04

What constitutes NBS monitoring?

How do I develop a robust NBS monitoring plan?

How can I execute monitoring and impact assessment activities?

What indicators of NBS impact can I use?

How do I select appropriate indicators of NBS impact?

Indicators of NBS performance and impact

Appendix of Methods

Why is it important to evaluate the impacts of NBS?

How can I ensure NBS work for Disaster Risk Reduction?

What kinds of NBS monitoring data can I gather, and how should I manage these data?

4 Indicators of NBS Performance and Impact

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Summary

***What** is this chapter about?*

This chapter introduces 12 categories of societal challenges that NBS can address (Section 4.1). These are conceptually mapped against the UN Sustainable Development Goals. For each of the 12 societal challenge areas, Section 4.2 outlines and lists indicators to evaluate the performance and impact of NBS. It reviews the different types of NBS, gives examples of each NBS type, and lists the indicators related to the particular societal challenge in a series of tables. Associated methodologies are compiled in the related Appendix of Methods. To help navigate, the indicators are classified as structural, process-based or outcome-oriented. *Structural indicators* are particularly useful during the NBS planning process and can help identify where resources may be lacking or highlight policy and/or procedural gaps that require attention. *Process-based* indicators can provide information about the value or impacts of the collaborative processes that underpin NBS (co-creation, co-implementation and co-management). The *outcome-oriented* indicators are useful to understand NBS performance by establishing an understanding of baseline (pre-NBS) conditions and following changes to these conditions after NBS implementation. We distinguish between recommended and additional indicators. Recommended indicators are considered the most important ones to monitor NBS impact. Additional indicators can provide highly valuable information, depending on local context and particular data needs. The chapter concludes with a reflection on the importance of critical thinking to select the right indicators for a holistic assessment of NBS and the development of emerging indicators (Section 4.3).

***How** can I use this chapter in my work with NBS?*

This chapter helps to select the most appropriate indicators to assess the performance and impact of a given NBS. As resources are limited and it is simply not possible to monitor every single indicator, this buffet-style approach enables tailoring of a monitoring programme to address a specific context, both with respect to the challenges addressed and the NBS implemented in response.

***When** should I use this knowledge in my work with NBS?*

Selection of indicators can occur at any time during the cycle of adaptive management of NBS. The initial monitoring and assessment plan identifies “must-have” outcomes that can be linked to specific indicators. For example, if the primary objective of a given NBS is to attenuate flooding then indicators related to the impacts of floods (extent of flooded land, duration of flooding, number of buildings and/or persons affected, etc.) are critical to evaluate NBS impact. During the NBS co-creation process, review of planned NBS impact indicators can help to identify potential additional benefits and inform NBS design. Indicators can be added or replaced at any time in response to observed changes or new challenges (adaptive monitoring).

***How** does this chapter link with the other parts of the handbook?*

The previous chapters have detailed the concept of NBS and briefly described how NBS can support relevant public policies, why it is important to monitor NBS performance and evaluate their impacts, and how to develop a monitoring and evaluation strategy. This chapter focuses on which indicators to use in different local contexts in order to understand NBS performance and impacts. Chapter 4 should be read in conjunction with the Appendix of Methods, where the specific details of each indicator are further clarified, along with a brief methodology. The following Chapters 5 and 6 expand upon the list of indicators presented here by illustrating the application of selected indicators to NBS in different contexts, including NBS specifically designed for disaster risk reduction (DRR). Chapter 7 describes the different types of NBS monitoring data and provides detailed information about how to acquire and evaluate the quality these data.

4.1 Societal challenge areas addressed by NBS

The 2017 EKLIPSE Expert Working Group impact evaluation framework report (Raymond et al., 2017) identified ten challenge areas related to climate resilience in urban areas. The present report expands these original ten challenge areas to 12 separate societal challenge areas that can potentially be addressed by NBS (Figure 4-1). In addition to presenting a suite of indicators applicable to each challenge area, methods of indicator determination are presented in the separate report *Evaluating the Impact of Nature-based Solutions: Appendix of Methods* to support the application of impact indicators. The overarching objective of this *Handbook* and the accompanying *Appendix of Methods* is to provide standardized guidance and methods of indicator determination to support establishment of a robust European evidence base on NBS performance and impact. In order to compare different types of NBS, implemented in different environments and at varying scale we need to measure the same variables, using the same methods and report these outcomes using the same units of measure.

The 12 challenge areas elaborated herein are:

1. Climate Resilience
2. Water Management
3. Natural and Climate Hazards
4. Green Space Management
5. Biodiversity Enhancement
6. Air Quality
7. Place Regeneration
8. Knowledge and Social Capacity Building for Sustainable Urban Transformation
9. Participatory Planning and Governance
10. Social Justice and Social Cohesion
11. Health and Wellbeing
12. New Economic Opportunities and Green Jobs

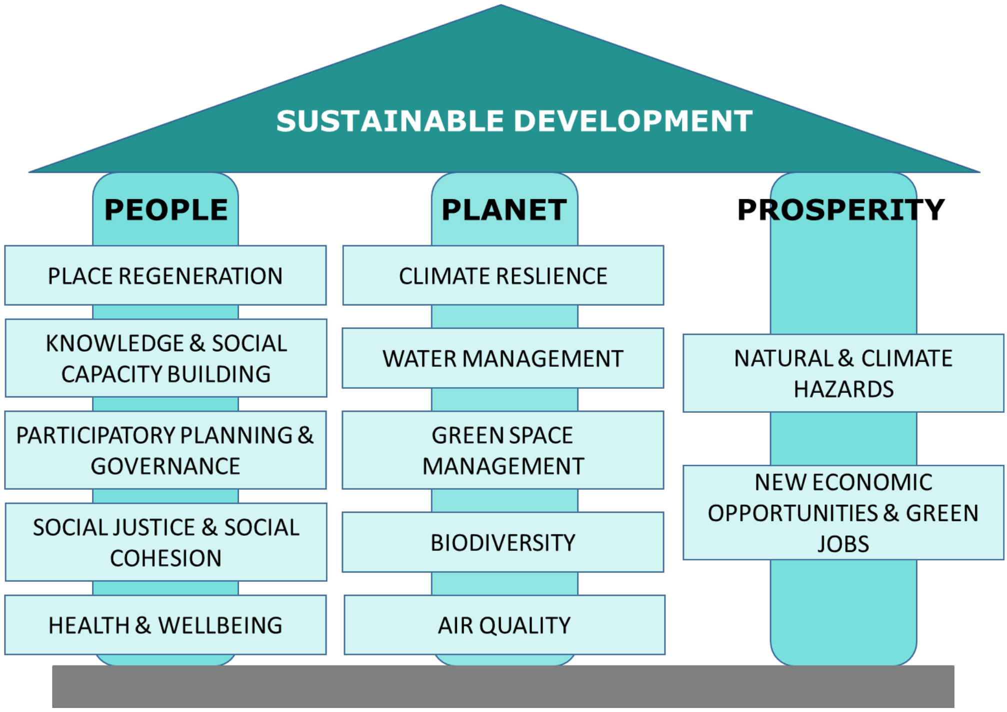

Figure 4-1. Conceptual mapping of societal challenge areas that can be addressed by NBS onto the triad of People, Planet, Prosperity pillars of sustainable development

Climate Resilience: Nature-based solutions are capable of providing resilience to the impacts of climate change through the provision of ecosystem services, and by enhancing social awareness and actions to combat climate change. The co-benefits delivered by NBS support climate change mitigation and adaptation efforts, particularly in urban areas, contributing to the liveability of cities.

Water Management: Nature-based solutions provide an excellent opportunity to address a diversity of issues associated with anthropogenic impacts on the water cycle. These include poor water quality, water availability for extraction, groundwater and surface water levels, recharging of aquifers, stormwater management, water treatment, wetland habitat management, soil water management, and ecological quality.

Natural and Climate Hazards: Risk is a combination of hazard and (negative) consequences. Nature-based solutions employed for disaster risk reduction are expected to reduce risk level (i.e., influence risk components corresponding to hazard or vulnerability). At the same time, NBS deliver further social, human, and environmental co-benefits. This challenge category was expanded based upon the further development of the "Coastal Resilience" challenge area described in the EKLIPSE Expert Working Group impact evaluation framework (Raymond et al., 2017) to include a wider array of climate-related and natural hazards.

Green Space Management: Green space management refers to the planning, establishment and maintenance of green and blue infrastructure in urban areas. Green and blue infrastructure (abbreviated as urban green infrastructure, UGI) are a type of NBS that refers specifically to the strategically managed network of natural and semi-natural ecosystems within urban boundaries. UGI provides a range of ecological and socio-economic benefits (Raymond et al., 2017) and, if correctly managed, contributes to solutions for numerous challenges such as air and noise pollution, heat waves, flooding and concerns regarding public well-being (Maes et al., 2019). NBS support the wider deployment of green and blue infrastructure (EC, 2019a; EC, 2019b), thus supporting the *EU Green Infrastructure Strategy* (EC, 2013) and the EU Biodiversity Strategy for 2030 (EC, 2020).

Biodiversity Enhancement: Biodiversity loss and ecosystem collapse are among the greatest threats society faces in the near term. There are five primary direct drivers of biodiversity loss: changes in land and sea use, overexploitation, climate change, pollution, and invasive alien species. The link between climate change and biodiversity loss involves a feedback loop whereby climate change accelerates loss of natural capital, which is in turn a key driver of climate change. NBS support the *EU Biodiversity Strategy for 2030* (EC, 2020) through the purposeful establishment of protected areas and restoration of degraded ecosystems. The enhancement and/or conservation of biodiversity was considered as part of the Green Space Management challenge in the EKLIPSE Expert Working Group impact evaluation framework (Raymond et al., 2017). Here, we consider Biodiversity Enhancement as a separate challenge area.

Air Quality: NBS based on the creation, enhancement, or restoration of ecosystems in human-dominated environments play a relevant role in removing air pollutants and carbon dioxide, reducing the air temperature (which slows down the creation of secondary pollutants) and increasing oxygen concentration, contributing to a beneficial atmospheric composition for human life.

Place Regeneration: Urbanisation has a lasting impact on the natural environment of towns and cities, not only visible through dereliction, but also through increasing environmental footprint fuelled by economic growth and unsustainable patterns of consumption. Nature-based solutions hold the potential to contribute to the aim of ensuring successful achievement of sustainable place regeneration by way of enhancing the green space and people-nature connection, as well as using fewer environmental resources, enhancing place resilience to natural disasters, fostering collective participation and social cohesion, and improving individual wellbeing (Korkmaz and Balaban, 2020; Roberts and Sykes, 2000; Xiang et al., 2017).

Knowledge and Social Capacity Building for Sustainable Urban Transformation: Sustainable urban transformation delineates sustainable urban structures and environments, as well as radical social, economic, cultural, organizational, governmental, and physical change processes (Ernst et al., 2016; McCormick et al., 2013). Knowledge and social capacity building through educational initiatives can contribute to the complex enterprise of amassing resources for sustainable urban places. This challenge area is a new addition to the original ten challenges described in the EKLIPSE Expert Working Group impact evaluation framework (Raymond et al., 2017).

Participatory Planning and Governance: Nature-based solutions demand approaches to planning and governance frameworks that support accessibility to green spaces, while maintaining their quality for ecosystem services provision. Urban environmental transformation is a highly complex undertaking that requires open collaborative governance and robust capacities for participatory planning. Nature-based solutions already implemented and functional across Europe have contributed a wealth of knowledge in the area of participatory planning and governance, indicating, for instance, that successful outcomes call for openness to learning and experimenting along other urban actors so as to co-create and co-maintain nature-based solutions while shaping institutional spaces in cities that allow for this co-creation, social innovation and collaboration to continue (Frantzeskaki, 2019). Significantly, open collaborative governance and participatory planning invested in nature-based solution strategies bring forward opportunities for social transformation and increased social inclusiveness in cities (Wendling et al., 2018).

Social Justice and Social Cohesion: Nature-based solutions have been linked to the notion of environmental justice across studies that explore the role of supporting urban processes involving equal access to neighbourhood green space in fostering social cohesion (e.g., bridging and bonding social capital) towards the cultural integration of typically-excluded social groups, like elderly, immigrants, persons with disabilities, etc. (i.e., recognition-based justice) (Ibes, 2015; Kweon et al., 1998; Raymond et al., 2017; Raymond et al., 2016; van Den Berg et al., 2017). Recently, Gentin et al. (2019) analysed the premises for a nature-based integration of immigrants in Europe and urged on researchers to set aside descriptions and analyses of immigrants’ perceptions or use of nature, and turn their focus towards exploring and developing nature-based solutions for the purposes of social integration.

Health and Wellbeing: Critical social and environmental determinants of health, including clean air, safe drinking water, sufficient food and secure shelter, are impacted by climate change[44]. More than half of the world’s population lives in urban areas (towns and cities), and this number is projected to increase to two in three people by 2050[45]. Climate change and other environmental issues affect all categories of population, however it is most threatening in urban areas where the majority of the population live. This means that the consequences of climate change, poor air quality and other current concerns are often very obvious and disruptive to urban living, and can affect services such as sanitation leading to public health issues.

New Economic Opportunities and Green Jobs: Key criteria of NBS are their cost-effectiveness, and their capacity to simultaneously provide environmental, social and economic benefits in support of resilience building. The adoption and implementation of NBS has the potential to create new economic opportunities

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[44] https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
[45] http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

and jobs in the green sector by enabling low-carbon, resource-efficient and socially inclusive economic growth. Within this paradigm, economic growth is driven by public and private investment in activities, infrastructure and assets that support reduced emissions of carbon and pollutants, and increased energy and resource efficiency whilst enhancing biodiversity and the provision of ecosystem services.

4.2 Recommended and Additional indicators for NBS impact assessment

The NBS impact evaluation relies strongly on the adoption of quantitative and qualitative impact markers – the performance and impact indicators. These serve as means for assessing the progress of an adopted pathway targeted at achieving specific objectives, including those of various temporal and spatial scales. The Recommended indicators for each of the twelve societal challenge areas presented herein serve as a 'starting point' for evaluating the NBS impact, and they are considered as the primary indicators to be addressed when creating NBS monitoring and evaluation schemes. The Recommended indicators listed herein represent a foundation of performance and impact indicators to be considered for all NBS projects and that they should also provide sufficient flexibility to be applicable to all NBS scenarios.

The list of Additional indicators comprise the remaining NBS performance and impact indicators adopted by the H2020 NBS project teams involved in the production of this Handbook (see Chapter 1), and can be used to complement the list of Recommended indicators for a more holistic assessment. The selection of Additional indicators aligns with specific NBS project objectives. Some examples of Additional indicator selection are presented in the following chapter (Chapter 5).

A suite of Recommended and Additional indicators for each of the twelve identified societal challenge areas are outlined in the following sub-sections. Indicators of NBS impact have been classified as structural, process or outcome based (Donabedian, 1966) to support the selection of a suite of indicators that holistically address the process of NBS co-creation, co-implementation and co-management.

- **Structural indicators (S)** – refer to supporting <u>infrastructure and resources</u> in place to achieve the desired goals (people, material, policies and procedures)

- **Process indicators (P)** – refer to the efficiency, quality, or consistency of specific <u>procedures</u> employed to achieve the desired goals

- **Outcome indicators (O)** – refer to <u>accomplishments or impacts</u>

Whilst this classification does not explicitly refer to the timing of indicator use, it follows that the structural indicators may be most useful during the planning of NBS, i.e., to determine what resources or supporting policies may be needed to ensure the success of the proposed NBS action. The process indicators are useful to evaluate the methods used to co-create, co-implement and co-manage NBS, and so can be applied throughout the adaptive management cycle but are most relevant during periods of intense activity. A large proportion of the NBS impact indicators listed herein are primarily focused on the impact or end result of NBS actions.

Note that nearly all of the indicators listed here can be used prior to NBS implementation to establish an understanding of pre-NBS, or 'baseline', conditions as well as during and following NBS actions. Comparison of pre-NBS measures with additional measurements during or following NBS implementation will show how conditions change with time. Measurements collected over time can be used to illustrate the longer-term impacts of NBS and how different outcomes are realised with time. It is important to be careful interpreting data, as not all observed changes can necessarily be directly attributed to NBS actions. In some cases the impacts of NBS may be more clear when comparing measurements taken at the same time at two different sites, i.e., the NBS site and an analogous location without NBS (a 'control site'). This is particularly important when there are multiple changes to an area or there are external influences on the system, such as significant changes to hydrologic regime from the original 'baseline' condition.

The following tables also show the applicability of each indicator to different types of NBS. Nature-based solutions can be broadly grouped based upon their primary objective or function and by the level of ecosystem intervention. The following NBS typology proposed by Eggermont et al. (2015) has been widely adopted (Figure 4-2):

- **Type 1 NBS** – minimal or no intervention in ecosystems, with objectives related to maintaining or improving delivery of ecosystem services within and beyond the protected ecosystems

- **Type 2 NBS** – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions

- **Type 3 NBS** – characterised by highly intensive ecosystem management or creation of new ecosystems

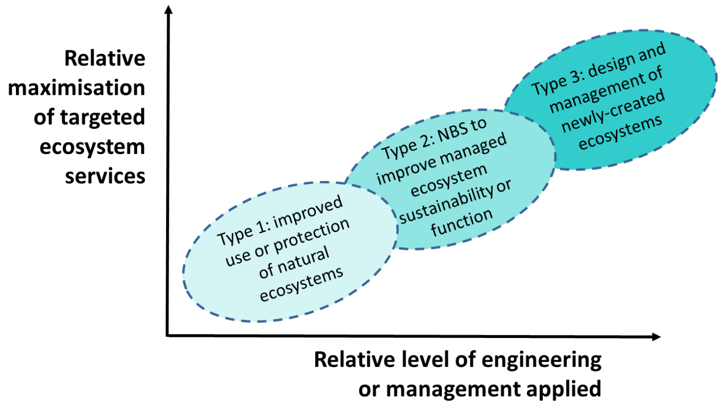

Figure 4-2. Schematic representation of NBS typology (adapted from Eggermont et al., 2015)

Type 1 NBS include protection and conservation strategies, urban planning strategies, and (environmental) monitoring strategies. Due to their nature, Type 1 NBS fall largely within the domain of governance, with implementation of Type 1 NBS strategies potentially limited or driven by a range of biophysical, social and institutional factors. Type 2 NBS are comprised of various sustainable management practices. Type 3 NBS are newly-created ecosystems, and therefore are the most "visible" solutions. **Examples** of Types 1-3 NBS may include (Cohen-Shacham et al., 2016; Eggermont et al., 2015; EC, 2015; Somarakis et al., 2019):

Type 1 NBS

- **Protection and conservation strategies**
  - Establishment of protected areas or conservation zones
  - Limitation or prevention of specific land use and/or practices
  - Ensuring of continuity of ecological networks (protection from fragmentation)
  - Maintenance or enhancement of natural wetlands

- **Urban planning strategies**
  - Ensuring of continuity of ecological network
  - Controlling urban expansion

- **Monitoring**
  - Regular monitoring of physical, chemical or biological indicators

Type 2 NBS

- **Sustainable management protocols**
  - Integrated pest/weed management
  - Spatial and/or time and frequency aspects of integrated and ecological management plans
  - Creation and preservation of habitats and shelters to support biodiversity (e.g., insect hotels for wild bees, next boxes for native bats and birds, stopover habitat/"rest stops" for migratory birds)

    - Installation of apiaries
    - Sustainable fertiliser use
    - Control of erosion through management of grazing animal stocking density and exclusion of grazing animals from riparian areas
    - Composting of organic wastes and reuse of composted material
    - Integrated water resource management
    - Protection of plant resources from pest and disease
    - Aquifer protection from pollution and sustainable management of withdrawals

Type 3 NBS

- **Green space** - multifunctional open space characterised by natural vegetation and permeable surfaces
    - Urban parks and gardens of all sizes
    - Heritage park
    - Botanical garden
    - Community garden
    - Cemetery
    - Schoolyards and sports fields
    - Meadow
    - Green strips
    - Green transport track
    - “Multifunctional” dry detention pond or vegetated drainage basin

- **Trees and shrubs**
    - Forests (including afforestation)
    - Orchards
    - Vineyards
    - Hedges/shrubs/green fences
    - Street trees

- **Soil conservation and quality management**
    - Slope revegetation
    - Cover crops
    - Windbreaks
    - Conservation tillage practices
    - Permaculture
    - Deep-rooted perennials
    - Organic matter enrichment (manure, biosolids, green manure, compost, etc.)
    - Inorganic soil conditioners and amendments (biochar, vermiculite, etc.)

- **Blue-green space establishment or restoration**
    - Riparian buffer zones
    - Mangroves
    - Saltmarsh/seagrass
    - Intertidal habitats
    - Dune structures

- **Green built environment**
    - Green roof

    - Green-blue roof
    - Green wall/façade
    - Green alley
    - Infiltration planters and tree boxes
    - Temporary and/or small-scale interventions including green furniture, green living rooms, etc.

- **Natural or semi-natural water storage and transport structures**
    - Surface wetland
    - Floodplains, floodplain reconnection with rivers
    - Restoration of degraded waterbodies
    - Restoration of degraded waterways, including re-meandering of streams and river daylighting
    - Retention pond/wet detention pond

- **Infiltration, filtration, and biofiltration structures**
    - Infiltration basin
    - Vegetated filter strip
    - Rain garden
    - Wet/dry vegetated swale, with or without check dams
    - Subsurface wetland or filtration system
    - Bioretention basin/bioretention cell

The preceding list of NBS is non-exhaustive and is intended only to provide examples of different types of NBS per the Type 1-3 classification system. The tables in this chapter indicate in general whether a particular indicator is applicable to Type 1, 2 or 3 NBS; however, the wide variety of NBS actions make consideration of all possible combinations of NBS and indicator application quite challenging. The NBS type 1-3 indicator applicability shown in the following tables should be considered a guide.

4.2.1 Climate Resilience

Indicators in the *Climate Resilience* challenge area primarily address:

- Direct impacts of NBS on greenhouse gas emissions via carbon storage and sequestration in vegetation and soil;

- Indirect impacts of NBS on avoided greenhouse gas emissions from various activities, through the provision of passive cooling, insulating and/or water treatment; and,

- Impacts of NBS on temperature and human comfort

Primary among the Recommended indicators for the *Climate Resilience* challenge area is carbon sequestration. Accounting for C stored in soil and vegetation, particularly in an urban area, can provide a tangible evaluation of local climate change mitigation and the impacts of local land use, planning and decision-making. This is reflected by *the total quantity of carbon removed or stored in soil and vegetation* (indicator 1.1) as it provides a measure for direct carbon sequestration by NBS. In contrast, the *quantity of avoided greenhouse gas emissions due to reduced building consumption* (indicator 1.2) reflects the cooling and/or insulating capacity of NBS, resulting in lesser energy use for building cooling or heating.

Nature-based solutions can be an effective means to combat urban heat islands. Although NBS cannot alter the weather, the presence of (large-scale) NBS may provide sufficient cooling to locally mitigate high temperatures during heat wave events. NBS can support reduced energy use and improved thermal comfort by moderating the urban microclimate (Demuzere et al., 2014), which is reflected by *monthly mean daily maximum* (TX_x, indicator 1.3) and *minimum* (TN_n, indicator 1.4) *temperature*, which provide a measure of the local cooling or warming effect of NBS. These indicators are related both to building energy use as well as human comfort. Indicator 1.5, *heatwave incidence*, reflects prolonged periods of abnormally high temperatures, and can be used to measure the local impact of NBS on ambient temperatures during these periods,

Additional indicators are listed that can be employed to quantify specific parameters generally related to NBS-provided ecosystem services in support of climate resilience. They can further be utilised to complement the assessment of the Recommended indicators for generating a more holistic picture of the local NBS performance.

Table 4-1. Indicators related to Climate Resilience classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
1.1	Total carbon removed or stored in vegetation and soil per unit area per unit time	kg/ha/y	O	●	●	●
1.2	Avoided greenhouse gas emissions from reduced building energy consumption	t CO_2e/y	O		●	●
1.3	Monthly mean value of daily maximum temperature (TX_x)	°C	O	●		●
1.4	Monthly mean value of daily minimum temperature (TN_n)	°C	O	●		●

1.5	Heatwave incidence: Days with temperature >90th percentile, TX90p	No./y	O	●		●
ADDITIONAL						
2.1.1 2.1.2	Total carbon stored in vegetation	kg/ha/y	O	●	●	●
2.1.3	Total leaf area	m^2	O	●	●	●
2.1.4	Carbon storage score	kg/day	O	●	●	●
2.1.5 2.1.6	Soil carbon content	ton/ha	O	●	●	●
2.1.7	Rate of soil carbon decomposition	% p.a.	O	●	●	●
2.2	Energy use savings due to NBS implementation	kWh/y	O		●	●
2.3	Carbon emissions due to building cooling	t CO_2e/y	O			●
2.4	Carbon emissions due to treatment of runoff water (combined sewers)	t CO_2e/y	O	●	●	●
2.5	Soil temperature	°C	O	●	●	●
2.6	Total surface area of wetlands	ha	O	●	●	●
2.7	Surface area of restored and/or created wetlands	ha	O	●	●	●
2.8	Aboveground tree biomass	t/ha	O	●	●	●
2.9.1	Human comfort: Universal Thermal Climate Index	°C	O	●		●
2.9.2	Thermal Comfort Score	unitless	O	●		●
2.9.3	Human comfort: Physiological Equivalent Temperature	°C	O	●		●

2.9.4	Mean or peak daytime temperature – Predicted Mean Vote-Predicted Percentage Dissatisfied	unitless	O	●		●
2.10.1	Urban Heat Island (incidence)	°C	O	●		●
2.10.2	Number of combined tropical nights and hot days	No.	O	●		●
2.10.3	Thermal Storage Score	J	O	●		●
2.10.4	Thermal Load Score	°C	O	●		●
2.11	Peak summer temperature (GI-Val)	°C	O	●		●
2.12	Maximum surface cooling	°C	O	●		●
2.13.1 2.13.2	Mean local daytime temperature	°C	O	●		●
2.13.1 2.13.2	Peak local daytime temperature	°C	O	●		●
2.14	Daily temperature range	°C	O	●		●
2.15 2.15.1 2.15.2	Air cooling	°C	O	●		●
2.16	Tree shade for local heat reduction	m^2	O	●	●	●
2.17	Rate of evapotranspiration	mm/day	O	●	●	●
2.18	Land surface temperature	°C	O	●	●	●
2.19	Surface reflectance - albedo	unitless	O	●		●
2.20	Carbon emissions from vehicle traffic	t C/y	O	●		●

†**Type 1 NBS** – minimal or no intervention in ecosystems, with objectives related to maintaining or improving delivery of ecosystem services within and beyond the protected ecosystems
Type 2 NBS – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions
Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.2 Water Management

The diversity of potential benefits, co-benefits, and trade-offs related to NBS use for water management is reflected in the comprehensive list of Recommended indicators presented. These Recommended indicators were selected by members of a range of EU H2020 NBS projects working across urban, peri-urban, and rural areas. The Recommended list is representative of this diversity of approaches.

From the comprehensive list of Water Management indicators proposed by the H2020 NBS project teams, the list of Recommended Indicators was selected based on those that were considered to be the key drivers of nature-based solution implementation, and thus those that were relevant to the highest proportion of nature-based solution initiatives. The indicators selected as Recommended address the potential benefits, co-benefits, and trade-offs associated with changes to surface water runoff volume (3.1) and to water quality (3.2-3.6).

The Additional indicators address a wide range of applicable metrics for the assessment of NBS impact from a broad perspective, further exploring potential impacts on soil-water interactions, additional aspects of stormwater and excess runoff management, and actions pertinent to the implementation of the Water Framework Directive[46], including quantitative, hydromorphological, ecological and physico-chemical status of surface and groundwaters.

Table 4-2. Indicators related to Water Management classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
3.1	Surface runoff in relation to precipitation quantity	mm/%	O	●	●	●
3.2	Water quality: general urban	various	O	●	●	●
3.3	Water quality: TSS content	mg/L	O	●	●	●
3.4	Nitrogen and phosphorus concentration or load	%	O	●	●	●

[46] Directive 2000/60/EC, OJ L 327, 22.12.2000

3.5	Metal concentration or load	%	O	●	●	●
3.6	Water quality: total faecal coliform bacteria content of NBS effluents	No.	O	●	●	●
ADDITIONAL						
4.1 4.2	Infiltration rate	% or mm/h	O	●	●	●
4.1 4.2	Infiltration capacity	mm/d	O	●	●	●
4.3	Rate of evapotranspiration	mm/m^2 day	O	●	●	●
4.4	Peak flow variation	%	O	●	●	●
4.5	Flood peak reduction	%	O	●	●	●
4.5	Flood peak delay	h	O	●	●	●
4.6	Height of flood peak	m^3/s	O	●	●	●
4.6	Time to flood peak	h	O	●	●	●
4.7	Flood Excess Volume	m^3	O	●	●	●
4.8	Rainfall interception of NBS	mm/h	O	●	●	●
4.9	Runoff rate for different rainfall events	m^3/s	O	●	●	●
4.10	Run-Off Score (ROS)	unitless	O	●	●	●
4.11	Rainfall storage capacity of NBS	mm/%	O	●	●	●
4.12	Quantitative status of groundwater	Good or Poor	O	●	●	●
4.13	Depth to groundwater	m	O	●	●	●
4.14	Chemical status of groundwater	Good or Poor	O	●	●	●

4.15	Trend in piezometric levels	m^3/y	O	●	●	●
4.16	Groundwater Exploitation Index	%	O	●	●	●
4.17	Aquifer surface ratio with excessive nitrate	%	O	●	●	●
4.18	Aquifer surface ratio with excessive arsenic	%	O	●	●	●
4.19	Rainwater or greywater use for irrigation purposes	m^3/y	O	●	●	●
4.20	Water Exploitation Index	%	O	●	●	●
4.21	Water dependency for food production	m^3	O	●	●	●
4.22	Calculated drinking water provision	$m^3/ha/y$	O	●	●	●
4.23	Net surface water availability	m^3/y	O	●	●	●
4.24	Volume of water removed from wastewater treatment system	m^3/y	O	●	●	●
4.25	Volume of water slowed down entering sewer system	m^3/s	O	●	●	●
4.26	Total surface area of wetlands	ha	O	●	●	●
4.27	Surface area of restored and/or created wetlands	ha	O		●	●
4.28	Soil water saturation	%	O	●	●	●
4.29	Soil water retention capacity	m^3/m^3	O	●	●	●
4.30	Stemflow rate	mm/h	O	●	●	●
4.31	Percolation rate under different rainfall events	mm/d	O	●	●	●

4.32	Dissolved oxygen content of NBS effluents	mg/L	O	●	●	●
4.33	Eutrophication	unitless	O	●	●	●
4.34	pH of NBS effluents	unitless	O	●	●	●
4.35	Electrical conductivity of NBS effluents	μS/cm	O	●	●	●
4.36	Physico-chemical quality of surface waters	High, Good, Moderate, Poor, Bad	O	●	●	●
4.37	Total pollutant discharge to local waterbodies	unitless	O	●	●	●
4.38	Water quality: basic physical parameters	various	O	●	●	●
4.39	Total PAH content of NBS effluents	ng/L	O	●	●	●
4.40	Total organic carbon content of NBS effluents	mg/L C	O	●	●	●
4.41	General ecological status of surface waters	High, Good, Moderate, Poor, Bad	O	●	●	●
4.42	Ecological potential for heavily modified or artificial water bodies	Maximum, Good, Moderate, Poor, Bad	O	●	●	●
4.43	Biological quality of surface waters	High, Good, Moderate, Poor, Bad	O	●	●	●
4.44	Extended Biotic Index: total number and species richness of aquatic macroinvertebrates	unitless	O	●	●	●
4.45	Morphological Quality Index	unitless	O	●	●	●
4.46	Hydromorphological quality of surface waters	High, Good, Moderate, Poor, Bad	O	●	●	●

4.47	Fluvial Functionality Index	unitless	O	●	●	●

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Type 2 NBS – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions
Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.3 Natural and Climate Hazards

Indicators of NBS impact with respect to natural and climate hazards provided in this list are expected to be useful to measure the effectiveness of NBS. Application of these indicators will enable measurement of the effects of NBS on risk due to natural and climatic hazards (reduction of risk, effect on one risk component). Recommended indicators relate to three main categories and correspond to several levels of integration ranging from global policy objectives to hazard specific indicators.

Recommended indicators are more integrated and can be used to assess NBS effectiveness:

- Global policy (5.1, 5.2): These integrated indicators correspond to the way risk perception/culture is affected by the measure. Indicator 5.1 is itself the result of a lengthy assessment process and aggregation of several criteria.

- Vulnerability (5.3, 5.4, 5.5)

- Hazard and threat (5.6)

Additional indicators are mainly basic, unitary indicators primarily related to hazard intensity. They are broadly listed by types of hazard (e.g., floods, coastal erosion, landslides, water availability, and heat waves). It should be noted that this list is non-exhaustive; however, the indicators provided herein can provide the basis for a comprehensive NBS performance and impact monitoring scheme focused on evaluating NBS with respect to disaster risk.

Table 4-3. Indicators related to Natural and Climate Hazards classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
5.1	Disaster Resilience	unitless	S	●	●	●
5.2	Disaster-risk informed development	unitless	S	●		
5.3	Mean annual direct and indirect losses due to natural and climate hazards	€	O	●	●	●
5.4	Risk to critical urban infrastructure	%	O	●	●	●
5.5	Number of people adversely affected by natural disasters each year	unitless	O	●	●	●
5.6	Multi-hazard early warning	unitless	S	●		
ADDITIONAL						
6.1.1	Urban/residential areas exposed to risks	ha	O	●	●	●
6.1.2	Productive areas exposed to risks	ha	O	●	●	●
6.2	Natural Areas, Site of Community Importance (SCI), Special Protection Areas (SPA) exposed to risks	ha	O	●		
6.3.1	Inhabitants exposed to risks	No./ha	O	●	●	●
6.3.2	Area exposed to flood risk	ha	O	●	●	●
6.3.2	Local population exposed to flood risk	No./ha	O	●	●	●

6.3.3	Other people (workers, tourists, homes) exposed to risk	No./ha	O	●	●	●
6.3.4	Elderly, children, disabled exposed to risk	No./ha	O	●	●	●
6.4 6.4.1	Population vulnerable to risks	No./ha	O	●	●	●
6.5.1	Housing potentially exposed to risks	No.	O	●	●	●
6.5.2	Agricultural and industrial buildings potentially exposed to risks	No.	O	●	●	●
6.5.3	Strategic buildings exposed to risk	No.	O	●	●	●
6.6.1	Roads exposed to risk	m/km^2	O	●	●	●
6.6.2	Railways exposed to risk	m/km^2	O	●	●	●
6.6.3	Lifelines exposed to risk	m/km^2	O	●	●	●
6.7.1	Buildings vulnerable to risks	$No./km^2$	O	●	●	●
6.7.2	Transportation infrastructure and lifelines vulnerable to risks	m/km^2	O	●	●	●
6.8	Insurance against catastrophic events	%	P	●		
6.9	Flood hazard	unitless	O	●	●	●
6.10	Flooded area	ha	O	●	●	●
6.11	Height of flood peak	m^3/s	O	●	●	●
6.11	Time to flood peak	h	O	●	●	●
6.12	Peak flow rate	m^3/s	O	●	●	●
6.13	Peak flood volume	m^3	O	●	●	●

6.14	Flood Excess Volume	m^3	O	●	●	●
6.15	Moisture Index	unitless	O	●	●	●
6.16	Flammability Index	unitless	O	●	●	●
6.17	Soil type	unitless, qualitative	S		●	
6.18	Soil shear strength	kPa	S		●	
6.18	Soil cohesion	kPa	S		●	
6.19	Soil temperature	°C	O	●	●	●
6.20	Level of groundwater table	m below ground surface	O	●	●	●
6.21	Slope stability factor of safety	unitless	O	●	●	●
6.22	Landslide safety factor	unitless	O	●	●	●
6.23	Landslide risk – history of instability on site	unitless; binominal (yes/no)	S	●		
6.24	Occurred landslide area	%	S	●		
6.25	Landslide risk	%	O	●	●	●
6.26	Soil mass movement	kg/ha	O	●	●	●
6.27	Velocity of occurred landslide	m/s	O	●		
6.28	Erosion risk	m^3/year	O	●	●	●
6.29	Total predicted soil loss	t/ha/y	O	●	●	●
6.30	Days with temperature >90^{th} percentile, TX90p	%	O	●	●	●
6.31	Warm Spell Duration Index	unitless	O	●	●	●

6.32	Heatwave incidence	No./y	O	•	•	•
6.33	Human comfort: Universal Thermal Climate Index	°C	O	•	•	•
6.34	Human comfort: Physiological Equivalent Temperature	°C	O	•	•	•
6.35	Mean or peak daytime temperature – Predicted Mean Vote-Predicted Percentage Dissatisfied	unitless	O	•	•	•
6.36	Urban Heat Island (incidence)	°C	O	•	•	•
6.37	Effective Drought Index	unitless	O	•	•	•
6.38	Standardised Precipitation Index	unitless	S	•		
6.39	Quantitative status of groundwater	Good or Poor	O	•	•	•
6.40	Trend in piezometric levels	m^3/y	O	•	•	•
6.41	Groundwater exploitation index	%	O	•	•	•
6.42	Calculated drinking water provision	$m^3/ha/y$	O	•	•	•
6.43	Water Exploitation Index	%	O	•	•	•
6.44	Net surface water availability	m^3/y	O	•	•	•
6.45	Rainwater or greywater use for irrigation purposes	m^3/y	O	•	•	•
6.46	Avalanche risk: Snow cover map	unitless	S	•		

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Type 2 NBS – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions
Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.4 Green Space Management

The management of UGI interventions has impact at a range of scales, from building and street level to district, urban, regional, national and transnational level. Green spaces, or UGI, are a key component of many urban planning and climate change adaptation and mitigation strategies. Related actions are included in several transnational initiatives including, for example, the EU Strategy on Green Infrastructure and the EU Biodiversity strategy (EC, 2013; EC, 2019b; EC, 2020). Section *2.2.8. Greening urban and peri-urban areas* of the EU Biodiversity Strategy to 2030 makes explicit reference to UGI, stating: '... *This strategy aims to ... stop the loss of green urban ecosystems*. *The promotion of healthy ecosystems, green infrastructure and nature-based solutions should be systematically integrated into urban planning, including in public spaces, infrastructure, and the design of buildings and their surroundings*' (EC, 2020, p. 13).

Urban green spaces provide a broad range of benefits through the maintenance of ecological function and by contributing to the enhancement of biodiversity (Benedict et al., 2006; Maes et al., 2020). Strategically deployed and managed UGI can be multi-functional, providing a wide range of regulating and provisioning ecosystem services alongside a range of cultural and social values. Some of the ecosystem services provided by green space that are particularly relevant in urban areas include air quality and microclimate regulation, protection against flooding, pollination, recreation and other cultural services (Haase et al., 2014).

The quantity, quality and distribution of green-blue areas is particularly important for urban ecosystems, human well-being and social cohesion (Raymond et al., 2017; Sinnet, 2017; Tzoulas et al., 2017). The benefits provided by UGI are strongly related to other challenge areas. The objective of the Green Space Management indicators identified herein is to provide a means to assess the quantity, quality and distribution of green space within cities and their availability for citizens. Quantity and distribution of UGI are measured considering different typologies of urban green areas and using as a reference value the total surface of the city or the total population. The quality of UGI is reported using indicators related to soil, vegetation, water condition, capacity to provide local food.

The availability of UGI for citizens is measured in terms of accessibility and can be combined with other indicators to understand users' preferences and behaviours, and the availability of facilities that support nature-based activities. Numerous methods are available to evaluate green space accessibility (Handy and Niemeier, 1997; Páez et al., 2012). Herein, we propose two approaches:

- A relatively simple method that can be easily applied at district and municipal level and implements parameters recommended by the World Health Organisation (WHO, 2016; WHO, 2017); and,

- A more complex potential accessibility measure which considers the cumulative opportunities for nature based recreation and the probability to reach them according to a function of the distance (Páez et al., 2012).

Other important indicators of Green Space Management, shown herein under Additional indicators, provide an overview of urban land use intensity considering, for example, land use types and changes, surface sealing (Maes et al., 2019) and local networks of pedestrian and bicycle paths.

Table 4-4. Indicators related to Green Space Management classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
7.1	Green space accessibility	%	O	●		●
7.2	Share of green urban areas	Number (0-1)	O	●		●
7.3	Soil organic matter content	%	O	●	●	●
7.3.1	Soil organic matter index	Number (0-1)	O	●	●	●
ADDITIONAL						
8.1	Ecosystem services provision	N/A; descriptive	O	●	●	●
8.2	Annual trend in vegetation cover in urban green infrastructure	%	O			●
8.3	Edge density	m/ha	O	●		●
8.4	Public green space distribution	ha per capita	O	●		●
8.5	Distribution of blue space	%	O	●		●
8.6	Effective green infrastructure at the urban-rural interface	%	S	●		
8.7	Hot spot in peri-urban green infrastructure	%	S	●		●

8.8	Biotope Area Factor	%	O	●	●	●
8.9	Total vegetation cover	%	O	●	●	●
8.9.1	Woody vegetation cover	%	O	●	●	●
8.9.2	Non-woody vegetation cover	%	O	●	●	●
8.9.3	Total leaf area	m^2	O	●	●	●
8.10	Diversity of green space	unitless	O	●	●	●
8.11	Stages of forest stand development -Number of class diameter	No. of individuals	O	●	●	●
8.12	Tree regeneration	number	O	●	●	●
8.13	Canopy gaps	dychotomic (Yes/No)	O	●	●	●
8.14	Tree biomass stock change	t/ha/y	O	●	●	●
8.15.1	Measured soil carbon content	t/ha/y	O	●	●	●
8.15.2	Modelled carbon content	t/ha	O	●	●	●
8.15.3	Soil carbon to nitrogen ratio	unitless	O	●	●	●
8.15.4	Soil carbon decomposition rate	%	O	●	●	●
8.16	Soil matric potential	kPa	O	●	●	●
8.17	Soil temperature	°C	O	●	●	●
8.18	Soil water holding capacity	mm/cm depth	O	●	●	●
8.19.1	Plant-available water	mm/cm depth	O	●	●	●

8.19.2	Soil Available Water (SAW) for plant uptake	mm/cm depth	O	●	●	●
8.20	Vegetation wilting point	%	O		●	
8.21	Degree of soil saturation	%	O	●	●	●
8.22	Stemflow funnelling ratio	unitless	O	●	●	●
8.23	Soil erodibility	mm^3/ha	O	●	●	●
8.24	Total predicted soil loss	t/ha/y	O	●	●	●
8.25	Soil ecotoxicological factor	Number (0-1)	O	●	●	●
8.26	Soil structure	unitless	S		●	
8.27	Soil chemical fertility/ cation exchange capacity	meq/100 g	O		●	
8.28	Flammability Index	unitless	O		●	
8.29	Community garden area	m^2 per capita	O		●	●
8.30	Food production in urban allotments and NBS	t/ha/y	O		●	●
8.31	Recreational opportunities provided by green infrastructure	Interactions/week	O	●	●	●
8.31.1	ESTIMAP nature-based recreation	%	O	●	●	●
8.31.2 8.31.3	Number of visitors to recreational areas	No.	O	●	●	●
8.31.3	Purpose of visits to recreational areas	unitless	O	●	●	●
8.31.4	Frequency of use of green and blue spaces	h/week	O	●	●	●

8.31.5	Activities allowed in recreational areas	No.	S	●		
8.32	Visual access to green space	Number (0-4)	O	●		●
8.32	Time spent viewing green space from residence each day	Number (0-3)	O	●		●
8.32.1	Viewshed	km^2	O	●		●
8.32	Satisfaction with green and blue spaces	Number (1-5)	O	●	●	●
8.34	Betweenness centrality	unitless	O	●		●
8.35	Proportion of road network dedicated to pedestrians and/or bicyclists	%	S	●		
8.35.1	New pedestrian, cycling and horse paths	km	O	●		●
8.35.2	Sustainable transportation modes allowed	Number	S	●		
8.36	Links between urban centres and NBS	Number	S	●		
8.37	Walkability	Number	O	●	●	●
8.38	Land composition	% use class A, N, D, M	O	●		●
8.39	Land use change and green space configuration	various	O	●		●
8.40	Soil sealing	%	O	●		●
8.41	Ambient pollen concentration	Number	O	●	●	●

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4.2.5 Biodiversity Enhancement

The fragmentation of green space is a significant impact of urbanisation and can reduce intra- and inter-species connectivity, leading to a loss of biodiversity. Thus, the *structural and functional connectivity of natural areas (green and blue spaces)* are key among Recommended indicators of biodiversity (indicators 9.1.1 and 9.1.2). Several indicators are recommended related to the *presence of native non-native or alien invasive species* (e.g., 9.2, 9.3 and 9.3.1). These indicators strongly support biodiversity initiatives focused on the re-introduction or maintenance of local fauna and flora.

Both the *Shannon Diversity Index* (9.4) and *Shannon Evenness Index* (9.5) are recommended indicators of biodiversity. The Shannon Diversity Index is commonly used to evaluate species diversity within a defined area. Whilst the Shannon Diversity Index does not qualify whether the species present are native, non-native or alien invasive, it accounts for the number of different species observed within a given space and their relative abundances. The Shannon Evenness Index provides information about the relative number of individuals of each species in a given area.

Numerous additional indicators of biodiversity can support evaluation of the complexity and multidimensionality of local ecosystems in order to underpin spatial planning, prioritise sites for interventions and assess the impacts of NBS initiatives on existing green networks.

Table 4-5. Indicators related to Biodiversity Enhancement classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
9.1 9.1.1	Structural connectivity of urban green and blue spaces	various	O	●		●
9.1 9.1.2	Functional connectivity of urban green and blue spaces	various	O	●	●	●
9.2	Number of native species	Number	O	●	●	●
9.3	Number of non-native species introduced	Number	O	●	●	●
9.3.1	Number of invasive alien species	Number	O	●	●	●

9.4	Species diversity within a defined area	Number	O	●	●	●
9.5	Number of species within a defined area	Number	O	●	●	●
ADDITIONAL						
10.1	Proportion of natural areas within a defined urban zone	%	O	●		●
10.2	Area of habitats restored	ha	O	●	●	●
10.3	Shannon Diversity Index of habitats	Number (unitless)	O	●	●	●
10.3.1	Abundance of ecotones/ Shannon diversity	unitless	O	●	●	●
10.4	Length of ecotones	km	O	●	●	●
10.5	Publicly accessible green space connectivity	%	O	●	●	●
10.6	Ecological integrity	%	O	●	●	●
10.7	Proportion of protected areas	%	O	●		
10.7.1	Sites of community importance and special protection areas	ha	O	●		
10.7.2	Article 17 habitat richness	No./grid	O	●	●	●
10.8	Number of veteran trees per unit area	No./ha	O	●	●	●
10.9	Quantity of dead wood per unit area	m^3/ha	O	●	●	●
10.10	Forest habitat fragmentation – effective mesh density	1/ha	O	●	●	●
10.11	Extent of habitat for native pollinator species	ha	O	●	●	●

10.12	Polluted soils	ha	O		●	●
10.13	Food web stability	unitless	O	●	●	●
10.14	Carbon and nitrogen cycling in soil	t/ha/y	O	●	●	●
10.15	Equivalent used soil	m^3	O			●
10.16	Number of conservation priority species	No.	O	●	●	●
10.17	Article 17 species richness	No./grid	O	●	●	●
10.18	Number of native bird species within a defined urban area	No./ha	O	●	●	●
10.19	Species diversity - general	No.	O	●	●	●
10.19.1	City Biodiversity Index	%	O	●	●	●
10.20	Bird species richness	No./grid	O	●	●	●
10.21	Animal species potentially at risk	No./ha	O	●	●	●
10.22	Typical vegetation species cover	%	O	●	●	●
10.23	Pollinator species presence	No./ha or %	O	●	●	●
10.24	Biodiversity conservation	various	O	●	●	●
10.25	Metagenomic mapping	unitless	O	●	●	●
10.25.1	Abundance of functional groups	Number (unitless)	O	●	●	●
10.25.2 10.25.3	Diversity of functional groups	Number (unitless)	O	●	●	●

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4.2.6 Air Quality

A number of factors threaten the quality of life in European cities and in most of the world. The drivers include increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity (Grimm et al., 2008). These can have detrimental effects for human health and well-being.

Air quality is a major concern worldwide, particularly in urban areas, due to its direct consequences on **human health, plants, animals, infrastructure and historical buildings** (among others). In the political agenda, air quality issues can be coupled with climate change mitigation policies, since many actions aimed at air quality improvement involve a concurrent reduction of greenhouse gas (GHG) emissions. This is the case, for example, of reductions of fossil fuel combustion since its derived emissions contain CO_2 and other GHGs and pollutants directly affecting human health. Nevertheless, measures to improve urban air quality and mitigate climate change tend to be considered separately even though many pollutants affect both environmental impacts.

The emission of the traditional air quality pollutants (AQPs) either direct or indirectly as a result of atmospheric chemistry, affect the concentrations of several climate pollutants. At the same time, the increase of air temperature due to global warming affects the concentrations of the AQPs. Some AQPs, such as ozone (O_3), are also GHGs. These interactions between them are complex and can both enhance and mitigate global warming. Accordingly, a large number of abatement measures are beneficial for mitigating both impacts; however, there are some measures that may be beneficial for mitigating climate change but increase emissions of the key urban air pollutants, or vice versa.

Policies to reduce climate change and improve urban air quality have generally been considered in isolation, with more importance being paid to the mitigation of climate change than to urban air quality over recent years. In the long term, large reductions in both AQPs and GHGs are necessary to mitigate climate change and improve public health. Therefore, priority should be given to measures where there are clear co-benefits such as energy conservation measures. However, large emissions reductions from this type of measures can be difficult to achieve and there will continue to be a need to use legislation to force the adoption of low AQP emitting technologies despite some CO_2 penalties.

Fuel switching to renewable fuels offers a huge potential for co-benefits, with only biomass and biofuels being problematic in terms of indirect GHG emissions from land use changes and higher emissions of particulate matter (PM) from solid biomass and gaseous pollutants from some liquid biofuel blends (Querol et al., 2016).

Air pollution is a local, pan-European and hemispheric issue. Air pollutants released in one country may be transported in the atmosphere, contributing to or resulting in poor air quality elsewhere.

Particulate matter, **nitrogen dioxide** and **ground-level ozone**, are now generally recognised as the three pollutants that most significantly affect **human**

health. Long-term and peak exposures to these pollutants range in severity of impact, from impairing the respiratory system to premature death. Around 90% of city dwellers in Europe are exposed to pollutants at higher concentrations than the air quality levels deemed harmful to health. For example, fine particulate matter ($PM_{2.5}$) in air has been estimated to reduce life expectancy in the EU by more than eight months. European Union legislation sets both short-term (hourly/daily) and long-term (annual) air quality standards[47] (Directive 2008/50/EU). This is reflected in and addressed by the Recommended indicators (11.1–11.3).

Air pollution also **damages our environment**. Problems such as acidification was substantially reduced between 1990 and 2010 in Europe's sensitive ecosystem areas that were subjected to acid deposition of excess sulphur and nitrogen compounds. Less progress was made in environmental problematics such as eutrophication, which is caused by the input of excessive nutrients into ecosystems. The area of sensitive ecosystems affected by excessive atmospheric nitrogen diminished only slightly between 1990 and 2010. High ozone concentrations also cause crop damage is caused. Most agricultural crops are exposed to ozone levels that exceed the EU long-term objective intended to protect vegetation. This notably includes a significant proportion of agricultural areas, particularly in southern, central and eastern Europe.

The Additional indicators of Air Quality focus more specifically on ambient air pollutant concentration, and the related aspects, such as pollutant removal by vegetation and associated health aspects.

Table 4-6. Indicators related to Air Quality classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
11.1	Number of days during which ambient air pollution concentrations in the proximity of the NBS ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO and/or PAHs expressed as concentration of benzo[a]pyrene) exceeded threshold	No. of days	O	●	●	●

[47] http://ec.europa.eu/environment/air/quality/standards.htm; http://ec.europa.eu/environment/basics/health-wellbeing/noise/index_en.htm

	values during the preceding 12 months					
11.2	Proportion of population exposed to ambient air pollution ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO and/or PAHs expressed as concentration of benzo[a]pyrene) in excess of threshold values during the preceding 12 months	%	O	●	●	●
11.3	European Air Quality Index	Good, Fair, Moderate, Poor, Very Poor, Extremely Poor	O	●	●	●
ADDITIONAL						
12.1	Removal of atmospheric pollutants by vegetation (leaves, stems and roots)	kg/ha/y	O	●	●	●
12.2	Total particulate matter removed by NBS vegetation	kg/ha/y	O	●	●	●
12.3	Modelled O_3, SO_2, NO_2 and CO capture/ removal by vegetation	kg/ha/y	O	●	●	●
12.3.1	Total leaf area	m^2	O	●	●	●
12.4	NO_x and PM in gaseous releases	PM- $\mu g/m^3$ NOx - ppb	O			●
12.5	Ambient pollen concentration	Number	O	●	●	●
12.6	Trends in emissions of NO_x and SO_x	$\mu g/m^3$	O	●	●	●
12.7	Concentration of particulate matter (PM_{10} and $PM_{2.5}$), NO_2, and O_3 in ambient air	$\mu g/m^3$	O	●	●	●

12.8	Concentration of particulate matter ($PM_{2.5}$ and PM_{10}) at respiration height along roadways and streets	μg/m³	O	●	●	●
12.9	Mean level of exposure to ambient air pollution	μg/m³	O	●	●	●
12.10	Morbidity due to poor air quality	No./y	O	●	●	●
12.10	Mortality due to poor air quality	No./y	O	●	●	●
12.10	Years of Life Lost due to poor air quality	y	O	●	●	●
12.11	Avoided costs for air pollution control measures	€	O	●	●	●

†**Type 1 NBS** – minimal or no intervention in ecosystems, with objectives related to maintaining or improving delivery of ecosystem services within and beyond the protected ecosystems
Type 2 NBS – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions
Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.7 Place Regeneration

Urban expansion and growth bring countless opportunities and challenges for cities, rendering place regeneration a significant priority while bringing the notions of environmental quality and sustainable development to the forefront. Urban regeneration is seen as a response to the forces pressuring cities to adapt by addressing decline and increasing the resources for sustainable growth. Urban regeneration reflects a comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change (Roberts and Sykes, 2000).

In line with the state-of-the-art in the field of sustainable place regeneration, all indicators listed here – both recommended and Additional - should be analysed and applied with consideration for the specific context that defines regeneration actions at city level, at any given time, the history of a city or area, previous nature-based initiatives and their impact, as well as other particular issues and opportunities presented by a town or city.

Table 4-7. Indicators related to Place Regeneration classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
13.1	Derelict land reclaimed for NBS	ha	O			●
13.2	Quantity of blue-green space (as a ratio to built form)	Number (0-1)	O	●		●
13.3	Perceived quality of urban blue-green spaces (accessibility, amenities, natural features, incivilities and recreational facilities)	various	O	●		●
13.4	Place attachment: Place identity or "sense of place"		O	●	●	●
13.5	Recreational value of public green space	various	O	●	●	●
13.6	NBS incorporated in building design / incorporation of environmental design in buildings	Number (0-5)	P			●
13.7	Cultural heritage protection	Number (0-5)	P	●		
ADDITIONAL						
14.1	Share of green urban areas	%	O	●		●
14.2	Land composition	% use class A, N, D, M	O	●	●	●
14.3	Land take index	%	O			●
14.4	Area devoted to roads	Number (0-1)	O	●		●

14.5	Traditional knowledge and uses reclamation	Yes/No	O	●	●	●
14.6	Traditional events organised in NBS areas	No.	O	●		●
14.7	Social active associations	No.	S	●	●	●
14.8	Direct economic activity: Retail and commercial activity in proximity to green space	%	O	●		●
14.9	Direct economic activity: Number of new businesses created and gross value added to local economy	No. of businesses and €	O	●		●
14.10	Social return on investment	€/€	O			●
14.11	Population mobility	%	O	●	●	●
14.12	Population growth	%	O	●	●	●
14.13	Proportion of elderly residents	%	O	●	●	●
14.14	Areal sprawl	m^2/m^2	O	●		
14.15	Access to public amenities	various	O	●		●
14.16	Average distance of natural resources from urban centres/ train station/ public transport	km	O	●		●
14.17	Natural and cultural site availability	km^2	O	●		●
14.18	Historical and cultural meaning	unitless	O	●	●	●
14.19	Cultural value of blue-green spaces	various	O	●		●
14.20	Opportunities for tourism	No./year	O	●		●

14.21	Building structure – Urban form	Dimensionless (0-140)	P	●		
14.22	Material used coherence	Yes/No	P			●
14.23	Techniques used coherence	Yes/No	P			●
14.24	Design for sense of place	Number (0-5)	P	●		●
14.25	Viewshed	km^2	O	●		●
14.26	Scenic routes and landmarks created	No.	O	●		●
14.27	Scenic paths created	km	O	●		●

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Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.8 Knowledge and Social Capacity Building for Sustainable Urban Transformation

Environmental education opportunities are envisioned as a significant indicator of urban resources for associational involvement in nature-based solutions, and of communal contexts for building trust. Although not all environmental education programs have the potential to generate social capital among participants (e.g., classroom instruction), there are forms that can foster social connectivity, trust, and associational and volunteer involvement. Examples of such programs include those that incorporate collective opportunities for volunteer and associational involvement around stewardship, like community gardening and tree planting, or those that incorporate opportunities for intergenerational learning and collective decision-making, like place-based learning, school-community partnership for sustainability, environmental action, action competence, community-based natural resource management, social-ecological systems resilience) (Krasny et al., 2015).

The Recommended indicators listed here have been extensively researched as significant dimensions playing a role in green and pro-environmental behaviour, NBS impact, and foreseeable sustainability (Derr, 2017; Hedefalk et al., 2015; Kudryavtsev et al., 2012; Varela-Candamio et al., 2018). The Additional indicators provide further the means and methods to explore various dimensions of sustainable urban societal transformation.

Table 4-8. Indicators related to Knowledge and Social Capacity Building for Sustainable Urban Transformation classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
15.1	Citizen involvement in environmental education activities	No. of people	O	●	●	●
15.2	Social learning regarding ecosystems and their functions	Qualitative data (dimensionless)	O	●	●	●
15.3	Pro-environmental identity		O	●	●	●
15.4	Pro-environmental behaviour	Number (0-168)	O	●	●	●
ADDITIONAL						
16.1	Children involved in educational activities	No./y	O	●	●	●
16.2	Engagement with NBS sites and projects	Qualitative data (dimensionless)	P	●	●	●
16.3	Mindfulness	Number (0-3)	O	●	●	●
16.4	Proportion of schoolchildren involved in gardening	%	O			●
16.5	Citizens' awareness regarding urban nature and ecosystem services	Number (0-5)	O	●	●	●
16.6	Green intelligence awareness	No. activities; No. attendees; No. publications	O	●	●	●
16.7	Positive environmental		S, O	●	●	●

	attitudes motivated by contact with NBS					
16.8	Urban farming educational and/or participatory activities	Qualitative data (dimensionless)	O		●	●

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Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.9 Participatory Planning and Governance

The implementation and scaling of nature-based solutions requires new forms of planning and governance approaches. In particular, nature-based solutions' planning and governance need to embrace experimental approaches for innovation and continuous learning, institutional space for cross-sectoral dialogue and collaboration and citizen participation (Davies and Lafortezza, 2019; Frantzeskaki et al., 2019; Kabisch et al., 2017). Citizen participation in environmental decision-making is extremely valuable, underscoring the importance of careful consideration of dynamic participation processes through all the stages of an urban greening project in order to harness the individual and collective empowering potential of participatory practices (Feldman and Westphal, 2000). Participatory planning and governance are advocated to enhance social, political and financial support of the nature-based solution (EC, 2016; Frantzeskaki and Kabisch, 2016; Pauleit et al., 2017).

The recommended indicators capture these cardinal dimensions and processes, paving the way for a dynamic assessment framework that accounts for processual variables (e.g., empowerment, trust in decision-making) as well as changes in existing planning and governance approaches (e.g., new partnerships and policy learning) (see also Calliari et al., 2019). The additional indicators further explore relevant participatory processes by examining citizen/stakeholder participation in NBS planning and implementation, additionally considering the involvement of under-represented groups. Further dimensions of innovative governance and financing actions can be explored alongside the adoption of the climate resilience strategies that highlight the importance of integrated approaches and stakeholder involvement.

Table 4-9. Indicators related to Participatory Planning and Governance classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
17.1	Openness of participatory processes	Number (1-5)	P	●	●	●
17.1.1	Proportion of citizens involved in participatory processes	%	P	●	●	●
17.2	Sense of empowerment: perceived control and influence over decision-making		O	●	●	●
17.3	Adoption of new forms of participatory governance: PPPs activated	No.	O	●	●	●
17.4	Policy learning for mainstreaming NBS: Number of new policies instituted	No.	S	●	●	●
17.5	Trust in decision-making procedure and decision-makers	Number (1-5)	O	●	●	●
ADDITIONAL						
18.1	Community involvement in planning	Number (0-5)	P	●	●	●
18.1.1	Citizen involvement in co-creation/ co-design of NBS	No.	P			●
18.1.2	Stakeholder involvement in co-creation/ co-design of NBS	No.	P			●
18.2	Community involvement in implementation	Number (0-5)	P		●	●

18.3	Involvement of citizens from traditionally under-represented groups	Number (0-5)	P	●	●	●
18.4	Active engagement of citizens in decision-making	%	P	●	●	●
18.5	Consciousness of citizenship	Number (0-5)	O	●	●	●
18.6	Number of governance innovations adopted	Number (0-5)	S	●	●	●
18.7	Adoption of new forms of NBS (co-)financing	Number (0-5)	O	●	●	●
18.8	Development of a climate resilience strategy (extent)	Number (0-7)	O	●	●	●
18.9	Alignment of climate resilience strategy with UNISDR-defined elements	Number (0-5) across 117 categories	O	●	●	●
18.10	Adaptation of local plans and regulations to include NBS	Number (0-5)	O	●	●	●
18.11	Perceived ease of governance of NBS	Number (0-5)	O	●	●	●
18.12	Diversity of stakeholders involved	%	P	●	●	●
18.13	Transparency of co-production	Number (1-5)	P	●	●	●
18.14	Activation of public-private collaboration	No.	O	●	●	●
18.15	Reflexivity: identified learning outcomes	No.	P	●	●	●
18.16	Facilitation skills for co-production	Number (1-5)	P	●	●	●
18.17	Procedural fairness	Number (1-5)	P	●	●	●
18.18	Strategic alignment	Number (1-5)	P	●	●	●

18.19	Reflexivity: time for reflection	No.	P	●	●	●

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Type 2 NBS – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions
Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.10 Social Justice and Social Cohesion

Social cohesion has been long proved to represent an important resource for long-term environmental sustainability in that socially cohesive communities tend to be more supportive of environmentally sustainable attitudes and behaviours compared with those communities where social cohesiveness is weaker (Uzzell et al., 2002). Bridging social capital's (indicator 19.1.1) impact on collective initiatives like nature-based solutions can be far-reaching, as it allows different groups to share and exchange information, ideas and innovation and builds consensus among the groups representing otherwise diverse interests. Conversely, bonding social capital (indicator 19.1.2) fulfils an important social function by providing the norms and trust that facilitate the kind of collaborative action required by initiatives like NBS.

Trust, solidarity, tolerance, and respect are generally understood as manifestations of a cohesive society, one that works towards the well-being of all the members, that is, towards the common good. While the benefits of communitarian social capital depend upon basic structural factors (of which inequality, level of education of the population and its ethnic-racial composition are considered most important), trust, solidarity, tolerance, and respect (indicators 19.3-19.5) are cardinal dimensions of the process of creating or building social capital which enables people to expect good from others (reciprocity) and to act on behalf of others in order to create a better future for all (Cloete, 2014).

Moreover, whilst good governance has a significant impact on social cohesion by increasing trust, tolerance, and acceptance of diversity, creating trust and guaranteeing reciprocity through concurrent values and abiding to norms that guide the process of participation in networks are, in fact, acts that fall into the realm of individual responsibility. It seems that people with values like honesty, trustworthiness, integrity, who care for their fellow humans, are likely to create social capital that could lead to the formation of public good (Cloete, 2014). Therefore, trust, solidarity, tolerance, and respect are considered fundamental resources in the inception, implementation, and potential success of any collective initiatives like nature-based solutions.

All things considered, the Recommended indicators included here address the main dimensions pertinent to state-of-the-art research of nature-based solution and their role in creating social capital and fostering global priorities oriented towards social cohesion and social justice. The Additional indicators focus on the supplementary details, including perceived social interactions, safety and inclusion, and crime.

Table 4-10. Indicators related to Social Justice and Social Cohesion classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS[†]		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
19.1.1	Bridging– quality of interactions within and between social groups		O	●	●	●
19.1.2	Bonding – quality of interactions within and between social groups		O	●	●	●
19.2	Inclusion of different social groups in NBS co-co-co processes	Number (0-5)	P	●	●	●
19.3	Trust within the community		O	●	●	●
19.4	Solidarity among neighbours		O	●	●	●
19.5	Tolerance and respect		O	●	●	●
19.6	Availability and equitable distribution of blue-green space	map	O	●	●	●
ADDITIONAL						
20.1	Linking social capital		O	●	●	●
20.2	Perceived social interaction	Number (0-5) across 4 categories	O	●	●	●
20.3	Quantity and quality of social interaction	Frequency	O	●	●	●

20.4.1	Perception of socially supportive network	Number (0-5) across 5 categories	O	●	●	●
20.4.2	Perceived social support	Number (0-4)	O	●	●	●
20.5	Perceived social cohesion	Number (0-4)	O	●	●	●
20.6	Perceived ownership of space and sense of belonging to the community	Number (0-5) across 2 categories	O	●	●	●
20.7	Proportion of community who volunteer	Number (0-5)	O		●	●
20.8	Proportion of target group reached by an NBS project	%	O	●	●	●
20.9	Perceived personal safety	Number (0-5)	O	●	●	●
20.10	Perceived safety of neighbourhood		O	●	●	●
20.11	Number of violent incidents, nuisances and crimes per 100 000 population	No. per 100 000	O	●	●	●
20.12	Realised safety		O	●	●	●
20.13	Area easily accessible for people with disabilities	km^2	O	●	●	●
20.14	Change in property incomes	%	O	●	●	●

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4.2.11 Health and Wellbeing

The effects of climate change, such as heatwaves, lead to urban areas becoming increasingly uncomfortable, with vulnerable members of society feeling such impacts the most[48]. In the heat wave of summer 2003 in Europe for example, more than 70 000 excess deaths were recorded (Robine et al., 2008).

High temperatures also raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease[49]. Air quality (see section 4.2.6) is also a major concern worldwide, particularly in urban areas, due to its direct consequences on human health, plants, animals, infrastructure and historical buildings (among others). Increasing evidence supports the idea that ecological features such as the diurnal cycles of light and day, sunlight exposure, seasons, and geographic characteristics of the natural environment such as altitude, latitude, and green spaces are important determinants of cardiovascular health and cardiovascular disease (CVD) risk (Bhatnagar, 2017). Some of the beneficial cardiovascular effects of greenery might relate to a decrease in the levels of local air pollution, increased proximity to walking spaces, or lower levels of mental stress (Bhatnagar, 2017). With an abundance of convenient, palatable, energy dense foods and increasingly fewer demands for physical activity in usual lifestyles, the contemporary environment enables the energy balance to be tipped in favour of weight gain (obesogenic environment) (Bhrem and D'Alessio, 2014). In adults, obesity is associated with increasing risk of cardiovascular disease, type 2 diabetes, and all-cause mortality. Most of the associated mortality and morbidity is mediated through major chronic diseases related to obesity, such as cardiovascular disease, diabetes, and cancer (Bhrem and D'Alessio, 2014). Overweight children face a greater risk of a host of problems, including type 2 diabetes, high blood pressure, high blood lipids, asthma, sleep apnoea, chronic hypoxemia (too little oxygen in the blood), early maturation, and orthopaedic problems (Samuels, 2004). They also suffer psychosocial problems, including low self-esteem, poor body image, and symptoms of depression (Samuels, 2004). This is highlighted by Recommended indicators (21.1, 21.5, 21.6).

Climate change means that floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation is expected to continue to increase throughout the current century (IPCC, 2014). A decrease in experienced nature is one aspect of urbanisation that has drawn researchers' attention with the purpose of developing methodologies to explore the affective and cognitive benefits of nature experience, and demonstrate the psychological benefits of our exposure to/engagement with nature (Bratman et al., 2015). The mental health benefits of urban green space have been highlighted by a growing body of knowledge and empirical evidence attesting to the complex interplay among stress responses, neighbourhood conditions, and health outcomes (Beyer et al., 2014; Frumkin et al., 2017; Hartig et al., 2014). More greenery in the neighbourhood was linked to lower levels of depression, anxiety, and stress (Beyer et al., 2014; Pope et al., 2015). Moreover, mental restoration and relaxation from leisure activities (e.g., walks in parks vs. walks in urban settings, gardening) pursued in the nature and green space have been studied as strong evidence of mental health benefits consequent to nature experience (Aspinall et al., 2013; Bratman et al., 2015; Braubach et al., 2017;, Hartig et al., 2014; van der Berg and Custers, 2011). These aspects are addressed in Recommended indicators 21.2–21.4, and 21.6.

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[48] Climate change, justice and vulnerability. http://bit.ly/16STKgy
[49] http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

Numerous authors emphasize that modern urban wellbeing challenged by chronic stress (indicator 21.2) and insufficient physical activity can be healthily nurtured by natural environment exposure, which promotes mental and physical health and reduces morbidity and mortality in urban residents by providing psychological relaxation (indicators 21.3, 21.4) and stress alleviation, enhancing immune function, stimulating social cohesion, supporting physical activity (indicator 21.1), and reducing exposure to air pollutants, noise and excessive heat (Braubach et al., 2017; Hartig et al., 2014).

These health and wellbeing benefits are important not just at the individual level, but if implemented widely they could save expenditure on health care. Increasing the extent and improving the quality of green spaces in areas of cities where health outcomes are poor could also play an important role in addressing multiple deprivations.

Research on complex/multi-dimensional relationship between nature connectedness/nature affiliation (i.e., affective, cognitive and experiential factors related to our belonging to the natural world) and wellbeing indicate that exposure to elements of the natural world affects our well-being by boosting our positive affect, by eliciting feelings of ecstasy, respect, and wonder, by fostering feelings of comfort and friendliness, by heightening our intrinsic aspirations and generosity, and by increasing our vitality (Capaldi et al., 2014; Howell and Passmore, 2013), highlighted in Recommended indicators 21.3 and 21.4, and Additional indicators 22.11, 22.13, and 22.15.

The Additional indicators of NBS impacts on Health and Wellbeing focus on evaluating health and wellbeing aspects in relation to noise, heat and air pollution, and exploring psychological and chronic stress changes, including anxiety, in greater depth.

Table 4-11. Indicators related to Health and Wellbeing classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
21.1	Level of outdoor physical activity		O	●		●
21.2	Level of chronic stress (perceived stress)	Number (0-4)	O	●	●	●
21.3	General wellbeing and happiness	Number (0-7)	O	●	●	●

21.4	Self-reported mental health and wellbeing	Number (1-6)	O	●	●	●
21.5	Prevalence of cardiovascular disease	%	O	●		●
21.5	Incidence of cardiovascular disease	% per year	O	●		●
21.6	Quality of life	Number (1-5)	O	●	●	●
ADDITIONAL						
22.1	Self-reported physical activity	Minutes per week	O	●		●
22.2	Observed physical activity within NBS	% over three levels of physical activity (sedentary, walking, or vigorous)	O	●		●
22.3	Encouraging a healthy lifestyle	Number (1-5)	O	●		●
21.5	Morbidity due to cardiovascular disease	No./y	O	●		●
21.5	Mortality due to cardiovascular disease	No./y	O	●		●
22.4	Incidence of obesity	% per year	O	●		●
22.5	Heat-related discomfort: Universal Thermal Climate Index (UTCI)	°C	O	●		●
22.6	Hospital admissions due to high temperature during extreme heat events	No. per 100 000	O	●		●
22.7	Heat-related mortality	No. per 1 000 000 per year	O	●		●
22.8	Exposure to noise pollution	%	O	●		●

22.9	Perceived chronic loneliness	Number (1-3) across 3 categories	O	●	●	●
22.10	Somatisation	Low, Moderately high, Very high	O	●	●	●
22.11	Mindfulness	Number (0-4) across 12 categories	O	●	●	●
22.12	Visual access to green space	Number (0-4)	O	●		●
22.12	Time spent viewing green space from residence each day	Number (0-3)	O	●		●
22.13	Perceived restorativeness of public green space/ NBS	Number (0-10) across 4 categories	O	●	●	●
22.14	Perceived social support	Number (0-4)	O	●	●	●
22.15	Connectedness to nature	Number (1-5) across 14 categories	O	●	●	●
22.16	Prevalence of attention deficit hyperactivity disorder (ADHD)	%	O	●		●
22.17	Exploratory behaviour in children		O	●		●
22.18	Self-reported anxiety	Mild, Moderate, Severe	O	●	●	●
22.19	Prevalence of respiratory diseases	%	O	●	●	●
22.19	Incidence of respiratory diseases	% per year	O	●	●	●
22.19	Morbidity of respiratory diseases	No./y	O	●	●	●
22.19	Mortality of respiratory diseases	No./y	O	●	●	●

22.20	Morbidity due to poor air quality	No./y	O	●	●	●
22.20	Mortality due to poor air quality	No./y	O	●	●	●
22.20	Years of life lost (YoLL) due to poor air quality	No. of years	O	●	●	●
22.21	Prevalence of autoimmune diseases	%	O	●	●	●
22.21	Incidence of autoimmune diseases	% per year	O	●	●	●
22.22	Prevalence of chronic stress	%	O	●	●	●
22.22	Incidence of chronic stress	% per year	O	●	●	●
22.22	Morbidity due to chronic stress	No./y	O	●	●	●

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Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.2.12 New Economic Opportunities and Green Jobs

The economic opportunities that are created by the adoption and implementation of NBS as a consequence of their social attractiveness and restorative value can be evaluated using the Recommended indicators 23.2, 23.4–23.6. Indicator 23.2 and related sub-indicators 23.2.1-23.2.3 provide several different metrics to evaluate changes in mean land or property value attributable to the implementation of local NBS. Indicator 23.4 specifically evaluates the use of ground floor building space for retail, commercial or public purposes in the proximity of NBS, whilst indicator 23.5 examines the gross value added (GVA) to the local economy each year in the area near implemented NBS. The value of recreational activities occurring in NBS is addressed by indicator 23.6.

Indicators of new economic opportunities are supported by assessment of the value of new jobs created per annum (23.3) as a result of new business opportunities and new jobs in the green sector. Green jobs are those that contribute environmental benefit. The International Labour Organization (ILO) defines green jobs within three categories: primary green activities (i.e., organic agriculture, sustainable forestry), secondary activities (i.e., renewable energy, clean industry, sustainable construction) and tertiary activities (i.e., recycling, sustainable tourism, and sustainable transport).

There has been a great deal of research on the valuation of the benefits provided by the natural environment using a wide range of techniques. Indicators supporting the valuation of urban nature (23.1.1 and 23.1.2) and its ecosystem services enable quantification of NBS benefits translated into monetary terms. Economic valuation of NBS benefits provides a much-needed means to inform decision-making.

Additional indicators within the New Economic Opportunities and Green Jobs challenge area examine indirect economic activity in the area surrounding NBS, elements of NBS cost-benefit analysis (including the value of hydro-meteorological risk reduction), social return on investment, the value of NBS-based tourism, and the impact of local innovation, among others. The indicators identified for the New Economic Opportunities and Green Jobs challenge area address a relatively broad range of actions and potential or realised economic consequences.

Table 4-12. Indicators related to New Economic Opportunities and Green Jobs classified as structural (S), process focused (P) or outcome-based (O) indicators and their general applicability to different types of NBS

No.	Indicator	Units	Class	Applicability to NBS†		
				Type 1	**Type 2**	**Type 3**
RECOMMENDED						
23.1.1	Valuation of NBS: Value of NBS calculated using GI-Val	€	O	●	●	●
23.1.2	Economic value of urban nature	€	O	●	●	●
23.2	Mean land and/ or property value in proximity to green space	€	O	●		●
23.2.1	Change in mean house prices/ rental markets	€	O	●		●
23.2.2	Average land productivity and profitability	€/ha	O	●	●	●
23.2.3	Property betterment and visual amenity enhancement	€/m^2	O	●		●

23.3	Direct economic activity: Number of new jobs created	€/year	O	●	●	●
23.4	Direct economic activity: Retail and commercial activity in proximity to green space	%	O	●		●
23.5	Direct economic activity: Gross value added to local economy from new business creation	%/year	O	●	●	●
23.6	Recreational monetary value	€/year	O	●		●
23.7	Overall economic, social and health well-being	Human Development Index	O	●	●	●
ADDITIONAL						
24.1	Indirect economic activity: number of new businesses established in proximity to NBS	No./year	O	●		●
24.2	Indirect economic activity: Value of rates paid by businesses in proximity to NBS	€/year	O	●		●
24.3	Indirect economic activity: New customers to businesses in proximity to NBS	Mean No./day per quarter	O	●		●
24.4	Indirect economic activity: local economy GDP in proximity to NBS	€/year	O	●		●
24.5	NBS cost/benefit analysis: Initial costs	€	O	●	●	●
24.6	NBS cost/benefit analysis: Maintenance costs	€/year	O	●	●	●
24.7	NBS cost/benefit analysis: Replacement costs	€	O	●	●	●

24.8	NBS cost/benefit analysis: Avoided costs	€	O	●	●	●
24.9	NBS cost/benefit analysis: Payback period	year	O	●	●	●
24.10	Reduced/ avoided damage costs from hydro meteorological risk reduction	€/year	O	●	●	●
24.11	Social return on investment (SROI)	€/€	O	●	●	●
24.12	Income generated via application of green administrative policies within Living Lab district	€/year	O	●	●	●
24.13	Subsidies applied for private NBS measures	€/year	O	●	●	●
24.14	Private finance attracted to the NBS site/ private investment in the bioeconomy	€/year	O	●	●	●
24.15	Increase in tourism	Mean no. visitors/day per year	O	●		●
24.16	New activities in the tourism sector	Number (1-5)	O	●		●
24.17	Gross profit from nature-based tourism	€/year per km^2	O	●		●
24.18	Number of new jobs in green sector	%	O	●	●	●
24.19	Number of new jobs related to NBS construction and maintenance	Number (1-5)	O	●	●	●
24.20	New employment in the tourism sector	Number (1-5)	O	●		●
24.21	Turnover in the green sector	%	O	●	●	●
24.22	Employment in agriculture	No./ha	O	●	●	●

24.23	Rural Productivity Index	€/ha	O	●	●	●
24.24	Economic value of the productive activities vulnerable to risks	€/km^2	O	●	●	●
24.25	Innovation impact	No. innovations	O	●	●	●
24.26	Income per capita	€/year per person	O	●	●	●
24.26 24.26.1	Disposable income per capita	€/year per person	O	●	●	●
24.27	Upskilling and related earnings increase	Increase in employment earnings per person per year	O	●	●	●
24.28	Population mobility	% in 1 y % in 2 y % in 5 y	O	●		●
24.29	Avoided cost of run-off treatment	€/y	O	●	●	●
24.30	Correction cost of groundwater quality	€/m^3	O	●	●	●
24.31	Dissuasive cost of water abstraction	€/m^3	O	●	●	●
24.32	Average water productivity	€/m^3	O	●	●	●
24.33	New areas made available for traditional productive uses	km^2	O	●	●	●
24.34	Value of food produced in NBS	€/y	O		●	●
24.35	Renewable energy produced in NBS	kWh/y	O			●

[†]**Type 1 NBS** – minimal or no intervention in ecosystems, with objectives related to maintaining or improving delivery of ecosystem services within and beyond the protected ecosystems
Type 2 NBS – extensive or intensive management approaches seeking to develop sustainable, multifunctional ecosystems and landscapes in order to improve delivery of ecosystem services relative to conventional interventions
Type 3 NBS – characterised by highly intensive ecosystem management or creation of new ecosystems

4.3 Conclusions

4.3.1 Summary of the indicator framework presented

The Recommended indicators, taken together, are designed to provide a holistic assessment of the multiple potential co-benefits of NBS. Practitioners are encouraged to adopt as many of these Recommended indicators as practicable. Depending upon the specific context, some Recommended indicators may not be entirely applicable or may require adaptation to the local conditions or to overcome resource (personnel, equipment, finance) limitations. In such cases, the Additional indicators presented herein may serve as support, providing opportunity for monitoring and evaluation framework adaptation and tailoring to local conditions as necessary.

Critical thinking is required to select the indicators that suit the purpose and the scope of the NBS assessment strategy. Detailed information regarding the applicability and requirements for each indicator analysis are presented in the Appendix.

4.3.2 Emerging concerns and further development needs

There were a number of indicators initially discussed by the members of the H2020 NBS projects involved in producing this handbook that were ultimately not included herein due to a lack of consensus regarding assessment methodology. In many cases, further work is required to validate evaluation methods for a variety of the NBS forms and functions in order to establish a standardised procedure for assessment of NBS impact. Outcomes of on-going and future NBS projects are expected to deliver novel indicators of NBS impact across all societal challenge areas identified here.

Greater confidence in techniques for evaluation are needed, particularly for carbon flux measurements from natural ecosystems and heterogeneous urban areas. Reduction in price of monitoring equipment with technological advances should make monitoring more accessible and applicable.

Concerning the water management challenge, one of the main concerns is the identification and development of synergic strategies to safeguard and properly support ecosystem services. The effective detection of spatial and temporal scales allows assessing and fostering the ecosystem resilience and sustainability. Attention should be paid to investigating alternations to flow regime to account for the uncertainty and non-stationarity of the hydrologic methodologies. Technological advancement will make monitoring more accessible and applicable, particularly in relation to automated sampling and analysis, and in-pipe measurements of low flowrates. Advances in the accessibility of high-resolution imagery will yield more monitoring options.

For biodiversity assessment, greater standardisation of approaches is needed, this may come through increased requirement for reporting through legislative and planning processes. There is also a need for indicators that capture the complexity and diversity of biodiversity evaluation beyond the usual suspects.

Additionally, a wide variety of indicators and methodologies are presented in this manual, not all of which have been validated to assess large-scale NBS interventions. In this sense, the results obtained in the current H2020 projects will serve to guide future projects and implementations in the selection of the most appropriate in each case. Likewise, it is necessary to consider the impacts of the COVID-19 pandemic on some of the assessment methodologies presented in this handbook and Appendix of Methods as some KPIs may require modifications to the way they are evaluated (e.g., changes to how use of green spaces is assessed due to local restrictions on movement). In some cases, the units of the KPIs may be modified to better apply to a specific case study or to improve the understanding of results.

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