest products and ecosystem services

by Fabio Salbitano, Simone Borelli, Michela Conigliaro and Yujuan Chen

FAO Forestry Paper No. 178

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