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

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 km^3 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.

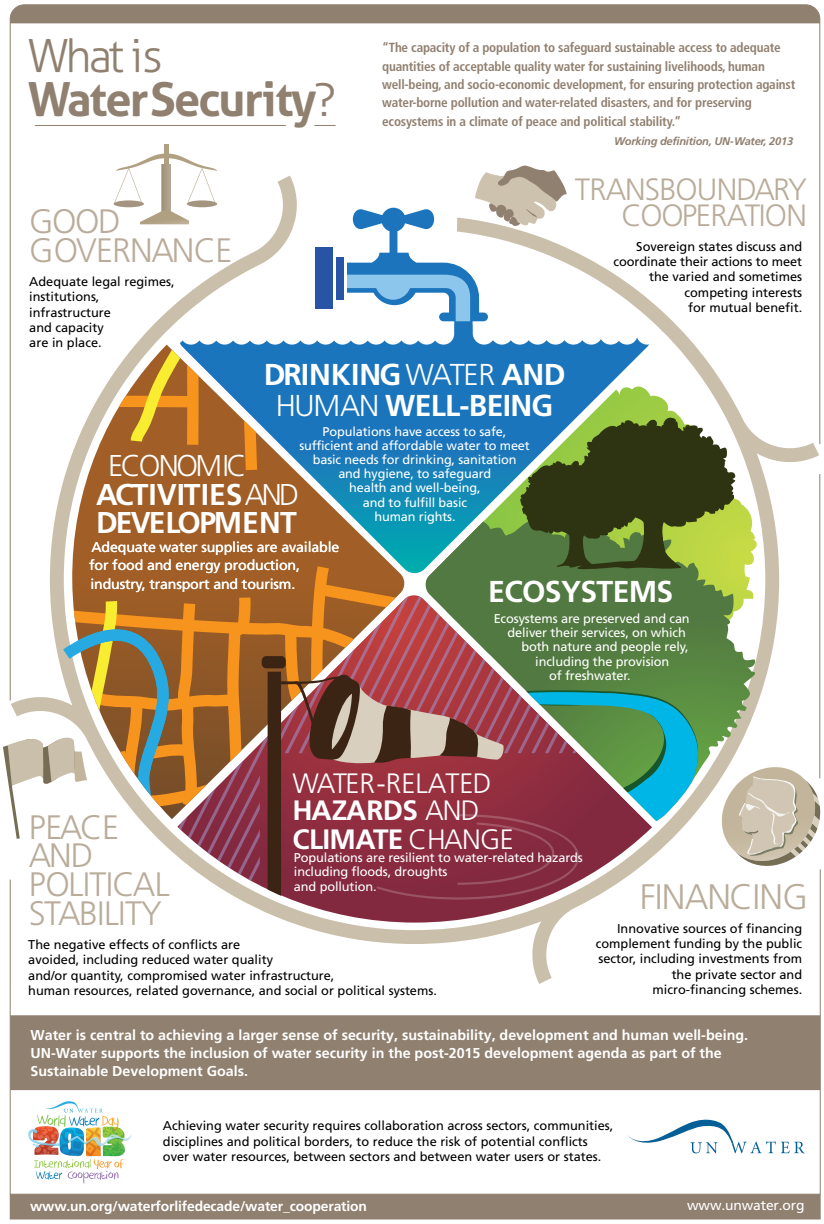
CITIES NEED TO BE WATER-SMART

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



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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.

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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

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.

* 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).

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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

[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.

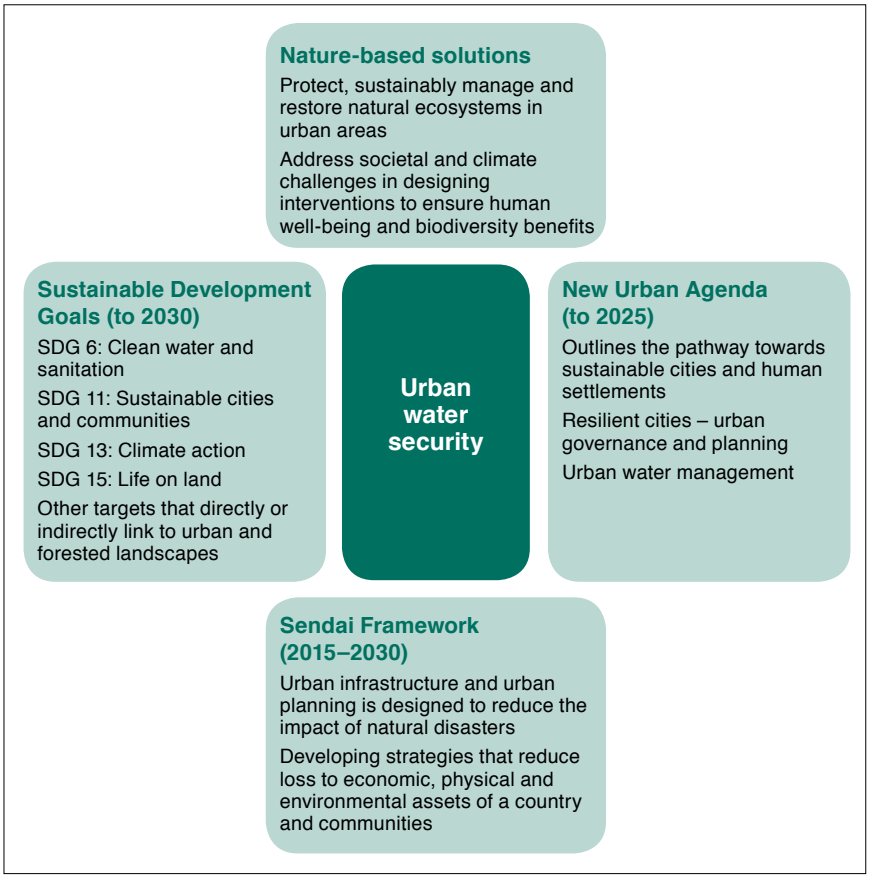
WATER SECURITY AND SUSTAINABLE DEVELOPMENT

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

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

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

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. ◆

References

Abell, R., Asquith, N., Boccaletti, G., Bremer, L., Chapin, E., Erickson-Quiroz, A. & Higgins, J. *et al.* 2017. *Beyond the source: the environmental, economic and community benefits of source water protection*. Arlington, USA, The Nature Conservancy.

Aydin, A.F., Koyuncu, I., Demir, A., Aydin, D., Guclu, S. & Turken, T. 2013. Water supply structures of the Ottoman period in Istanbul (Asian side). *Water Science and Technology: Water Supply*, 13(3): 615–625.

Bakker, K. 2009. *Water security: Canada's challenge* [online]. Policy Options. [Cited 18 December 2017]. http://policyoptions.irpp.org/magazines/canadas-water-challenges/water-security-canadas-challenge

Barrett, K. 2017. Lima kicks off development of 30-year green infrastructure plan [online]. Ecosystem Marketplace, 3 March 2017. [Cited 18 December 2017]. www.ecosystemmarketplace.com/articles/lima-kicks-off-development-30-year-green-infrastructure-plan

Boberg, J. 2005. Freshwater availability. In: J. Boberg, *Liquid assets: how demographic changes and water management policies affect freshwater resources*, pp. 15–28. Santa Monica, Arlington & Pittsburgh, USA, RAND Corporation (also available at www.jstor.org/stable/10.7249/mg358cf.9).

Boonsong, K., Piyatiratitivorakul, S. & Patanaponpaiboon, P. 2003. Use of mangrove plantation as constructed wetland for municipal wastewater treatment. *Water Science and Technology*, 48(5): 257–266.

BP. 2017. *BP Statistical Review of World Energy June 2017*. London (also available at www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf).

Cohen-Shacham, E., Walters, G., Janzen, C. & Maginnis, S. eds. 2016. *Nature-based solutions to address global societal challenges*. Gland, Switzerland, International Union for Conservation of Nature.

Dudley, N. & Stolton, S. 2003. *Running pure*. Research report for the World Bank and the WWF Alliance for Forest Conservation and Sustainable Use.

Ellison, D., Morris, C.E., Locatelli, B.D., Sheil, D., Cohen, J., Murdiyarso, D. & Gutierrez, V. 2017. Trees, forests and water: cool insights for a hot world. *Global Environmental Change*, 43: 51–61.

Ernst, C. 2004. *Protecting the source: land conservation and the future of America's drinking water*. San Francisco, USA, The Trust for Public Land and the American Water Works Association.

FAO. 2007. *Mangroves of Asia 1980–2005. Country reports*. Forest Resources Assessment Programme Working Paper No. 137. Rome.

FAO. 2015. *Global Forest Resources Assessment 2015*. Rome (also available at www.fao.org/3/a-i4808e.pdf).

Fearnside, P. 2005. Deforestation in Brazilian Amazonia: history, rates and consequences. *Conservation Biology*, 19(3): 680–688.

Gammie, G. & de Bievre, B. 2015. *Assessing green interventions for the water supply of Lima, Peru*. Report for Forest Trends and CONDESAN. Washington, DC, Forest Trends.

Kam Ng, M. 2017. Governing green urbanism: the case of Shenzhen, China. *Journal of Urban Affairs*, 15 February 2017: 1–19.

Lee, E. 2017. *Urban designers look to nature as solution for flood-prone cities* [online]. VOA. [Cited 18 December 2017]. www.voanews.com/a/urban-designers-look-to-nature-as-solutions-for-flood-prone-cities/4026615.html

MacKinnon, K., Sobrevila, C. & Hickey, V. 2008. *Biodiversity, climate change, and adaptation: nature-based solutions from the World Bank portfolio*. Washington, DC, World Bank.

Mehta, P. & Nagabhatla, N. 2017. *Without water, nothing is secure*. UNU-INWEH Policy Brief Issue 3. Hamilton, Canada, United Nations University (UNU) Institute for Water Environment and Health (INWEH).

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being*. Washington, DC, Island Press.

Nagabhatla, N. & Metcalfe, C.D., eds. 2017. *Multifunctional wetlands: pollution abatement and other ecological services from natural and constructed wetlands*. Cham, Switzerland, Springer International.

Nobre, A. 2014. *The future climate of Amazonia: scientific assessment report*. São José dos Campos, Brazil, Earth System Science Center, National Institute of Space Research and National Institute of Amazonian Research (also available at www.ccst.inpe.br/wp-content/uploads/2014/11/The_Future_Climate_of_Amazonia_Report.pdf).

OECD. 2012. *Water quality and agriculture: meeting the policy challenge*. Organisation for Economic Co-operation and Development (OECD) Publishing (also available at www.oecd.org/tad/sustainable-agriculture/49849932.pdf).

Pearce, F. 2015. *Pre-Inca canals may solve Lima's water crisis* [online]. *New Scientist*, 9 April. [Cited 18 December 2017]. www.newscientist.com/article/dn27311-pre-inca-canals-may-solve-limas-water-crisis

Peng, Y., Li, X., Wu, K., Peng, Y. & Chen, G. 2009. Effect of an integrated mangrove-aquaculture system on aquacultural health. *Frontiers of Biology in China*, 4(4): 579–584.

Qin, Y., Gartner, T., Minnemeyer, S., Reig, P. & Sargent, S. 2016. *Global Forest Watch water metadata document*. Technical note. Washington, DC, World Resources Institute (also available at www.wri.org/publication/GFW_Water_metadata).

SEDAPAL. 2016. *SEDAPAL y AQUAFONDO buscan recuperación ecológica de ríos Rímac, Chillón y Lurín* [online]. Nota de prensa no. 46 2016. Servicio de Agua Potable

y Alcantarillado de Lima (SEDAPAL). [Cited 18 December 2017]. https://goo.gl/Tpb2QW

Spalding, M.D., Ruffo, S., Lacambra, C., Meliane, I., Zeitlin Hale, L., Shepard, C.C. & Beck, M.W. 2014. The role of ecosystems in coastal protection: adapting to climate change and coastal hazards. *Ocean and Coastal Management*, 90: 50–57. DOI https://doi.org/10.1016/j.ocecoaman.2013.09.007

Tam, F.Y. & Wong, Y.-S. 1997. Accumulation and distribution of heavy metals in a simulated mangrove system treated with sewage. *Hydrobiologica*, 352(1–3): 67–75.

Thompson, S. 2017. *A green pursuit: seeking nature-based solutions for cities* [online]. The Irish Times. [Cited 18 December 2017]. www.irishtimes.com/news/science/a-green-pursuit-seeking-nature-based-solutions-for-cities-1.3232941

UNDESA. 2014. *World Urbanization Prospects: The 2014 revision. Highlights*. New York, USA, United Nations Department of Economic and Social Affairs (UNDESA) (also available at https://esa.un.org/unpd/wup/publications/files/wup2014-report.pdf).

UNESCO. 2006. *World Water Development Report 2006: Water: a shared responsibility*. United Nations World Water Development Report 2. Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO).

United Nations. 2015. *Transforming our world: the 2030 Agenda for Sustainable Development*. Report number: A/RES/70/1. New York, USA.

UN-Water. 2013. *Water security and the global water agenda*. UN-Water Analytical Brief. Hamilton, Canada, United Nations University (also available at http://inweh.unu.edu/wp-content/uploads/2014/05/Water-Security-and-the-Global-Water-Agenda.pdf).

UN-Water. 2017. *Step-by-step monitoring methodology for SDG indicator 6.6.1: change in the extent of water-related ecosystems over time* [online]. UN-Water. [Cited 18 December 2017]. www.unwater.org/publications/step-step-methodology-monitoring-ecosystems-6-6-1

Watts, J. 2017. *The Amazon effect: how deforestation is starving São Paulo of water* [online]. The Guardian Online, 28 November 2017. [Cited 18 December 2017]. www.theguardian.com/cities/2017/nov/28/sao-paulo-water-amazon-deforestation

World Bank. 2012. *Inclusive green growth: the pathway to sustainable development*. Washington, DC, World Bank (also available at http://siteresources.worldbank.org/EXTSDNET/Resources/Inclusive_Green_Growth_May_2012.pdf).

WWAP. 2015. *The United Nations World Water Development Report 2015: Water for a sustainable world*. United Nations World Water Assessment Programme (WWAP). Paris, United Nations Educational, Scientific and Cultural Organization (UNESCO).

Zekavat, S. 2017. *Syrian architects challenge 'post-war' reconstruction with real-time designs* [online]. Global Voices. [Cited 18 December 2017]. https://globalvoices.org/2017/10/15/syrian-architects-challenge-post-war-reconstruction-with-real-time-designs

Zweynert, A. 2017. *Sponges, urban forests and air corridors: how nature can cool cities* [online]. Reuters. [Cited 18 December 2017]. www.reuters.com/article/us-heatwave-cities-nature/sponges-urban-forests-and-air-corridors-how-nature-can-cool-cities-idUSKCN1C100Q ◆