DEVELOPMENT AND IMPLEMENTATION OF A HOLISTIC FRAMEWORK FOR NBS ACTUATION IN URBAN AREAS

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KEYWORDS

Nature-based solutions; policy implications; sustainable development; climate change; disaster and risk reduction; urban water resilience

ABBREVIATIONS

DWD	Drinking Water Directive
ICZM	Integrated Coastal Zone Management
IUCN	International Union for the Conservation of Nature
IWRM	Integrated Water Resources Management
NBS	Nature-based Solution
SDG	Sustainable Development Goal
UNaLab	Urban Nature Labs EU Horizon 2020 project
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive

ABSTRACT

Reconnecting urban water networks with local hydrological systems is essential for the long-term resilience of urban areas and minimisation of environmental degradation. Nature-based solutions (NBS) have emerged as an umbrella concept that combines social benefits with sustainability and conservation strategies. The key strategic, spatial planning, engineering and performance dimensions of NBS encompass previous concepts such as ecosystem-based adaptation, green infrastructure, water-sensitive urban design, and ecosystem services. The Urban Nature Labs (UNalab) project, supported by the EU's Horizon 2020 funding scheme, aims to establish a framework for NBS implementation in cities based upon the outcomes of large-scale demonstrations in Tampere (FI), Genova (IT) and Eindhoven (NL). UNaLab and similar projects seek to contribute to the evidence base on NBS by systematising key indicators of NBS performance and impact. UNaLab further seeks to empower municipal decision-makers through the validation of a robust NBS roadmapping framework. The present study explores the existing policy context for effective integration of NBS with supporting technical or "engineered" solutions to reconnect the urban hydrologic cycle and sustainably manage both surface water quality and quantity, including the planning, implementation and evaluation of deployed solutions.

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1 INTRODUCTION

Current societal challenges broadly focus on mitigating and adapting to the impacts of climate change, conserving and restoring biodiversity, and ensuring human well-being. Sustainable management of water resources plays a key role in each of these areas. The impacts of climate change-driven intensification of the global water cycle are amplified in urban areas due to widespread surface sealing, the overexploitation of available water resources and water pollution. Rapidly increasing urban populations concomitant with increasing frequency and intensity of extreme weather events challenge ageing water infrastructure in cities.

Urban water management has traditionally been accomplished using grey infrastructure solutions, including sewer networks, dams, levees, channels, and embankments. These grey infrastructure solutions are reliable but do not resolve the discontinuity of the urban hydrologic cycle presented by surface sealing and limited infiltration. The integration of nature-based solutions (NBS) with conventional urban water networks can reconnect the urban hydrologic cycle whilst improving floodwater management and the quality of surface runoff in cities, simultaneously providing multiple environmental, social and economic co-benefits. In addition to the many co-benefits afforded urban citizens, decentralising water management through hybridisation of green-blue infrastructure such as wetlands, forests and floodplains and traditional grey infrastructure can benefit water utilities, flood management agencies, and hydropower companies by enhancing the respective system’s capacity to respond to extreme weather events (Browder et al., 2019).

A diverse range of NBS applicable at different spatial scales can support urban mitigation of adaptation to climate change and enhance the connectivity of the urban hydrologic cycle. Although a multitude of guidance documents exists, there is currently no widely accepted standard for NBS selection and implementation or for blue-green-grey infrastructure integration. Thus, decision-makers are tasked with interpreting existing NBS and hybrid blue-green-grey infrastructure guidance documents concomitant with numerous applicable policy instruments (European Parliament, Council of the European Union, 2000; UNISDR, 2015; United Nations, n.d.). Decentralisation of urban water systems through the implementation of NBS or hybrid blue-green-grey infrastructure must be underpinned by a robust roadmapping framework, including clear indicators of NBS performance and impact in order to facilitate adaptive management of assets (Wendling et al., 2019). System performance and impact indicators must in turn align with applicable national and international policy instruments, further contributing to the European Green Deal strategy (European Commission, 2019) by addressing the climate change adaptation and ecosystem services provision in the urban areas. The present study explores the existing policy context with respect to NBS targeting urban water quantity and quality management, including the planning, implementation and evaluation of deployed solutions.

2 METHODS

Water-related European and international policy instruments and NBS guidance documents were analysed concomitant with selected Sustainable Development Goals (SDGs) and associated indicators (United Nations, n.d.). The SDGs selected for evaluation included 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.b, 11.3, 11.4, 11.5, 11.7, 11.a, 11.b, 13.1, 13.2, 13.3, 13.a, 14.2, 15.1, and 15.3. Indicators specified for each of the listed SDGs were qualitatively evaluated with respect to alignment with major policy instruments, including the Water Framework Directive (European Parliament, Council of the European Union, 2000), Drinking Water Directive (Council of the European Union, 1998), Floods Directive (European Parliament, Council of the European Union, 2007), Groundwater Directive (European Parliament, Council of the European Union, 2006), Urban Wastewater Treatment Directive (Council of the European Communities, 1991), Air Quality Directive (European Parliament, Council of the European Union, 2008), Habitats Directive (Council of the European Communities, 1992), Birds Directive (European Parliament, Council of the European Union, 2009), and the Sendai Disaster and Risk Reduction Framework (UNISDR, 2015). In addition, the IUCN standards for NBS (IUCN, 2020), including recommended NBS indicators, were qualitatively assessed with respect to alignment with SDG targets and indicators. Specific indicators of NBS or hybrid green-blue-grey infrastructure for urban water management that support urban water resilience and closely align with these major policy instruments were identified and summarised for decision-makers.

3 RESULTS

SDG6.1, *by 2030, achieve universal and equitable access to safe and affordable drinking water for all*, specifies indicator 6.1.1, the proportion of population using safely managed drinking water sources. Improved drinking water sources are defined as water piped into a dwelling, yard or plot, public taps or standpipes, boreholes or tubewells, protected dug wells and springs, packaged water, delivered water and rainwater. The Drinking Water Directive (DWD) targets drinking water quality but does not address the proportion of population using an improved water source, whereas SDG6.1 focuses primarily on the proportion of users rather than on the quality of water provided. The DWD and SDG6.1 are complementary with respect to the holistic assessment of drinking water supply, both availability of supply and drinking water quality. Nature-based solutions can enhance or maintain both the quality of water and the quantity of available water by filtering pollutants and increasing water infiltration. At a local scale, these can include, e.g., infiltration or bioretention basins, rain gardens, vegetated filter strips (bioswales), wetlands, multifunctional green spaces, and other green infrastructures that provide water filtration and infiltration capacity. Indicators that assess surface water and/or groundwater quality, specifically for sources of drinking water supply, can address the water quality element SDG6.1.

SDG6.2, *by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations*, specifies indicator 6.2.1, the proportion of population using (a) safely managed sanitation services, and (b) a hand-washing facility with soap and water. Basic sanitation facilities are defined as flush or pour toilets connected to sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, pit latrines with a slab, and composting toilets. The Urban Waste Water Treatment Directive (UWWTD) sets forth the requirements for urban wastewater treatment, including collection and quality of the discharged effluents. It indirectly contributes to the assessment of the population using basic sanitation facilities based on the UWWTD requirements to establish urban wastewater collection systems or other appropriate systems, both of which are targeted by SDG6.2. Access to handwashing facilities is not addressed by the UWWTD. Nature-based and hybrid water management solutions supporting SDG6.2 may include wetlands or similar water filtration green infrastructures for treatment of wastewater effluents. Where composted wastes meet minimum quality standards per the Waste Framework Directive (91/156/EED), Council Directive 86/278/EEC on the protection of the environment and the Council Directive 91/271/EEC concerning urban waste water treatment, and subject to local regulations, composted waste may be amended to soil to increase organic matter content and improve soil fertility. Indicators that address effluent quality and those related to decentralised wastewater treatment include, e.g., the extent of natural or constructed wetlands, nutrient (nitrogen and phosphorus) concentration or load, basic water quality characteristics (pH, electrical conductivity, dissolved oxygen and temperature), and concentration of total suspended solids.

SDG6.3, *by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally*, specifies two indicators. Indicator 6.3.1 refers to the proportion of on- and off-site wastewater safely treated, whereas indicator 6.3.2, the proportion of water bodies with good ambient water quality, assesses compliance with water quality targets. The Water Framework Directive (WFD) is directly related to SDG6.3 and provides criteria for the holistic assessment of the status of waterbodies. The DWD is directly related to both the WFD and SDG6.3 in terms of establishing and monitoring chemical and microbial quality of groundwater and surface waters used as a drinking water source. The WFD provides the framework for evaluation of water quality status whilst indicator 6.3.1 defines the calculation for the proportion of waterbodies having good status. Similar to SDG6.2, NBS and hybrid water management solutions can support improved water quality by filtering pollutants in wastewater prior to the discharge of effluents to local waterbodies. Constructed treatment wetlands are commonly used for this purpose.

SDG6.4, *by 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity*, specifies indicators related to water-use efficiency and water stress. Indicator 6.4.1 examines the change in water use efficiency over time in each of three sectors: (i) agriculture, forestry and fishing; (ii) mining and quarrying, manufacturing, electricity, gas, steam and air conditioning supply, and construction; and, (iii) all service sectors. Indicator 6.4.2, level of water stress, is defined as the total volume of freshwater withdrawal as a percentage of total renewable freshwater resources less environmental water requirements. The WFD calls for balance between water abstraction and recharge, supporting indicator 6.3.2. The implementation of NBS and hybrid water management solutions in urban areas can contribute to the realisation of SDG 6.4 by reducing the proportion of sealed surfaces in urban areas, facilitating greater infiltration and groundwater recharge, and the potential for rainwater harvesting.

SDG6.5, *by 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate*, defines two indicators addressing the degree of integrated water resources management implementation (6.5.1) and the proportion of transboundary basin areas with an operational arrangement for water cooperation (6.5.2). IUCN NBS criterion 2 calls for NBS design informed by scale, with indicators specifying: recognition of and response to interactions between the economy, society and ecosystems (2.1); integration of NBS design with complementary interventions and synergies across sectors (2.2); and incorporation of risk identification and management beyond the intervention site in NBS design (IUCN, 2020). The Sendai Disaster and Risk Reduction framework is consistent with indicator 6.5.2 as it calls for coordination efforts across sectors, including international, regional, sub-regional, transboundary and bilateral cooperation in the prevention and reduction of disaster risk. As an ecosystem-based approach, NBS and hybrid water management solutions are central to integrated water resources management (IWRM) concept. NBS are particularly well suited to large-scale regional and sub-regional IWRM schemes, including flood risk reduction, but also provide options for localised water management. Solutions may include, for example: the conservation of natural areas within the urban catchment; protection and/or restoration of wetlands; reforestation; river, stream and floodplain restoration; and/or the implementation of green infrastructures for water infiltration, filtration and biofiltration.

The two indicators for SDG6.6, *by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes*, specify analysis of change in the extent of water-related ecosystems over time (including extent of vegetated wetlands, rivers and estuaries, lakes, aquifers and artificial waterbodies; 6.6.1a), and in the total wetland area (6.6.1b). NBS targeting the conservation or restoration of terrestrial and aquatic ecosystems directly support SDG6.6. In addition, the integration of NBS and hybrid solutions in urban areas supports the restoration of hydrologic connectivity by moving away from water management using hard barriers and piped drains. Nature-based and hybrid water management solutions use natural processes such as evapotranspiration, filtration and infiltration to manage water quantity and quality. Indicators related to both the condition and extent of water-related ecosystems, and specifically wetlands, can track progress towards this goal.

SDG6.b is *support and strengthen the participation of local communities in improving water and sanitation management*. The indicator for SDG6.b is the proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management. This may be supported by the IUCN NBS criteria 1 requiring NBS to effectively address societal challenges, assuming that water and sanitation management are prioritized by rightsholder(s) and beneficiaries (IUCN indicator 1.1). The Sendai framework supports SDG6.b by calling for all-of society engagement and partnership, with local authorities and local communities empowered to reduce disaster risk with federal State Governments playing an enabling, guiding and coordinating role. Nature-based and hybrid water management solutions are fully consistent with SDG6.b through the co-creation, co-implementation and co-management of NBS with stakeholders. Applicable NBS indicators include the evaluation of the openness of participatory processes, specifically those related to municipal water and sanitation decision-making.

Indicators of the openness of participatory processes are also applicable to SDG11.3, *by 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries*. Recommended indicator 11.3.1 is a calculation of the ratio of land consumption to population growth rate, whilst indicator 11.3.2 is the proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically. This second indicator is supported by IUCN NBS criterion 5, NBS are based on inclusive, transparent and empowering governance processes, and its sub-indicators. SDG11.3 is also consistent with the Sendai framework goal to prevent and reduce existing disaster risk through integrated and inclusive measures that prevent and reduce disaster exposure and vulnerability, increase preparedness and thus strengthen resilience. In addition to all-of-society engagement and partnership, the Sendai framework notes the need for informed public and private investment for sustainable development as well as increasing public education and awareness of disaster risk. These elements are similarly required for the long-term sustainability of NBS and hybrid water management solutions. NBS are characterised by stakeholder participation in their creation, implementation and management.

The indicator for SDG11.4, *strengthen efforts to protect and safeguard the world's cultural and natural heritage*, is the share of national or municipal budget dedicated to the preservation, protection and conservation of national cultural heritage, including World Heritage Sites. Nature-based and hybrid water management solutions focus directly on environmental assets, but can provide benefits such as flood mitigation that support the protection of built heritage.

The Sendai framework encourages the establishment of mechanisms and incentives to ensure compliance with safety-enhancing provisions of sectoral regulations, including those addressing land use and planning, building codes, and environmental and resource management. Management of disaster risk is thus aimed at protecting cultural and environmental assets as well as persons and their property, health, livelihoods and productive assets. SDG11.5, *by 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations*, specifies two indicators by which to measure progress towards this goal. Indicator 11.5.1 is the number of deaths, missing persons and persons directly affected by disaster per 100 000 people, whilst indicator 11.5.2 quantifies direct economic loss in relation to global GDP, damage to critical infrastructure, and disruptions to basic services attributed to disasters. SDG11.5 is directly aligned with the Sendai framework goals to substantially reduce global disaster mortality and the number of people affected by disaster, and to reduce disaster economic loss, damage to critical infrastructure and disruption of basic services by 2030. Nature-based and hybrid approaches strongly support SDG11.5, in particular flood impact mitigation through infiltration and evapotranspiration (bioswales, rain gardens, urban parks and forests, wetlands), and retention and detention (retention and detention ponds). Indicators

NBS may include a range of different public green spaces, such as urban parks and gardens, natural meadow areas, urban forests, linear parks that serve as green pedestrian and bicycle routes, etc. Implementation of NBS in urban areas is directly related to SDG11.7, *by 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children,* *older persons and persons with disabilities*. SDG11.7 is, in turn, applicable to urban water management with respect to water infiltration in areas of the city with unsealed surfaces. Indicators for SDG11.7 include the average share of the built-up area of a city that is open space for public use for all (11.7.1) and the proportion of persons subject to physical or sexual harassment during the previous 12 months (11.7.2). Additional indicators in this category may include perceived accessibility and perceived safety of public green spaces.

The indicator for tracking progress on SDG11.a, *support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning*, is the proportion of the population living in cities that implement urban and regional development plans that integrate population projections and resource needs. Because of their ecosystem focus and central role in IWRM, NBS and hybrid water management solutions can play an important role in regional and national development plans. In particular, catchment scale NBS that transcend jurisdictional boundaries can provide substantial co-benefits to downstream populations or to the wider environment.

Ecosystem degradation is a major driver of disaster risk. Operationalisation of ecosystem-based disaster and risk resilience via implementation of NBS and hybrid water management solutions can support the realization of SDGs 11.b and 13.1 whilst providing multiple co-benefits in the form of ecosystem services. SDG11.b is to *by 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels*. Indicators include the number of countries (11.b.1) and local governments (11.b.2) that adopt and implement disaster risk reduction strategies in line with the Sendai Framework. SDG13.1, *strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries*, similarly cites as indicators the number of countries (13.1.2) and local governments (13.1.3) that adopt and implement disaster risk reduction strategies in line with the Sendai Framework, as well as the number of deaths, missing persons and persons affected by disaster per 100 000 people (13.1.1).

SDG13.2 is to *integrate climate change measures into national policies, strategies and planning*. In many parts of the world, regions subject to flooding coincide with over-exploitation of available freshwater resources and scarcity due to a temporal misalignment between water supply (precipitation) and demand (withdrawal) which is exacerbated in urban areas by limited infiltration and groundwater recharge. Climate change and freshwater resource security are critical interrelated worldwide concerns in the face of the growing global population. Indicators of progress towards SDG13.2 should assess the extent to which policy instruments incorporate science-based climate change scenarios, including water resources availability.

Through co-creation, co-implementation and co-management processes, NBS and hybrid water management solutions contribute to SDG13.3, *improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning*. Indicator 13.1.1 specifies the extent to which global citizenship education and education for sustainable development are mainstreamed in national education policies, curricula, teacher education and student assessment. Creation, implementation and management of NBS and hybrid solutions can augment formal educational programmes by creating informal educational opportunities for the local community. Additional indicators of progress towards SDG13.3 may include, e.g., the creation of and citizen involvement in environmental education activities or citizen science initiatives, or citizens' awareness regarding urban nature and ecosystem services. IUCN NBS indicator 1.2 calls for clear understanding and documentation of the societal challenge(s) addressed by NBS; specific metrics related to environmental awareness and stakeholder involvement in disaster resilience planning can support evaluation of stakeholders' understanding.

Resilience of coastal and insular territories from storm surges and coastal erosion is addressed by SDG14.2 is *by 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans*. The SDG14.2 is reliant on the Integrated Coastal Zone Management (ICZM) concept, an ecosystem-based adaptation approach, in which NBS play a central role, for example by reducing coastal erosion, flood susceptibility and enhancing carbon sequestration. The NBS for ecosystem-based adaptation of coastal and insular areas and the progress towards SDG14.2 implementation can additionally be evaluated in terms of economic benefits, such as avoided costs for flood damages and casualties, and provisioning ecosystem services, such as fisheries or aquaculture.

SDG15.1, *by 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements*, is heavily supported by the Birds (2009/147/EC) and Habitats (92/43/EEC) Directives that aim at conserving the natural habitats and wild flora and fauna. NBS comprising semi-natural and natural water storage and transport systems, such as restored waterbodies and waterways, their floodplains and wetlands, within urban agglomerations contribute to the preservation and re-establishment of natural habitats. They additionally contribute to the water balance of urban catchments and consequently on their ability to convey excess runoff thus providing vital regulating ecosystem services. The establishment of NBS such as urban forests supports the progress towards the indicator 15.1.1, forest area as a proportion of total land area.

SDG15.3, *by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world* is evaluated as the proportion of total land that is degraded over total land area within the national boundary. Soil degradation and extensive soil sealing are recognised to be the primary drivers for increased risk for biodiversity, water scarcity and flooding (European Commission, 2012). Nature-based and hybrid water management solutions provide the enhancement of the natural water loss through evapotranspiration (e.g., urban parks and forests) and infiltration (e.g., rain gardens and bioswales). Soil quality management can be addressed through erosion control and fertility management measures, e.g., by planting deep-rooted perennials or the addition of soil amendments. The progress towards the restoration of degraded land and soil rehabilitation can be evaluated by establishing indicators evaluating the ratio of un-sealed surfaces to the total area of impervious surfaces, or as total area, area per capita or percent of degraded land reclaimed.

SDGs 14.2, 15.1 and 15.3 are strongly supported by the IUCN criterion 3, which states that NBS result in a net gain to biodiversity and ecosystem integrity. Implemented NBS should seek to enhance ecosystem function and connectivity, both to support biodiversity and ecosystem integrity and to ensure the long-term resilience and durability of the NBS. Recommended indicators for this IUCN criterion, which support the aforementioned SDGs, include:

- NBS actions directly respond to evidence-based assessment of ecosystem condition and drivers of degradation/loss;
- biodiversity outcomes are identified, benchmarked and periodically assessed; monitoring includes periodic assessments of unintended adverse consequences to local ecosystems arising from the NBS; and,
- opportunities to enhance ecosystem integrity and connectivity are explicitly identified and incorporated in the NBS strategy.

Conclusions

At an international level, the existing policy context broadly supports the integration of NBS with technical or "engineered" solutions to reconnect the urban hydrologic cycle and sustainably manage both surface water quality and quantity, including the planning, implementation and evaluation of deployed solutions. Although consistent with one another, the multiple applicable policy instruments and recommendations with respect to the design and implementation of NBS and hybrid water management solutions may be viewed by decision-makers as overly complex or burdensome. The derivation of a simple, user-friendly framework of indicators that support integrated urban water resources management via implementation of NBS and hybrid infrastructure solutions supports NBS mainstreaming, as well as climate change adaptation and mitigation efforts that employ NBS and urban greening strategies.

Water security and resilience to water-related perturbations of urban areas and agglomerations are directly linked to the national and international policy measures and implications, and the legal obligations municipalities are required to meet. Although the EU-level frameworks and legal acts provide a holistic assessment, they are not successful at providing the *metrics* assisting in providing the ways to meet the legal requirements and the SDGs. Each of the aforementioned indicators of progress towards applicable SDGs should be adopted as an indicator of NBS or hybrid water management system performance or impact, and augmented with additional indicators from the IUCN standards for NBS (IUCN, 2020) and other applicable metrics. A draft assessment scheme for water resource management-focused NBS and hybrid solutions, organized by the People-Planet-Prosperity pillars of sustainable development, is presented in Table 1. Although the economic feasibility of innovations for water and climate resilience is widely recognized, relatively fewer metrics related to the Prosperity pillar of sustainable development have been identified to date that are specific to urban water management.

Table 1. A draft assessment scheme for water resource management-focused NBS and hybrid solutions

People	Planet	Prosperity
Proportion of population using improved drinking water sources	Proportion of discharged wastewater compliant with UWWTD effluent quality	Water use efficiency over time in: agriculture, forestry and fishing; mining and quarrying, manufacturing, electricity, gas, steam and air conditioning supply, and construction; and, all service sectors
Proportion of population with access to drinking water compliant with DWD quality guidelines	Proportion of sewage sludge or composted waste utilised as a soil amendment/ to enhance soil fertility	Recognition of and response to interactions between the economy, society and ecosystems
Proportion of population using safely managed sanitation services	Proportion of surface waterbodies characterised by good ecological status	Integration of NBS design with complementary interventions and synergies across sectors
Proportion of local administrative units with established and operational policies and	Quantitative status of groundwater	Share of national or municipal budget dedicated to the preservation, protection and

procedures for participation of local communities in water and sanitation management	Groundwater chemical status	conservation of national cultural heritage, including World Heritage Sites
Openness of participatory processes	Degree of integrated water resources management implementation	Direct economic loss in relation to global GDP, damage to critical infrastructure, and disruptions to basic services attributed to disasters
Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically	Proportion of transboundary basin areas with an operational arrangement for water cooperation	Proportion of the population living in cities that implement urban and regional development plans that integrate population projections and resource needs
Adoption and implementation of disaster risk reduction strategies in line with the Sendai Framework	Change in the extent of water-related ecosystems over time	Total value of critical urban infrastructures exposed to disaster risks
Stakeholder involvement in disaster resilience planning	Change in the extent of total wetland area over time	Economic value of productive activities vulnerable to disaster risks
Incorporation of risk identification and management beyond the intervention site in NBS design	Forest area as a proportion of total land area	Mean land or property value in proximity to urban green space
Number of deaths, missing persons and persons directly affected by disaster per 100 000 people	Ratio of land consumption to population growth rate	Public and private finance attracted to NBS and hybrid water management solution projects
Average share of the built-up area of a city that is open space for public use for all	Extent to which local policy instruments incorporate science-based climate change scenarios, including water resources availability	
Perceived accessibility of urban public green spaces	Proportion of total land that is degraded	
Proportion of persons subject to physical or sexual harassment during the previous 12 months (in or near green and public spaces)	Total area, area per capita or percent of degraded land reclaimed	
Perceived safety of urban public green spaces	Ratio of un-sealed surfaces to the total area of impervious surfaces	
Citizen involvement in environmental education activities or citizen science initiatives	Soil organic matter content	
	Soil fertility status	
Citizens' awareness regarding urban nature and ecosystem services	Structural and functional connectivity of urban green and blue spaces	

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