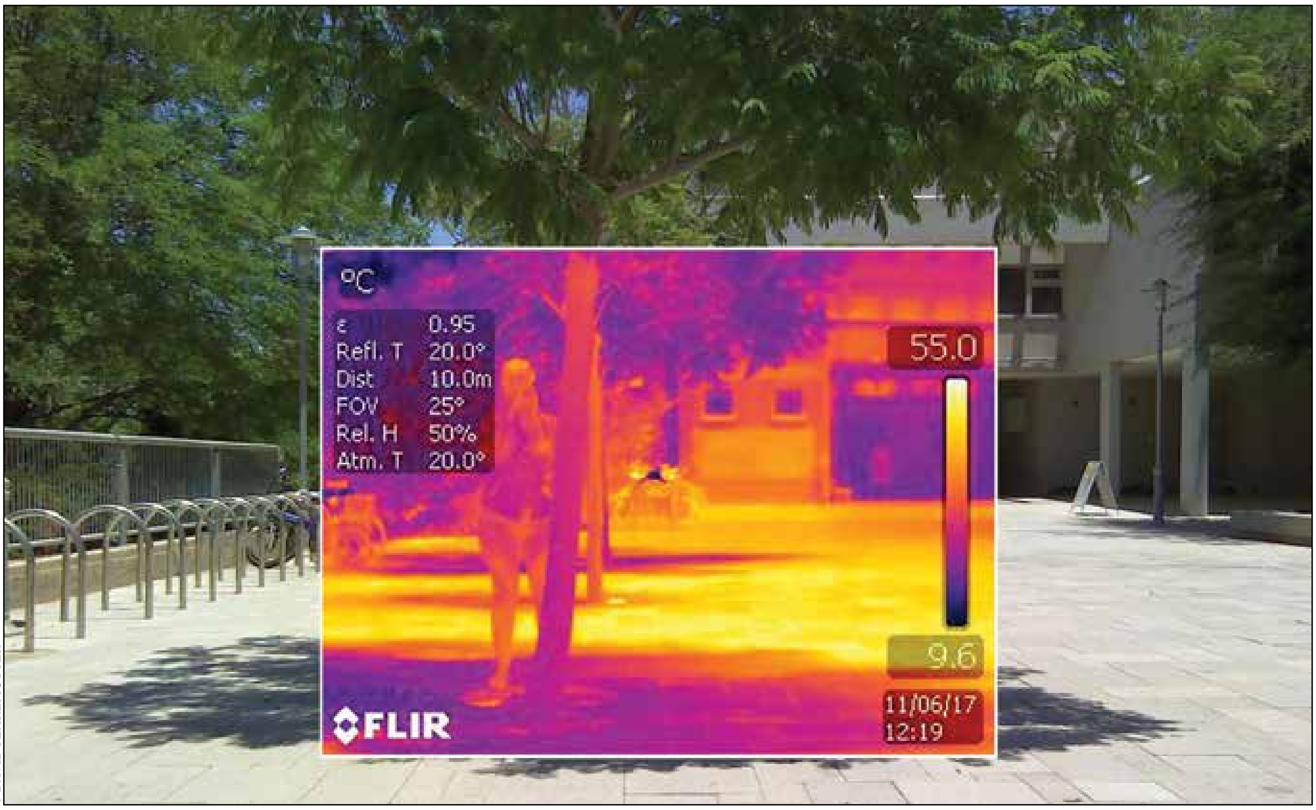

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The role of urban and peri-urban forests in reducing risks and managing disasters

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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)

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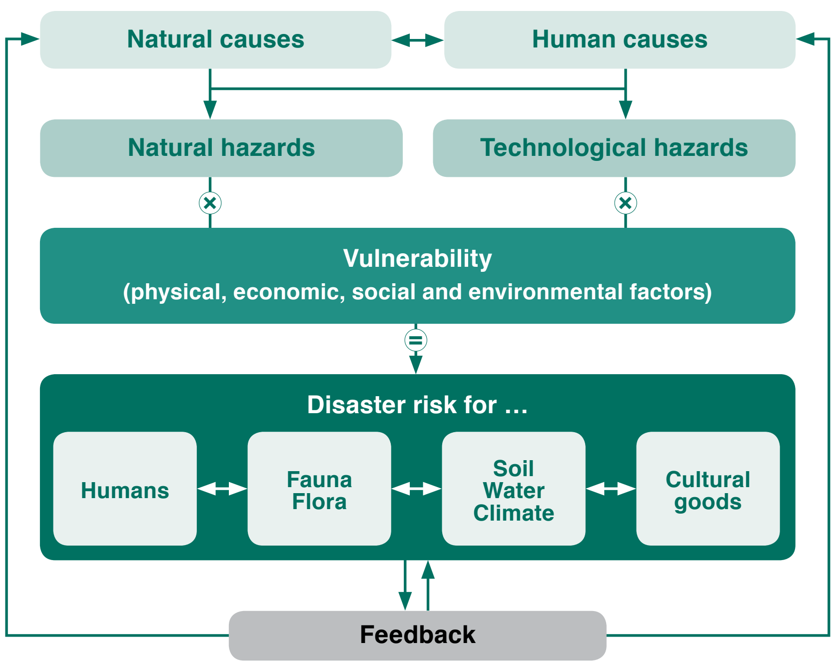

Source: International Federation of Surveyors (2006).

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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.

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 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.

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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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