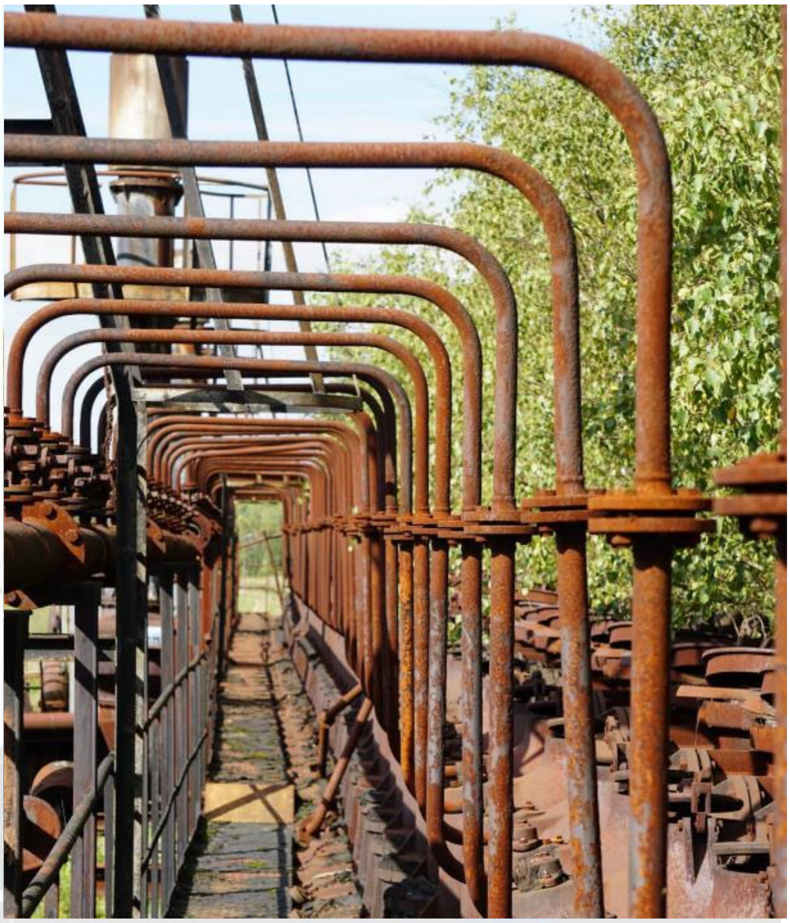
proGIreg



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Guidelines for upscaling

Deliverable 4.6

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Partner organisations

No.	Name	Short name	Country
1	Rheinisch-Westfaelische Technische Hochschule Aachen	RWTH	Germany
2	Stadt Dortmund	DORTMUND	Germany
3	Comune di Torino	COTO	Italy
4	Grad Zagreb	ZAGREB	Croatia
17	Starlab Barcelona SL	SL	Spain
20	Fundacion Privada Instituto de Salud Global Barcelona	ISGLOBAL	Spain
21	Università degli Studi di Torino	UNITO	Italy
22	Consiglio Nazionale delle Ricerche	CNR	Italy
24	Università degli Studi di Bari Aldo Moro	UNIBA	Italy
33	The Forestry Bureau of Ningbo City (FBNC), City	FBNC	China (People's Republic of)
34	Institute of Urban Environment, Chinese Academy of Sciences	IUE-CAS	China (People's Republic of)

Abbreviations

BASE: spatial data from existing databases

Dx.x: deliverable

EDX: energy-dispersive X-rays spectroscopy

EU: European Union

FC: Follower City

FRC: Front-Runner City

GHG: greenhouse gas

GI: Green Infrastructure

GIS: geographic information system

GQ: general questionnaire

HIA: Health Impact Assessment

KPI: key performance indicator

LCA: Life Cycle Assessment

LL: living lab

NBS: nature-based solutions

NDVI: Normalized Difference Vegetation Index

NGO: non-governmental organization

PM: particulate matter

proGIreg: productive Green Infrastructure for post-industrial urban regeneration

SEM: scanning electron microscopy

SME: small and medium enterprise

SOPARC: system for observing play and recreation in communities

WP: work package

Executive Summary

Monitoring and assessing the benefits produced by nature-based solutions (NBS) is a crucial step of the implementation process itself. Indeed, NBS are realised in urban contexts to provide responses, and possibly solutions, to societal challenges, and it is of utmost importance to verify if (and to which extent) such challenges are addressed. This would be important, for instance, to allow the stakeholders to demonstrate the efficacy of the implemented actions or to ameliorate it in future NBS planning.

To achieve a reliable, comprehensive, and holistic assessment of the produced benefits, a well-suited monitoring and assessment plan should be prepared before the starting of the NBS implementation, and regularly updated during all the NBS implementation and maintenance period, as a function of the possible encountered barriers or newly emerged challenges. The design of a monitoring and assessment plan should take under consideration several factors, such as the type of NBS, its extent, the neighbouring and its local challenges. Within this context, many tools are available to drive stakeholders into the monitoring and assessment plan design.

In recent years, the European Union (EU) funded a number of H2020 projects devoted to the implementation and study of the NBS methodology, obtaining two main results: a case study repository where stakeholders can take advantages of the previous experience in planning, implementing, monitoring and assessing benefits (**www.oppla.eu**) and a "Handbook for practitioners"[1], where a systematic approach to the building of NBS impact assessment plans is described. A common framework relies behind both tools, which describes the NBS impact in terms of the same NBS type description, societal challenges to be addressed, and related key performance indicators (KPIs) to assess.

Among the EU-funded H2020 NBS sister projects, the project entitled "productive Green Infrastructure for post-industrial urban regeneration (proGIreg)" is focused on the implementation of eight different types of NBS in post-industrial sites (Living Lab, LL) identified in four Front Runner Cities (FRCs). To obtain an overview as comprehensive as possible of the benefits produced by the implemented NBS, four assessment domains are explored: 1) socio-cultural inclusiveness; 2) increased health and wellbeing; 3) ecological and environmental restoration; and 4) economy and labour market benefits. Due to the type, the extension, and the spatial distribution of the implemented NBS, in proGIreg, NBS impact is mainly assessed at the NBS level, and only for some KPIs the LL district level is considered. To do this, several assessment tools have been developed within the project, most of which are in accordance with the EU guidelines. A second group of cities, called Follower Cities (FC), is also included in proGIreg: these cities follow the work done by the FRC to learn lessons about the design, implementation, monitoring, and benefit assessment of NBS.

[1] Evaluating the impact of nature-based solutions: A handbook for practitioners, A. Dumitru and L. Wendling Eds, European Union (2021).

The present document (Deliverable 4.6 – “Guidelines for Upscaling”) is a key deliverable for Work Package 4 (WP4 - “NBS benefit assessment and monitoring”) in proGIreg. It aims at providing crucial instructions regarding the temporal and spatial upscaling of NBS impact monitoring, which is strictly connected with the upscaling of the NBS implementation. In particular, two different upscaling perspectives are considered and discussed in the present document. First, in a future planning perspective, it will be presented how, starting from the available data on the benefits provided by a certain NBS implementation (such as the data obtained by the proGIreg FRCs), the use of provisional models may allow to estimate the potential benefits that could be obtained by upscaling that NBS implementation. Then, it will be illustrated how the benefits provided by the NBS upscaling (such as those implemented in the proGIreg FC) can be estimated by adapting the monitoring and assessment plan already adopted for that specific NBS type in previous implementations (for instance, in the proGIreg FRC). For the sake of clarity, the upscaling strategies presented for both perspectives are discussed in connection with the NBS type and case studies developed within the proGIreg context, but they may be of interest for any stakeholders who could be interested in upscaling analogous NBS implementation types, beyond the proGIreg experience.

1. Introduction

1.1. Introduction to the project and WP4

Productive Green Infrastructure for post-industrial urban regeneration (proGIreg) is co-creatively developing and testing nature-based solutions (NBS) with public authorities, civil society, researchers, and businesses. Eight types of NBS, which support the regeneration of urban areas affected by de-industrialisation, are deployed in the so-called Front Runner Cities (FRC), Dortmund (Germany), Turin (Italy), Zagreb (Croatia) and Ningbo (China). The cities of Cascais (Portugal), Cluj-Napoca (Romania), Piraeus (Greece) and Zenica (Bosnia and Herzegovina), so-called Follower Cities (FC), have started to develop their strategies for embedding NBS at local level through co-design processes.

The NBSs implemented during proGIreg aim at achieving several benefits, in different field of interest. Work Package (WP) 4 of proGIreg is devoted to the assessment of the benefits produced by these implemented NBSs. WP4 is a collaborative action involving local authorities, the civic sector, small-medium enterprises (SMEs), and research institutes, with the aim of providing a significant and comprehensive evaluation of NBS, which ultimately can be translated into informed policies and targeted interventions aimed at promoting healthy, equitable, sustainable, and economically thriving urban environments.

To this aim, four assessment domains and related spatial and temporal scales of interest, significant key performance indicators (KPIs) and methods are identified and described in the Monitoring and Assessment Plan (Deliverable 4.1; D4.1)[2]. These aspects are developed in line with the guidelines described in 2017 by the EKLIPSE – Expert Working Group (EWG)[3] on NBS evaluation. In 2021, based on the experience gained by the H2020 NBS projects, including proGIreg, the NBS Impact Evaluation Taskforce of the European Commission (EC) released the Handbook entitled “Evaluating the impact of Nature-Based Solutions”, which presents the most updated knowledge in the field. Thus, the proGIreg benefit assessment strategy has been (and will be) adapted to match with these newly released guidelines and will be discussed referring to them in the present document.

[2] Baldacchini, C. (2019) Monitoring and Assessment Plan, Deliverable No. 4.1, proGIreg. Horizon 2020 Grant Agreement No 776528, European Commission, 124.

[3] Raymond, Berry, Breil, Nita, Kabisch, de Bel, Enzi, Frantzeskaki, Geneletti, Cardinaletti, Lovinger, Basnou, Mon-teiro, Robrecht, Sgrigna, Munari and Calfapietra (2017) An Impact Evaluation Framework to Support Plan-ning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wall-ingford, United Kingdom.

1.2. Introduction to the deliverable

Being able to effectively assess NBS and their provision of co-benefits is important for assessing their efficiency, increasing the measurability of their effects and the comparability between different solutions. To this aim, the definition of a monitoring and assessment plan is a core driver for NBS decision-making, However, NBS funded projects are often characterised by a small spatial and temporal development, mainly connected to small NBS implementation areas, short project duration and finally shortage of resources and expertise, which represent the major barriers for NBS planning, implementing, and maintaining, as largely described by WP5 within proGIreg[4]. Therefore, also the assessment results are affected by the same limitation, resulting extremely important to be able also to spatially and temporally upscale these results, thus evaluating the NBS impact on a larger scale. Such an upscaling can be obtained by two main approaches: upscaling the small scale obtained results by means of models or calculations, or upscaling the NBS implementation, and the consequent benefit assessment.

In the present document, guidelines to set a monitoring and assessment plan are firstly described, within the framework described by the Handbook for Practitioners "Evaluating the impact of Nature-Based Solutions" (Section 2) edited by the EU. The monitoring and assessment plan defined within proGIreg is then presented in detail, as a reference for the monitoring and the assessment of the benefits associated to the eight NBS types developed within the project framework (Section 3). ProGIreg monitoring activities are mainly conducted at two spatial scales: the district and the NBS levels. These monitoring activities are respectively described in Section 3.1 and Section 3.2.

Due to the high complexity of the upscaling concept, Section 4 of this Deliverable is dedicated to its description in terms of different definitions, dimensions and applications. This concept is described in general, with respect to the upscale (spatial and temporal) of the assessed NBS benefits, and in connection with the spatial and temporal upscale of NBS implementations themselves. To this aim, three types of spatial upscaling are considered, the roll-out, expansion and replication[5] and they are described in relation to their dynamics, context sensitivity and scaling barriers. Then, in Section 5, strategies for temporal and spatial upscaling of the assessed benefits are described, and discussed in connection with the proGIreg monitoring tools, at both LL district and NBS level. An expert-based approach is followed for the upscaling, depending on the parameter under investigation. Finally, in the last Section of this Deliverable (Section 6), to provide a more practical and tangible guide to the NBS benefit assessment, guidelines for upscaling of monitoring and assessment plans are described, with insights on the application of the LL district and NBS level monitoring tools and their specific encountered barriers and lesson learned.

[4] Pölling, B. (2021) Collective scheme/report of technological and non-technological barriers, Del. 5.5, proGIreg. Horizon 2020 Grant Agreement No 776528, European Commission

[5] Willem van Winden & Daniel van den Buuse (2017) Smart City Pilot Projects: Exploring the Dimensions and Conditions of Scaling Up, Journal of Urban Technology, 24:4, 51-72, DOI: 10.1080/10630732.2017.1348884.

2. How to set-up a monitoring and assessment plan

The NBS benefit assessment can be carried out by applying an effective and scientifically sound monitoring plan[1]. **Monitoring** can be defined as the systematic and standardised gathering of information on a system, using a well-documented approach that can be reliably repeated, so that changes can be compared from time to time and place to place. The definition of an effective monitoring plan is certainly related to the ability of evaluating the **NBS performance or effectiveness**, defined as the degree to which targeted problems are solved. Additionally, monitoring is essential to **raise awareness** and **build knowledge** about the effectiveness of solutions and provide supporting information which can be used by stakeholders to discuss and select which solutions fit the best to their aims. Within this context, monitoring can be considered as an important **driving factor** for **evidence-based decision making** for future NBS implementation. It also enables cities to learn from one another by following the best examples and avoiding NBS that are not successful.

To these aims, an effective monitoring plan needs to be **scientifically sound**, **practical** and based on a **transdisciplinary** approach, thus being focused on the integrated evaluation of the provision of cross-sectoral benefits. The best compromise should be found among **scientific robustness**, **understandability**, **applicability** of data and finally **feasibility** of data collection. To reach this goal, a good **communication** among the different partners is a crucial prerequisite, to achieve both a **resilient monitoring and assessment plan**, able to adapt to barriers and challenges encountered during the NBS implementation and maintenance periods, and efficient data collection tools, that should be scientifically reliable and user-friendly, at the same time. The design of an impact evaluation plan is, thus, a multi-facetted process where general principles are operationalised for a specific context and evaluation results are communicated to feed back into policy processes.

The process of designing an effective impact monitoring plan may be resumed through the following eight steps.

1. **Constructing a theory of change that enables identifying objectives and challenges.** First of all, it should be clarified which issues the implementing NBS is expected to address, and to which extent. For the sake of clarity and comparability, many categorizations are proposed for the societal challenges in which NBSs can be involved. The most recent classification has been proposed within the EU assessment framework[1] and identifies 12 societal challenge areas: 1. Climate Resilience 2. Water Management 3. Natural and Climate Hazards 4. Green Space Management 5. Biodiversity 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 Well-being 12. New Economic Opportunities and Green Jobs.

2. **Identifying the scales of intervention and the related scales for impact assessment, either spatial or temporal ones.** The specific desired impacts that relate to any of the identified challenges should be defined upon a spatial mapping

and identification of context-based spatial issues. This further lead to define both the scale of NBS intervention and the related spatial scales for impact assessment. Four main spatial scales are identified and largely described within common assessment frameworks[1]: Element/local/NBS level (building, public space, etc.); neighbourhood/district/LL level; city level; regional level. Also, temporal scales are strongly affected by the NBS intervention and expected results, as well as from the project and funding duration. In general, the impact of a NBS is likely to be better understood over the long-term. Some impacts require a longer time to become apparent, while others can be verified almost immediately. In this regard, three broad categories are identified (Raymond et al., 2017)[3]: short (within 5 years), medium (5-10 years), and long term (over 10 years). These temporal scales imply that, when the NBS intervention is realized and monitored within the context of a funded project with limited lifetime, only short-term impacts and (sometimes) intermediate impacts are assessable during the project.

3. **Selecting the key performance indicators (KPIs) that answer the evaluation question(s) and allow the assessment of performance and process.** It is crucial that the KPIs are selected among the framework of a **common standard**, which will further allow to compare NBS effectiveness and to make results transferable and thus support decision-makers in evidence-based design of interventions. In particular, within the EU assessment framework[1], per each societal challenge areas, selected and normalized KPIs are described. Furthermore, five KPIs per area are identified as "recommended": they are those to be identified at least to have a reliable and comprehensive overview of the produced benefits.

4. **Identify and collect the data needed to assess the selected indicators.** Based on the selected KPIs, different types of data can be required, with different needed competences. It is crucial to identify since the phase of the NBS planning who will be responsible for data collection among the different stakeholders involved, how often data needs to be collected, what are the desirable quality standards (completeness, precision, uncertainty) and to estimate the costs associated with the monitoring. It could be also useful to take into consideration the already available databases (data availability/gap analysis within the local authority and externally), their alignment with selected indicators, and the potential synergies.

5. **Assess risks associated with data collection activities and mitigation measures**. Risks may arise in data collection activities, such as delays in data collection, low response or unaffordable costs for municipalities. Establishing risk mitigation plans before the start of data collection will make it easier for local teams to avoid delays and inefficiencies.

6. **Implementing the impact evaluation, evaluating positive/negative features of NBS impacts related to the different challenges, analysing and interpreting the findings.** Once data has been identified and collected, the next step is to analyse and interpret it, in order to assess both positive and negative NBS impacts, as well as synergies and trade-offs. If several impacts (positive and/or negative) are considered in relation to an expected objective, the performance evaluation should consider trade-offs and possible differences in time scales over which indicators show that an objective has been achieved or not.

7. **Limitation identification and post-monitoring reassessment of the monitoring plan.** After the impact evaluation, it could be obtained that some monitoring activities are not as informative as planned, either because the selected monitoring tool is poorly designed, or because it is not possible to quantitatively measure certain benefits, or due to context-related reasons (e.g., cultural aspects and the reluctance of certain societies to share certain information, or even willingness to participate in certain monitoring activities). The inadequacy of the desired data should lead to a reassessment of the monitoring methodology framework and allows to modify certain monitoring methods or even establishing new indicators for future monitoring.
8. **Disseminating results and achieving policy impact.** The wider the dissemination, the more benefits it will have: citizens will be informed of the activities of their local government, companies will be made aware of business opportunities, and scientists will be able to continue advising on and researching the best methodologies for NBS impact assessment. It is important to not only register and report positive results, but to do so for all the results obtained, in order to help the replicability of the NBS.

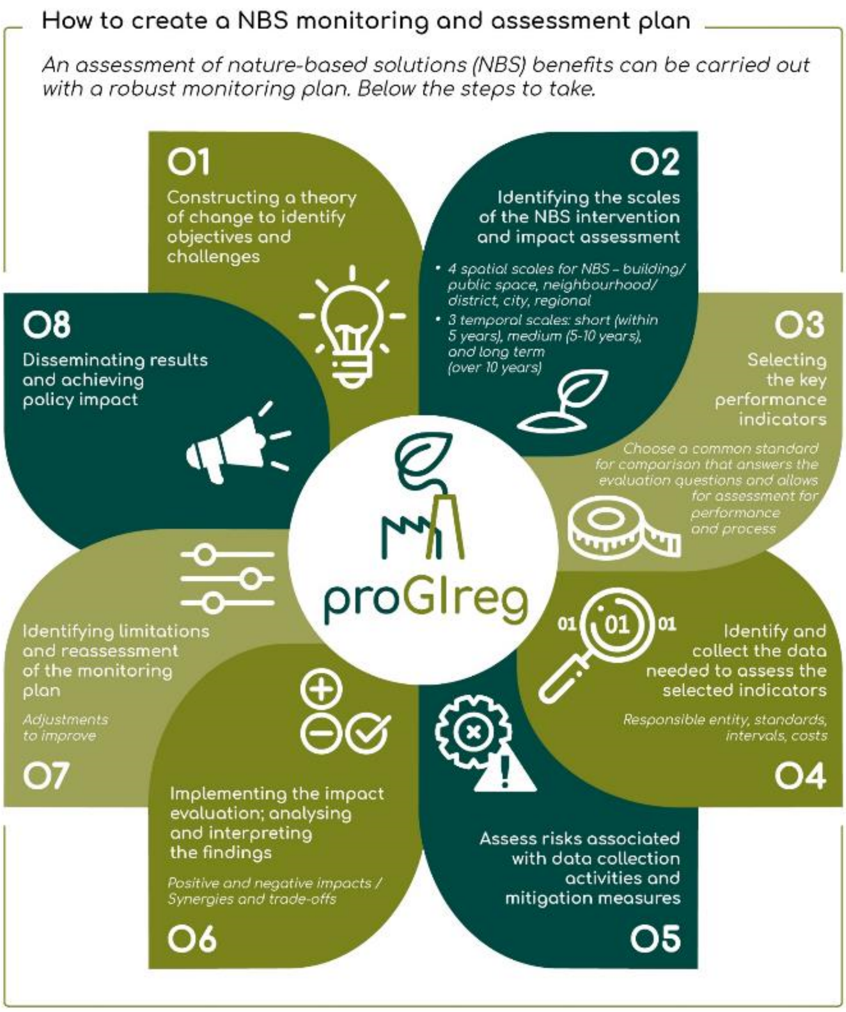

Figure 1. Schematic representation of the process of constructing a monitoring and assessment plan (image @ ICLEI)

Although NBS benefit assessment and, thus, the definition of a monitoring plan, is a core driver for NBS decision-making, it often remains a **marginal activity** in NBS projects. This is likely due to the fact that benefit monitoring and assessment are resource demanding tasks (also in terms of time and expertise), Nevertheless, it is important that impact evaluation is designed at the **early planning phases** of a NBS intervention, in order 1) to allocate necessary resources and develop the stakeholder engagement strategy and 2) to be able to set on time an effective pre-implementation (baseline) monitoring plan. **Baseline data** are important for measuring pre-intervention outcomes that are used later in the assessment process for the before-and-after comparison. Moreover, additional information on the characteristics of the NBS intervention may be also necessary to understand the reasons for effectiveness and the conditions necessary for replicating the results in different contexts. NBS impact and effectiveness can be assessed by comparing against results from before the intervention, from different NBS interventions or from alternative non-NBS interventions, and may also analyse trends over time. Moreover, to be able to discriminate the impact of NBS from the ones caused by other factors, and be able to attribute the outcomes specifically to the NBS intervention, it is important to carry out a comparison with a **control area**. This should be as identical as possible to the actual implemented area and it should be located in the same site/district/city/region (depending on the scale at which effects are expected, by scaling a level up the spatial scale) in order to take local conditions (e.g., climatic conditions or cultural ones) into account. To date, the NBS assessment still represents a **challenge** since it rarely accounts for the **cross-sectoral** and **simultaneous provision** of the benefits. Within this context, the use of indicators themselves may present some **limitations**. This latter aspect may be mainly connected to 1) **data unavailability** in general or unavailability at the right spatial/temporal scale; 2) **lack of resources** or **expertise**; and finally 3) issues in capturing the **complexity** and cross-sectoral provision of benefits. Difficulties may be also connected to the measurability of "**intangible**" impacts, as well as the accounting for **trade-offs**.

Finally, the assessment of NBS effectiveness or impacts is a **multi-scale** and **multi-temporal** problem. Indicators for urban scales and issues may not be relevant for wider scale and vice versa. Moreover, once the monitoring plan is defined and indicators are selected, major issues may come from lack of **longer-term evaluations** to assess effects over time and guaranteeing **continuity** of monitoring measurements: monitoring plans lack the continuity of measurement from the pre-implementation to the long-term effects in the post-implementation phase. As previously described, and to this aim, it could be necessary to take in account also the potential upscaling (spatial and temporal) of data obtained through the monitoring plan, to assess the NBS impact at a wider spatial scale and to evaluate their long-term effects.

3. The proGIreg monitoring and assessment plan

During the proGIreg project, eight different types of NBS are implemented in post-industrial districts (the LLs) of four FRCs: Dortmund (Germany), Turin (Italy), Zagreb (Croatia) and Ningbo (China).

Located in the Ruhr region, Dortmund is a former centre for coal mining, steel industry and beer production, and is known for its cultural diversity due to its industrial history. Already decades before the last steel mill closed in 2001, Dortmund has become a modern university city with diverse industries ranging from logistics to biomedicine. Dortmund has partly redeveloped its large brownfield sites - formerly used for industry - into new industrial sites, industrial heritage sites, residential areas and green recreational areas. Dortmund's LL area runs along the Emscher river, next to the Huckarde district. It is located north-west of the city centre and integrates former Hansa coking plant and former Deusenberg landfill.

Turin is the capital of the Piedmont region and one of Italy's most economically important cities. Since the 1990s it has been transforming from an automotive industrial centre into a hub for start-ups and business innovation. Thanks to the introduction in recent years of networks of parks, green cycling lanes, and green corridors along rivers and former-railway lines, Turin has more green space per inhabitant than any other Italian city. Turin's LL is the district of Mirafiori Sud. Located on the river Sangone, it is a former working-class area with 40,000 inhabitants and various social groups. The area has high potential for urban regeneration, with its active local associations, strong cultural heritage and abandoned industrial buildings available for new community ventures.

Croatia's capital Zagreb is the country's largest and economically strongest city. The LL is within the Sesvete district in the east of Zagreb at the foothills of the Medvednica mountain. With its 70,000 inhabitants, Sesvete has the youngest population in Croatia, and a strong community and entrepreneurial spirit. Located on various key European traffic routes, Sesvete has an industrial past and present, with a particularly active car and construction industry. In particular, the site of the former meat-processing factory, Sljeme, is the core of the LL, with green plans in place for the silo buildings themselves and the surrounding areas.

Ningbo is located in the northeaster province of Zhejiang between the East China Sea and various mountain ranges, it has over 1,500 km of coastline and over 600 islands. A major exporter of electrical goods and textiles, Ningbo is one of China's main industrial and economic centres. Like many cities on the eastern coast, Ningbo is facing the challenges of rapid urbanisation and on-going industrialisation. Ningbo's LL is the parkland area surrounding an urban eutrophic lake in the central district of the city called Moon Lake Park.

The eight implemented NBS types are depicted in Figure 2 and are labelled as:

- NBS1: Leisure activities and clean energy on former landfills;
- NBS2: New regenerated soil;
- NBS3: Community-based urban farms and gardens;
- NBS4: Aquaponics;
- NBS5: Green walls and roofs;
- NBS6: Accessible green corridors;
- NBS7: Local environmental compensation processes;
- NBS8: Pollinator biodiversity.

Not all the NBS types are implemented in all FRCs, given to local settings and available expertise. Both the LLs and the NBS interventions are described in detail in D3.2 ("Four Implementation Plans: Dortmund, Turin, Zagreb, Ningbo")[6].

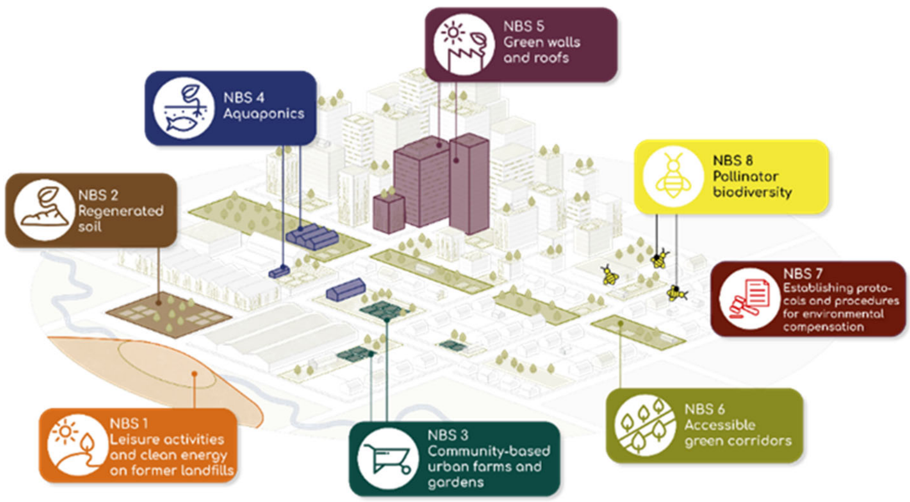

Figure 2. Eight NBS implemented in the proGIreg FRC (image @ RWTH Institute of Landscape Architecture)

Four assessment domains are identified within proGIreg, and considered as priorities for the NBS benefit monitoring and assessment plan. They are schematically represented in Figure 3, and include most of the above-mentioned EU societal challenges, as follow:

- **"Socio-cultural inclusiveness"** is aimed at assessing indicators of socio psychological benefits derived from the implemented NBS in each FRC.[7] This domain matches EU societal challenges 8, 10 and 11. Data for the calculation of several indicators, such as connectedness to nature, mindfulness, social interaction and cohesion, and perceived restorativeness of NBS, are collected using a LL district level tool called the "General Questionnaire", and NBS level tool called the

[6] Saraco, R. (2020) FRC Implementation PLans, Deliverable No. 3.2, proGIreg. Horizon 2020 Grant Agreement No 776528, European Commission.
[7] Raymond, C. M. et al. (2017) A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science & Policy, 77, 15-24.

"NBS-visitor questionnaire". The Walkability Index is also calculated, which is an objective measure of how much a particular area is more or less likely to be walkable by people. It provides additional information on the urban structure of cities and districts and correlates with physical activity of local populations and with social indicators, such as perceived social interaction;

- **"Human health and wellbeing"** domain matches EU societal challenges 4 and 11. Previous evidence has shown an association between exposure to greenspace and improved physical and psychological outcomes, including, among others, better mental health and wellbeing, improved pregnancy outcomes and child health and development, reduced risk of non-communicable diseases, and promoting healthy ageing. However, the knowledge on the public health benefits that new NBSs in urban settings may provide still deserve a strong interest. The data collected within proGIreg include indicators on general health, mental health, well-being, lifestyle habits, physical activity, and time spent in and perceived quality of the NBSs. To be able to detect a change in health and wellbeing indicators that could be attributed to the new NBSs, data are collected before and after the NBS implementation. Additionally, the number and demography of visitors and their physical activity levels in the surroundings of the implementation sites is assessed before and after NBS implementation. Finally, the perceived quality of and satisfaction with the different NBSs is also assessed. In addition, the Health Impact Assessment (HIA) tools is used to quantify the number of cases for different adverse health conditions that could be prevented by the NBSs. The HIA tools can be used to upscale the findings by predicting health benefits of future NBSs and different "scenarios", for which the input from various stakeholders can be used[8].
- **"Ecological and environmental restoration"** domain includes in itself the EU societal challenges 1, 2, 4, 5, and 6. Ecological and environmental benefits are provided both at global and local scale by NBS implementation[9]. At global scale there are direct and indirect interactions with the carbon biogeochemical cycle. Vegetation directly removes carbon dioxide (CO_2) from the atmospheric pool, and, thanks to temperature regulation, the energy demand can be reduced. At local scale, the major benefits are related to air quality amelioration and microclimate regulation. NBSs can positively impacts air pollution formation and deposition: vegetation through stomata removes oxides and other secondary pollutants as ozone (O_3). Moreover, airborne particulate matter (PM), particularly harmful for human health, is deposited in greater quantities and at higher rates on green surfaces, than on manufactured surfaces. If properly planned and managed, NBSs are also important for maintaining and increasing biodiversity. Finally, some NBS applications, such as soil regeneration and aquaponics, can contribute to solving issues related to soil consumption and use of natural resources in the urban environment, especially with the forecasted increase of population and urbanization. Within proGIreg, direct information on the provided benefits is experimentally obtained on a local level (i.e., in the proximity of the NBS). When possible, these benefits are scaled to the city level by using provisional models.
- **"Economic and labour market benefits"** domain matches the EU societal challenges 12. Extensive research has shown that increasing NBSs in cities is accompanied by multiple direct and indirect economic and labour benefits[10]. Effects such as increased real estate values, new commercial initiatives, new (and frequently green) job opportunities and new business opportunities, among others, are all possibilities when implementing NBSs in a city. The main tool

[8] Pereira Barboza, E. et al. (2021) The Lancet – Planetary Health, 5, E718-E730.

[9] Seddon, N. (2021) Getting the message right on nature-based solutions to climate change, Global Change Biology 27, 1518–1546.

[10] Ravazzi Douvan, A. (2021) Policy Instruments to Foster NBS Implementation, Croci, E. and Lucchitta, B. (Ed.) Nature-Based Solutions for More Sustainable Cities – A Framework Approach for Planning and Evaluation, Emerald Publishing Limited, Bingley, pp. 241-253. https://doi.org/10.1108/978-1-80043-636-720211020.

within proGIreg to capture the direct and indirect economic and labour costs and benefits of the implemented NBSs is the “Economic and Labour Market Questionnaire” (ELMQ), which is tailored to each combination of NBS+city+stakeholders and administered at least 1 year after the NBS implementation.

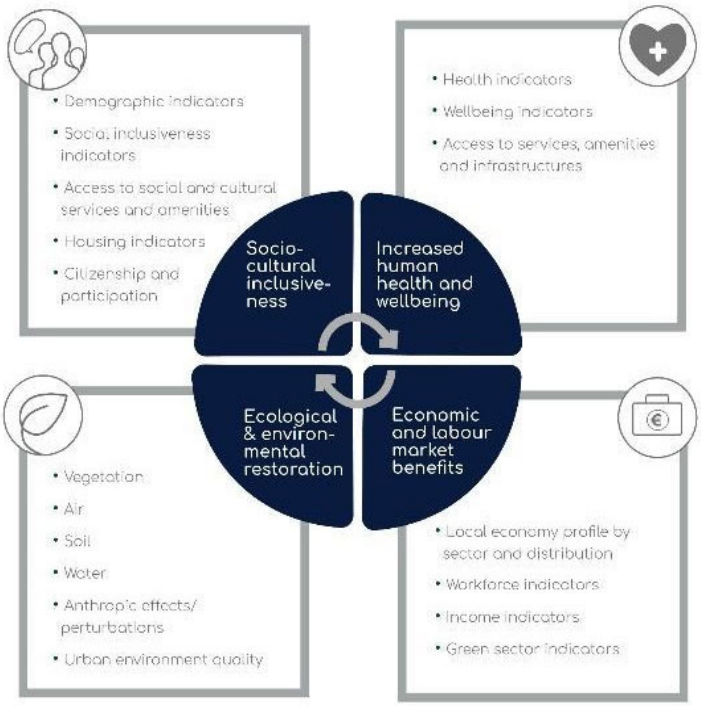

Figure 3. proGIreg assessment domains (image © ICLEI).

Per each assessment domain, there is a corresponding Task in WP4, handled by a proGIreg scientific partner having a clear expertise in the related field. Namely:

- Task 4.1: Assessing socio-cultural inclusiveness, in charge of UNIBA;
- Task 4.2: Increased human health and wellbeing, in charge of ISGLOBAL;
- Task 4.3: Ecological and environmental restoration, in charge of CNR, with UNITO and IUE-CAS support for biodiversity and water quality assessment;
- Task 4.4: Economic and labour market benefits, in charge of SL.

The Task responsible partners oversee planning the monitoring activities, training the data collectors, and analysing data. Local partners (coordinated by the FRC) are responsible for data collection. The coordination of the WP4 activities is overseen by CNR. A graphical representation of the partners involved in WP4 is shown in Figure 4.

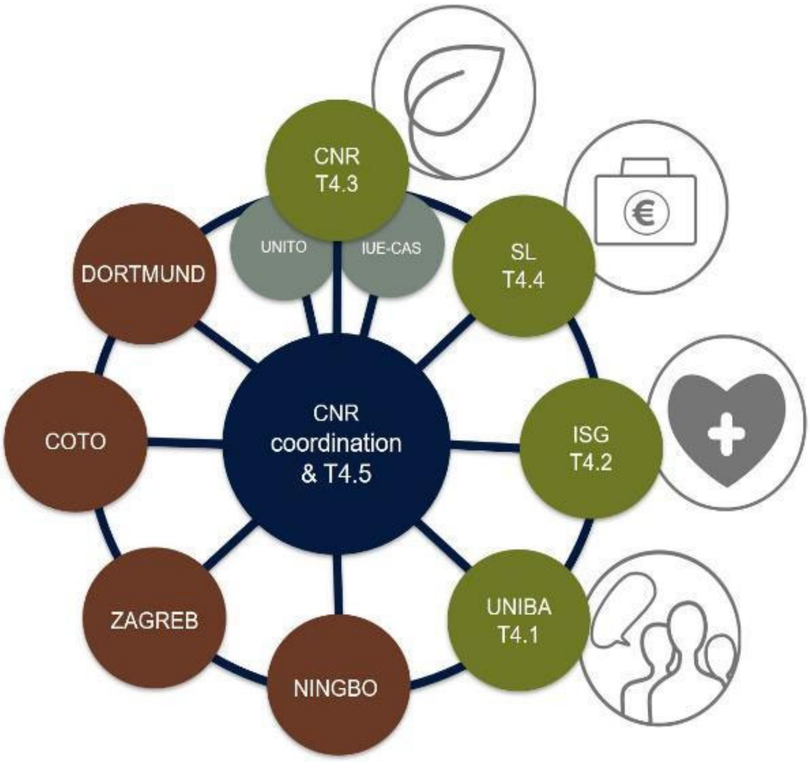

Figure 4. WP4 partners. Task responsibilities are highlighted, together with the corresponding assessment domains, represented by icons (image © ICLEI).

Per each assessment domain, the leading scientific partners identifies the spatial and temporal scales of interest, and the protocols of measurements, by selecting the KPIs to assess and developing the tools to collect the required data. The monitoring of the NBS is performed by using two different types of data over three different scales (Figure 4). Spatial data from existing databases are collected both at the city and district level. New experimental data are collected at the district and NBS level. The definition of the three scale levels has been extensively discussed in proGIreg D2.2 "Spatial Analysis in Front Runner and Follower Cities"[6]. Data at NBS and district level are used to calculate KPIs. The city level data are used only to upscale the district and NBS level results, and to compare results among cities, since no direct effect of the proGIreg implementations is expected at the city level due to the small size and number of the implemented NBSs.

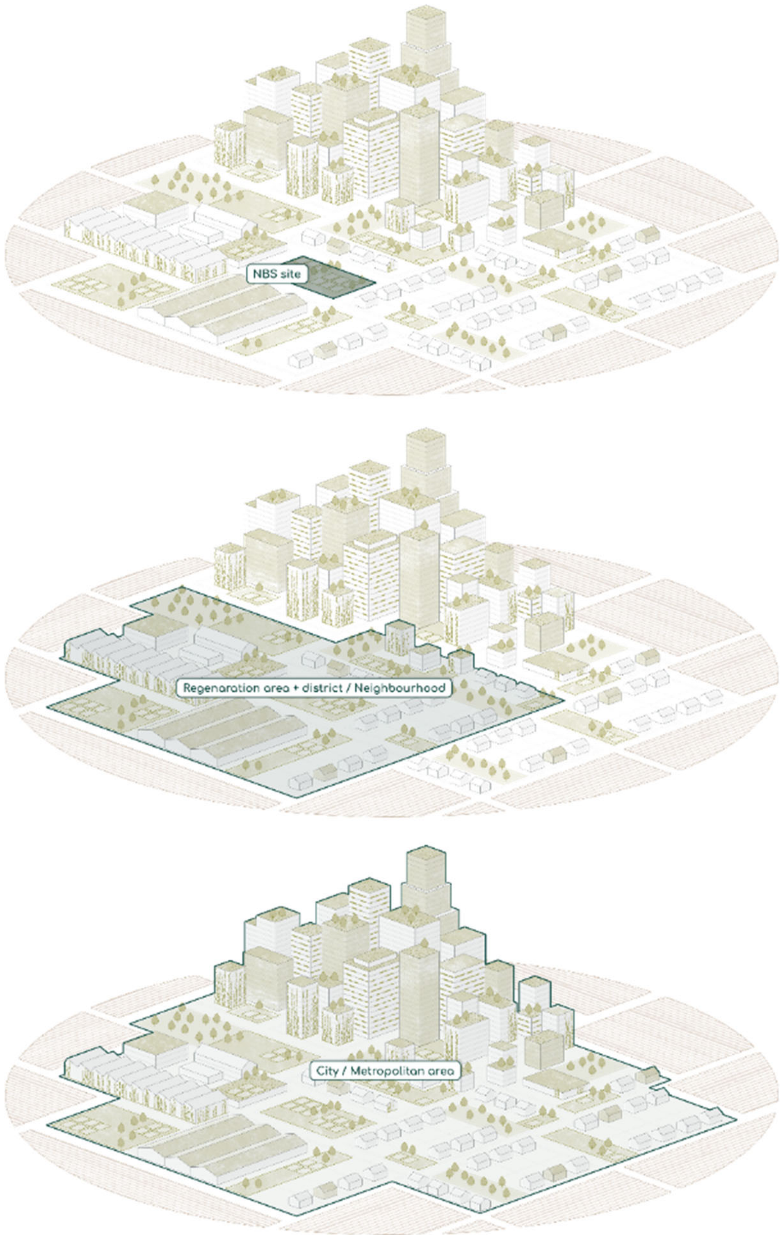

Figure 5. Spatial scales of interest in the proGIreg monitoring activity: city, LL district and NBS (image @ RWTH Institute of Landscape Architecture).

3.1. District level monitoring tools

The benefits produced by the implemented NBSs at the LL district level are assessed by using new experimental data and spatial data. Social, health and economic benefits at the district scale are assessed by experimental data collected, in a pre/post-implementation design through a general population survey, called the "General Questionnaire" (GQ). Spatial data from already existing administrative databases (BASE) or geographic information system (GIS)-derived ones are collected with the double aim of assessing specific KPIs and to be further used to upscale the results obtained at the NBS level. A schematic description of the tools is reported in the following Table 1. A detailed description of the monitoring tools and of the related KPIs is reported respectively in D4.1[2] and D4.5 - Report on benefits produced by implemented NBS[11].

Table 1. Monitoring tools used in the proGIreg project to assess benefits at the district (LL) level. Corresponding KPI are reported with the same name and number with which they are identified in the EU "Handbook for Practitioners"[1].

Monitoring tool	Assessing domains	Data types	Timing	KPIs
General Questionnaire (GQ)	Socio-cultural inclusiveness Human health and wellbeing Economic and labour market benefits	Anonymous surveys	Pre/post-implementation data collection. Post-implementation data is collected with a 36-months temporal delay.	8.31.1 Number of and reasons for visits to an NBS area 8.31.4 Frequency of use of green and blue spaces 8.32 Visual access to green space 8.33 Satisfaction with green and blue spaces 16.3 / 22.11 Mindfulness 15.4. Pro-environmental behaviour 20.2 Perceived social interaction 20.5 Perceived social cohesion 20.2 Perceived social Interaction 20.4.2. Perceived social support 22.13 Perceived restorativeness of public green space/NBS

[11] Baldacchini, C. (2021) Report on benefits produced by implemented NBS, Deliverable No.4.5, proGIreg. Horizon 2020 Grant Agreement No 776528, European Commission, 146.

				22.15 Connectedness to nature 22.4 Incidence of obesity 22.10 Somatisation 22.18 Self-reported anxiety 22.21 Prevalence of autoimmune diseases (asthma/allergies) 23.2.1 Change in mean house prices /rental markets 24.18 Number of new jobs in green sector
Databases (BASE)	Socio-cultural inclusiveness Human health and well-being Ecological and environmental restoration Economic and labour market benefits	Spatial data from existing administrative databases	Once a year	12.7 Concentration of particulate matter (PM_{10} and $PM_{2.5}$), NO_2, and O_3 in ambient air 14.12. Population growth (Natality + Immigration) 23.2.1 Change in mean house prices /rental markets 24.18 Number of new jobs in green sector 24.21 Turnover in the green sector
GIS-derived (GIS)	Socio-cultural inclusiveness Ecological and environmental restoration	Geographic information system (GIS)-derived data Multispectral remote sensing data	Once a year	8.37 Walkability 8.2 Annual trend in vegetation cover in urban green infrastructure

3.2. NBS level monitoring tools

Ten different monitoring tools are developed to assess benefits at the NBS level. They are extensively described in D4.1[1] and they are resumed in the following Table 2. As described in D4.5[10], at least one case study per NBS type per FRC is selected for data acquisition. The list of the NBS implementations monitored for benefit assessment in proGIreg is reported in D4.5[10], together with the protocol of measurements performed, which includes description of the monitoring tools to be applied and of data collection timing. Data collections of the NBS level monitoring tool can be classified according to their protocol as:

- Pre/post-implementation collection: data are collected at the NBS site before the implementation and (possibly) 24 months after;
- Continuous collection: data are collected all along the project, since before the NBS implementation (providing, thus, pre/post-implementation data), with a frequency that depends on data itself;
- Only post-implementation collection: (a) indicators that depend on the existence of the NBS itself (such as, for instance, the number of jobs created or the number of users of a previously not accessible site); (b) for those NBS that were already realized when the monitoring activity started, or that changed site while the monitoring activity was already running.

Table 2. NBS monitoring tools applied in proGIreg to assess benefits at the NBS level. Corresponding KPI are reported with the same name and number with which they are identified in the EU "Handbook for Practitioners"[1].

Code - Short name	Assessing domains	Data types	Timing	KPIs
A - NBS-visitor questionnaire	Socio-cultural inclusiveness Human health and wellbeing	Quantitative social and health status indicators collected by anonymous survey Qualitative description of social and health status by keyword and cluster analysis (in case of vulnerable users)	To be performed 24 months after NBS implementation	8.31.1 Number of and reasons for visits to an NBS area 8.31.4 Frequency of use of green and blue spaces 8.32 Visual access to green space 8.33 Satisfaction with green and blue spaces 16.3 / 22.11 Mindfulness 15.4. Pro-environmental behaviour 20.2 Perceived social interaction 20.5 Perceived social cohesion 20.4.2. Perceived social Support 22.13 Perceived restorativeness of public green space/NBS 22.15 Connectedness to nature 22.4 Incidence of obesity 22.10 Somatisation 22.18 Self-reported anxiety 22.21 Prevalence of autoimmune diseases (asthma/allergies)
B - SOPARC	Human health and wellbeing	Number of users and type of physical activity for a specific NBS as obtained by an observational survey performed by using the "System for Observing Play and Recreation in Communities (SOPARC)"	The SOPARC survey is composed of a pre- and a post- implementation data collection. When possible, according to the implementation timing, the post evaluation is performed 24 months after the pre.	22.2 Observed physical activity levels within NBS 8.31.2 Number of visitors in new recreational areas

C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	Post implementation	23.2.1 Change in mean house prices /rental markets 23.3 Direct economic activity: Number of new jobs created 24.5 NBS cost/benefit analysis: Initial costs 24.6 NBS cost/benefit analysis: Maintenance costs 24.12 Income generated via application of green administrative policies within Living Lab district 24.15 Increase in tourism 24.19 Number of new jobs related to NBS construction and maintenance 24.34 Value of food produced in NBS 24.35 Renewable energy produced in NBS
D – Carbon impact	Ecological and environmental restoration	The carbon storage in specific NBS is obtained by elaboration through mathematical models of environmental, GIS or economic data. The saved carbon dioxide emissions are estimated by converting in CO2 equivalent the data on building energy demand or on energy production by photovoltaic systems	Post implementation	1.2 Avoided greenhouse gas emissions from reduced building energy consumption 2.1.1 Increased carbon stored in vegetation

E - Air quality	Ecological and environmental restoration	Discontinuous ozone (O_3) and nitrogen dioxide (NO_2) concentration measurements are obtained by passive diffusion tubes in the proximity of the NBS and in a control site	Three measurement campaigns are performed just before the implementation, after one year and after two years from the implementation	12.7 Concentration of particulate matter (PM_{10} and $PM_{2.5}$), NO_2, and O_3 in ambient air 12.1 Removal of atmospheric pollutants by vegetation 12.6 Trends in emissions of NO_X and SO_X
F - Air temperature	Ecological and environmental restoration	Measurement of air temperature inside the NBS and in a control site	Continuous measurement over three years	1.3 Monthly mean value of daily maximum temperature (TXx) 1.4 Monthly mean value of daily minimum temperature (TNn)
G – Particulate biomonitoring	Ecological and environmental restoration	PM uptake by the specific NBS is obtained by quali-quantitative characterizing the leaf-deposited PM, with scanning electron microscopy coupled with energy-dispersed x-ray spectroscopy (SEM/EDX)	Particulate matter abatement is measured twice during the project (few months after the NBS implementation and 2 years later)	12.2 Total particulate matter (PM) removed by NBS vegetation
H – Environmental footprint	Ecological and environmental restoration	Environmental and economic data are collected to perform the Life-Cycle Assessment (LCA) of the selected NBS	Post implementation	4.19 Rainwater or greywater use for irrigation purposes 4.21 Water dependency for food production 10.15 Equivalent used soil
I - Biodiversity	Ecological and environmental restoration	Observational data are collected for the biodiversity monitoring surveys of both selected pollinator and plankton species, according to sampling protocols which are adapted to the NBS	For pollinators, the observation is repeated once a week during the pollinators' season, and repeated for 3 years during the project, starting from before the NBS implementation For plankton, sampling occurred once a week, along the project duration, starting from before the NBS implementation	9.4 Species diversity within a defined area 9.5 Number of species within a defined area

J – Water quality	Ecological and environmental restoration	Water samples are collected in specific sites of the NBS and then analysed to obtain: transparency, water temperature, pH, dissolved oxygen, total suspended solids, chemical oxygen demand, total phosphorus, total nitrogen, chlorophyll, ammonia nitrogen	Water sampling was conducted once a week during the project duration, starting from before the NBS implementation	3.2 Water quality – general urban 3.3 Water quality: TSS content 3.4 Nitrogen and phosphorus concentration or load 4.33 Eutrophication

4. Upscaling concept

"Upscaling" is defined as the ability to effectively expand or adapt policies, programs or projects, in different places and over time, to reach more people and have a wider impact. This aspect certainly connects with the NBS concept, and the necessity to being able to spread both in time and in space these solutions and/or their associated impacts. Indeed, either the already assessed NBS impacts can be both temporally and spatially upscaled (for instance by using provisional models), thus obtaining an estimation on the possible effect of physical NBS upscaling. Otherwise, the NBS implementations themselves can be upscaled, thus requiring the consequent adaptation of the monitoring and assessing plan.

Temporal upscaling is a quite clear concept, since mainly relies with the maintenance for a longer time of an NBS and/or with a prolongation of the related impact monitoring and assessment activity. On the contrary, the spatial upscaling concept includes a high complexity in terms of definitions, dimension and applications, thus remaining in most of the cases, still quite unclear and undefined. Indeed, spatial upscaling may vary from being simply quantitative (increased number of beneficiaries) or geographical (regional expansion) to more complex dimensions, such as the organizational (expanding the capacity of existing business) or the institutional ones (transforming existing institutions and creating new ones). This is clearly summarized by Jolly et al.[12] in a synthesis paper where are reported seven dimensions of spatial upscaling and associate indicators, as found in sustainability experiments (Figure 6).

Dimensions of upscaling of sustainability experiments	Empirical indicators
Quantitative	Number of beneficiaries/people
Organizational	Organizational growth, improvement in technical and managerial capacity, development of infrastructure and resources, development of knowledge base and management systems, diversifying funding sources and becoming financially self-sustainable, upgrading in the external value chain, dissemination of knowledge and ideas, research and development activities
Geographical	Expansion to new geographical locations (local communities, villages, municipalities, cities, states, and countries)
Deep	Reaching extremely poor and vulnerable sections of the population, and/or greater impact in the same location where the enterprise was started
Functional	Increase in the number and type of project activities, new products, and services
Replication	Creating, incubating, or supporting new entrepreneurs; creating new affiliates; developing new branches; franchising
Institutional	Modification in public policy and regulations at national and international levels, transformation of existing institutions (regulative, normative, and cognitive)

Figure 6. Indicators for assessing the upscaling performance of sustainability experiments along different dimensions (Jolly et al. 2011[11]).

[12] Jolly, S., Raven, R. & Romijn, H. Upscaling of business model experiments in off-grid PV solar energy in India. Sustain Sci 7, 199–212 (2012). https://doi.org/10.1007/s11625-012-0163-7

In proGIreg the classification proposed by Cooley and Kohl (2005)[13] is adopted, which accounts for three different types of upscaling, with increased context sensitivity: *roll-out*, *expansion* and *replication* (Figure 7).

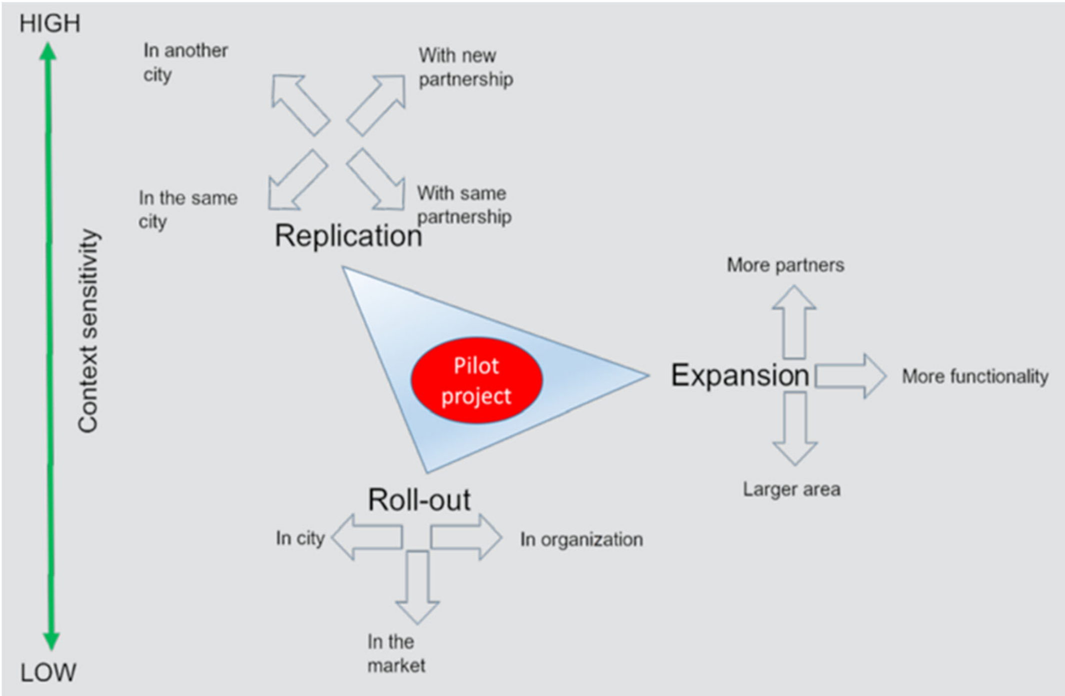

Figure 7. Three types of upscaling (van Winden and van den Buuse, 2017[4])

In the following sections, it will be presented how the proposed temporal and spatial upscaling taxonomy adapts to: (i) already assessed NBS impacts; (ii) the monitoring and assessment plans of upscaled NBS implementations.

However, in most cases, upscaling assessed benefits or NBS (with their benefits monitoring and assessment plan) still represents a challenge hampered by different barriers, which also affect NBS planning, implementing, and maintaining, as largely described in D5.5[4], such as: 1) lack of funding, especially when the NBS relies on expensive technologies or resources; 2) non supportive policy/institutional framework and complex bureaucracy; and finally 3) lack of capacity in terms of manpower or technical skills. These factors may limit NBS upscaling processes, especially when the contexts of application are culturally, socially and geographically heterogeneous.

[13] Cooley, L and Kohl, R (2005) Scaling Up----From Vision to Large----scale Change, A Management Framework for Practitioners. Management Systems International, Washington DC

4.1. Upscaling the assessed NBS benefits

The capability of upscaling the NBS impacts allows researchers and stakeholders to overcome the limitations of the monitoring and assessment plan associated to a too short lifetime of the funding action or to a small size of the NBS intervention. Indeed, these two factors can constrain the monitoring activities over scales that cannot provide enough information to encourage future NBS implementations, increasing the level of uncertainty of public authorities or stakeholders that could invest in this sector.

Thus, upscaling (temporally and/or spatially) the assessed benefits allow evaluating the replication potential of individual NBS interventions and establishing in this way a more robust knowledge base to guide planning and city-wide interventions.

This can be done by using well-established predictive models, which can be used to evaluate the temporal and spatial dynamics of NBS benefits, starting from existing data of a case study NBS. In other words, starting from the analysis of the assessed data, a predictive model is able to identify recurring patterns and trends and to provide a forecast of certain quantities of interest, also by using spatial data characterizing the NBS site or district. However, to use a model in order to get reliable outputs, often it is necessary to adapt it to the context in which it operates through a number of fundamental steps: input data collection and data processing including the algorithm calibration. The input data collection begins with the choice of the information base to be processed. This first step requires the necessary skills to eliminate superfluous data or supplement with additional data. Also, for data processing are required strong competencies for the model parametrization based on the available dataset of variables that will be used to predict future scenario with the highest accuracy and reliability. These model simulations are certainly useful tools, but it is important to underline that as all the simulations and modelling approaches, these may be affected by limitations and approximations.

An example of predictive models is the Health Impact Assessment (HIA) tool[8], which has been selected, for instance, for Task 4.2 “Human health and wellbeing” in proGIreg. HIA tool is a practical approach used to assess the potential health effects of a policy, programme, or project on a population, particularly on vulnerable or disadvantaged groups, and conduct economical and cost-benefit benefit analyses for the planned interventions (e.g., NBSs) under different scenarios to optimize such interventions. Recommendations are produced for decision-makers and stakeholders, with the aim of maximising the proposal's positive health effects and minimising its costs and unwanted by-products. For instance, HIA tool is able to quantify the number of cases for different adverse health conditions that could be prevented by the NBS itself. Also, HIA tools can be used to upscale the findings by predicting health benefits of future NBS and different “scenarios”, for which the input from various stakeholders can be used. HIA can answer questions such as if in a hypothetical city, the area of parks or the length of green corridors is increased for a certain percentage (i.e. scenario), how many cases of doctor visits for mental health conditions, or cardiovascular diseases, or even deaths, could be avoided[8].

Guidance documents often break HIA into different stages: screening, scoping, appraisal, reporting, and monitoring activities. The screening stage selects an intervention, a policy or a project for which an HIA would be beneficial. Potential effects on the determinants of health, health outcome and population groups are identified. The second step is the planning of the HIA and identifying what health risks and benefits to consider. Appraisal is the core of any HIA activity. All the data and evidence are gathered and analysed, affected populations are identified, and health impacts are estimated. Presenting clear results to communities and decision-makers is an important step in HIA. The contents of the report should include a description of the scope, the priorities identified at the beginning of the process, the views expressed by the stakeholders, the evidence available from the various sources, the overall findings, and any recommendations. Monitoring is the final step in the HIA process and allows to evaluate the process and the effectiveness of the HIA. Longer-term monitoring of the health of populations is sometimes a component of larger proposals. This long-term monitoring can be used to see if the predictions made during the appraisal were accurate, and to see if the health, or health-promoting behaviours, of the community, have improved.

A different example of predictive models that apply to environmental benefits is the *i-Tree eco* model[14], which has been also adopted by Task 4.3 in proGIreg. This model is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis with tools to estimates NBS impact on air quality, carbon impact and avoided stormwater runoff. The *i-Tree* tools can help strengthen forest management and advocacy efforts by quantifying forest structure and the environmental benefits that trees provide. Specifically, *i-Tree* provides baseline data so that the growth of trees can be followed over time, and it is used for planning purposes. Also, it can be used both for modelling of the current provision of a wide range of NBS and environmental benefits, and to simulate their temporal and spatial dynamics and evolution.

4.2. Monitoring and assessment plan of an upscaled NBS implementation

4.2.1. Temporal upscaling

If an NBS implementation is prolonged with respect to its originally planned lifetime, its assessment plan can be consistently replicated at specific time intervals, in order to monitor its benefit provision over time. A prolongation of the monitoring activity beyond the originally planned lifespan could be required if no clear answers about the benefit assessment are obtained in the short-term period. Indeed, some impacts, such as social or health impacts (e.g. reduction in the prevalence or incidence of different illnesses), require a longer time to become apparent, while others, mainly environmental ones, can be verified almost immediately (e.g. the reduction of local temperature through green walls). To be able to

[14] https://www.itreetools.org/

follow the temporal evolution of NBS and their provision of benefits is certainly crucial to collect pre-implementation data and create a solid baseline for future comparisons. Then, time frequency of post-implementation monitoring activities may vary depending on the type of NBS, the expected and to be monitored impacts and their scales of interest, but also on the type on monitoring tool adopted. The frequency of data collection should also consider the limitations associated to the fact that municipalities or stakeholders generally have limited budget/persons. This latter aspect is also connected to the fact that post-implementation assessment may be not carried out after the end of the project thus mining the potential evaluation of significant and long-term impacts. The temporal upscaling of the NBS benefit assessment and replication of the assessment plan is only possible if also the efforts in maintaining the NBS functionality are guaranteed over time, to be able to properly evaluate the temporal dynamics of NBS implementations and their associated impacts.

4.2.2. Spatial upscaling

NBS can embrace the micro-level of a single building, the meso-level of a LL, considered as the integrated impact of coexisting NBS, or the macro-level of the city. Surely, the spatial scale of a NBS affects its effectiveness in terms of provision of benefits. Therefore, the NBS benefits assessment need to take in account the scale of the implemented NBS (large vs. small scale NBS), and the expected scale of the impact for each indicator being evaluated. Thus, when an NBS intervention is upscaled, the associated monitoring and assessment plan needs to be accordingly adapted. However, the degree of needed adaptation depends on the type of spatial upscaling that the NBS undergoes.

Roll-out spatial upscaling

The *roll-out* is the less complex type of spatial upscaling, with a lower context sensitivity. This upscaling strategy usually applies to technologies or solutions that were already successfully tested in the pilot project and that proved to be easily adoptable. The *roll-out* may consists in the commercialization or distribution of the solution as it is, in the market (*market roll-out*), internally to an organization (*organization roll-out*) or across the city (*city roll-out*). Due to the success of the testing stage, no major modifications of the solution/technology are expected during the transition from the pilot to the upscaling stage. Furthermore, since no major behavioural or organisational changes are expected, usually only one organisation, often the one who initiated the pilot test, is responsible for the transition. This usually implies a substantial reduction in transaction and coordination costs, with very limited regulatory and legal barriers. However, the *roll-out* still requires specific competences, and in some cases, training of the staff that was not included in the pilot. In addition, it is questionable if the pilot test context is a reliable proxy for the upscaling at an international level.

Since no major behavioural or organisational changes are expected, the same monitoring and assessing plan adopted for the pilot NBS implementation can be used.

Expansion spatial upscaling

The *expansion* type includes different strategies such as 1) the addition of new partners to the pilot project; 2) the extension of the geographical area where the solution or technology may be adopted; and 3) the addition of new functionalities to the pilot solutions. Of course, if new partners need to be involved, negotiations are needed, and higher transactions and coordination costs need to be taken in account in respect to the *roll-out* type. A higher context sensitivity is also needed to be able to encounter and adapt to new geographical areas. This type of upscaling usually applies to co-production which depends on a close collaboration between more partners, and it certainly represent a more complicated strategy.

The adaptation of the NBS monitoring and assessment plan can be required. Indeed, the addition of new partners or new functionalities may require a new evaluation of the societal challenges of interest. In principle, the expansion on a larger area, within the same context, should not affect the type of benefits produced, and the same monitoring and assessment strategy previously used can be replicated, with some exceptions. For instance, the environmental impact of small green NBS can be negligible, while it could be relevant when the interested area increases.

Replication spatial upscaling

Finally, the third upscaling type, the *replication* one is the most complex and problematic and it occurs when the pilot solution or technology is replicated in another organisation, part of the city or at higher scale, in another city. In this specific case, the complexity of the new context (organisational or geographical) results to be a key factor and high context sensitivity is required. *Replication* can be carried out by the pilot partnership or by others and it usually requires a redesign of the solution, to be adapted to the new context. Main barrier of this type of upscaling is the lack of standards or protocols for this strategy, with very poor knowledge on transfer mechanisms.

The adaptation of the NBS monitoring and assessment plan in this case have an increasing degree of complexity which mainly pertain the societal challenges involved as well as the monitoring tools to apply. Indeed, these may change either changing the site within the same city and, even more, when changing the city, but also when changing the partner organization, since this would imply that different expertise is available.

5. Upscaling proGIreg results

5.1 Upscaling proGIreg NBS benefit assessed at the LL district level

The benefits produced by the NBS implemented in proGIreg at the LL district level are assessed by using experimental data and spatial data, which are collected both at the city and at the LL district scale, as previously described in Section 3. Specifically, a survey called the "***General Questionnaire***" (**GQ**) is conducted at the LL district level, where residents are likely to benefit from the NBS implemented by proGIreg, to collect data to assess social, health, and economic KPIs. Also, data from already existing administrative databases (**BASE**) or geographic information system (**GIS**)-derived ones are used to calculate large spatial scale indicators and to provide data to apply the provisional models to upscale the results assessed at the NBS level. BASE data are collected, as planned, on a yearly basis, by the FRCs, at both city and LL district levels, and they will provide KPIs such as: diversity statistics; educational attainment; recreational or cultural facilities; accessibility of public urban green space; and density of the built environment. Some of the BASE information are instead used to compare the cities or to upscale the assessed benefits, such as: total population; population density; migration rate; material deprivation rate. Starting from the GIS-derived data, the Walkability index and the Normalized Difference Vegetation Index (NDVI) are calculated at the two above mentioned scales. The Walkability index expresses the likelihood that a particular area will be walked by people. It provides useful information on the urban structure of a city and, in turn, of individual districts. NDVI is a simple index, derived from multispectral remote sensing data, expressing the vegetation health status. Within proGIreg, the index is calculated to assess the annual trend of vegetation cover in urban green infrastructure for each FRC.

Temporal and spatial upscale

KPIs obtained through the application of these monitoring tools at the LL district level can be upscaled both spatially and temporally by the use of predictive models, as previously described, obtaining estimation of the benefits expected by the same NBS implementations over time, or in different *scenarios* (e.g., districts), or at a different scale (e.g., at the city level). To estimate and model the evolution and dynamic of NBS benefits, models need either the historical time series of existing data of interest (for the temporal upscale) or the starting data of other districts or at the city level (for spatial upscale).

5.2 Upscaling ProGIreg NBS benefit assessed at the NBS level

The benefits assessed at the NBS level are different in data types, timing, and aim. As a consequence, the data obtained by each tool at the NBS level can be used as input data in different provisional models. Moreover, not necessary the benefits' upscaling can be obtained for every tool. Thus, the approaches to upscale results obtained by each NBS level tool is separately discussed in the following.

A: NBS-VISITOR QUESTIONNAIRE

The aim of the NBS-visitor questionnaire is to assess the social and health benefits obtained from the different NBS implementations. The relevance and originality of this tool lies in the opportunity to monitor different NBS, thus ensuring comparability among multiple NBS types and cities/neighbourhoods. The NBS-visitor questionnaire takes approximately 15 minutes and includes items about the perceived social and health benefits derived from the direct contact with the implemented NBS. The NBS-visitor questionnaire is designed to be conducted on-site at strategic spots (e.g., the entrance of an urban park) targeting all adult visitors who meet the inclusion criteria (i.e., sufficient understanding of the national language of the country where the data is collected, capacity to consent and participate, and absence of diagnosed neuropsychiatric disorders) to participate in the study. The tool also provides a section of self- and participant's evaluation on the quality of the interview.
For data collection with a sample of school children, a reduced and adapted version of the NBS-visitor questionnaire was designed. In cases where it is impossible to administer this tool (for example, with individuals vulnerable to intellectual disabilities), we applied an approach based on keyword clustering. A few keywords related to the experience with the new implemented NBS (from users or caregivers or both populations) were collected, thus, a cluster analysis was performed.

Temporal upscale
Information retrieved from the NBS-visitor questionnaire are valid for the specific sample populations on which data are collected. For this reason, temporal upscaling of the health and social co-benefits obtained from NBSs at a longer term is difficult to estimate. Further follow-ups are recommended to evaluate the trend of NBS benefits over the course of time.

Spatial upscale
Results obtained by data collection with NBS- visitor questionnaire may be generalized comparing similar NBS spots and similar population characteristics in other districts or cities. By similar characteristics of the population, we mean the same levels of age, education, gender and socio-economic status. As stated for temporal upscaling, it is very difficult to project these types of results given the high specificity of the samples on which the data is collected. This is particularly true for data collected on vulnerable populations.

B: SOPARC

The aim of the SOPARC[15,16] (System for Observing Play and Recreation in Communities) monitoring tool is to provide information on the increase or change in the use and levels of physical activity at a specific NBS spot.

[15] McKenzie, Cohen, Sehgal, Williamson, Golinelli, (2006). System for Observing Play and Recreation in Communities (SOPARC): Reliability and Feasibility Measures. J. Phys. Act. Health 3 Suppl 1, S208-S222.
[16] https://www.rand.org/health-care/surveys_tools/soparc/user-guide.html

Temporal upscale
Results retrieved from the SOPARC tool are valid for the specific season (preferably spring-summer) when the assessment is performed. The use of public space, as well as the type activities and levels of physical activity performed are dynamic and related to climatological conditions, among other factors. For this reason, a temporal upscaling of results is difficult to estimate with a single assessment. To evaluate the course of the trends observed over time and compile more reliable and robust data to upscale the assessed benefits, it would be recommended follow-ups at different time points to understand changes in dynamics of the NBS site and upscale the potential health related benefits more accurately.

Spatial upscale
As stated for temporal upscaling, it is very difficult to project the results given the high specificity of the data collected in relation to the use of a given NBS site that is in a concrete spot within a specific neighbourhood. As data is collected at a very local spatial resolution (i.e., the NBS spot), the results may be generalised to compare similar NBS sites in the same neighbourhood, but difficult to upscale to other districts and cities that might have different dynamics in the use of the public space. To better upscale the potential benefits of an NBS, multiple and similar NBS sites would be recommended to be assessed in different districts in the same temporal scale.

C: Economic and labour market questionnaire

The economic and labour market questionnaire (ELMQ) is the main tool to capture the direct and indirect economic and labour costs and benefits of the NBS implemented. The data collection takes place only after NBS implementation (post).

Temporal upscale
The results for several NBS implementations obtained via the ELMQ support the long-term perspective of NBS developments beyond the proGIreg project lifetime. Along with the evolution of NBS, the economic dimension can play an increasingly important role, e.g. by selling products from urban gardening and farming (NBS3) or Aquaponics systems (NBS4); rental concepts (e.g. Orti Generali (NBS3) in Turin); sponsorship or donation models (NBS7); cost-efficient public-private-partnership models, etc. The financial revenue streams and created jobs can be temporally prolonged and sustained when reaching and or developing a financially viable concept. Not only the income dimension is relevant here, but also ways to reduce currently existing costs with the implementation and maintenance/evolution of NBS. Additionally, the pioneering work carried out in proGIreg has the potential to reduce planning and preparatory costs for follow up implementations.

Spatial upscale
Similar to the temporal upscale, the spatial dimension is relevant for reaching financial viability. The ELMQ will allow for at least some NBS implementations to assess the profitability as well as anticipating spatial influence on economic and labour aspects. The spatially larger a NBS implementation can be realised, the better can economies of scale be

gained, especially by decreasing unit costs. Additionally, the pioneering work carried out in proGIreg has the potential to reduce planning and preparatory costs for follow up implementations.

D: Carbon impact

Impacts of the implemented NBS on atmospheric CO_2 concentration are estimated with two different approaches (CO_2 sequestration and reduced CO_2 emission), depending on the NBS under investigation. In both cases, the carbon accounting is carried out as a post implementation analysis, and it might be useful to inform the overall carbon balance of the NBS. Accordingly, results from the carbon impact analysis of an NBS can be compared with the greenhouse gas (GHG) emissions emitted along the life cycle of the solution, in order to estimate the point in time after which the NBS starts to become a net carbon sink[17].

Temporal upscale

For the temporal upscale of these types of results, the *i-Tree eco* model is likely to be employed being this tool particularly pertinent to characterise time-dependent dynamics of plants growth. Indeed, it allows the users to calculate the carbon storage, as carbon stored in the dry biomass, and the carbon annual sequestration mainly via photosynthesis. However, the *i-Tree eco* modelling of these ecosystem services is strongly based on the collection of data that are connected to the species, number of trees, biometric and health status conditions of the plants within a specific NBS. Thus, in case of using the model to forecast future perspectives, it would be necessary to design the scenario of the NBS in the future, in terms of biometric/health status of the plants, which are the data required by the model, at a certain time frequency. This will allow, through the application of the model, to evaluate the associated increase of the carbon storage and carbon sequestration.

Spatial upscale

The spatial upscale of the results related to the NBS impact on the atmospheric concentrations of CO_2 can be also obtained by the utilization of the *i-Tree eco* model. For instance, in the case of both roll-out and expansion upscale, the carbon impact can be obtained by increasing the number of plants within the model database, estimating this number by using the new area to be involved (as obtained by the BASE or the GIS data) and assuming that the same plant species and density will be adopted, thus obtaining a valuable estimation of the increased carbon impact connected to the expansion of the NBS-based land use and the number of its plants. In case of replication upscale, biogeographic traits of the new site (that could affect the plant species selection and growth) and the local administrative rules should be considered.

[17] Rugani, B. et al. (2015) Applied Energy 156, 449-464.

E: Air quality

This NBS level monitoring tool is based on the discontinuous measurement of the mean bi-weekly concentration of ozone (O_3) and nitrogen dioxide (NO_2) within the implemented NBS and in control points outside the implementation area.

Temporal upscale

Three possible results can be obtained when monitoring the impact of an NBS on the atmospheric concentration of pollutants. 1) The impact on the air quality is negligible, mainly this can happen when the size of the NBS is too small to have a measurable impact on the air quality or in pre-post analysis the land where the NBS will be implemented is an abandoned land where vegetation was born and grown spontaneously. 2) the vegetation in the NBS reaches its maximum growth level during the monitoring period, and a stable level of pollutant concentration is measured over time. 3) A trend in pollutant concentration is observed over time during the monitoring period, without reaching a stable level, likely because the vegetation growth in the NBS didn't reach its maximum development within the monitoring period. Although theoretically all the previous cases allow a temporal upscale using a proxy for leaf area increase (e.g. LAI or NDVI), only in case 3 a reliable prevision about the future behaviour can be done, for instance by applying the *i-Tree eco* model, starting from the already acquired data and modelling the growth of the vegetation.

Spatial upscale

For a spatial perspective, the situation is even more complicated and therefore the forecast is limited to a purely indicative role. Without any additional collection of air pollutants concentration and meteorological data, only a linear upscale can be performed by estimating the leaf area cover present in the new area (e.g. using LAI or NDVI) with a very low level of approximation or by a pure modelling approach (e.g. using I-tree eco model as for temporal variation), based on the input already acquired in location often far away from the location of the new NBS implementation with a very rough quality of the outcomes.

F: Air temperature

To evaluate the role of the vegetation towards cooling mechanisms, through evapotranspiration and shading, temperature and relative humidity is continuously measured within the implemented NBS and in control points outside the implementation area.

Temporal & Spatial upscale

On one hand, measuring air temperature and relative humidity by local sensors is the easiest and cheapest way to detect the efficiency of an NBS in ameliorating the thermal condition. On the other hand, if this tool is used alone, without any additional data related to vegetation, such as shaded area (e.g. leaf area projection) or cooling that could be assessed directly (measuring stomata or water transpiration) or indirectly (measuring soil water content), it is practically impossible to perform both temporal or spatial upscale.

G: Particulate biomonitoring

Particulate matter abatement is detected by monitoring PM deposition on tree and shrubs leaves, at different particle size fractions (e.g. PM_{10} or particle smaller than 10 μm and $PM_{2.5}$ characterized by particles smaller than 2,5 μm), through SEM/EDX microanalysis.

Temporal upscale

For the temporal upscale of the results obtained through the PM monitoring tool, it would be sufficient to evaluate the increased leaf area associated to the plant growth. *I-tree eco* model can be employed, provided that the previous collections of biometric and health status data allow to estimate the dynamics of the leaf area growth in the future. This could be obtained both through the GIS, with the NDVI calculation, and at the plant level, by the calculation of the Leaf Area Index, measured as the leaf area in m^2 per ground area in m^2. This index can be calculated through direct methods, which are based on the collection and in some cases the destruction of leaf materials, or indirect methods. To date, the most used method is based on the utilization of the so-called Plant Canopy Analysers, which use a hemispherical lens to take photos from beneath the canopy and automatically make calculations for the user to measure the Leaf Area Index. It is worth noticing that the plants growth is associated with changes not only of the leaf area, but also of the spatial configuration and density/porosity of the vegetation canopy. This may lead to substantial modifications in the interaction between atmospheric PM and the canopy, thus affecting also the leaf deposition of this pollutant, and this should be taken into account.

Spatial upscale

Since results obtained through the PM monitoring tool are obtained as a function of the unit leaf area, to spatially upscale these types of results it would be necessary to account for the increase of this parameter associated with the expansion of the NBS and the increased number of plants employed. To this aim, and similarly to what was described for the carbon impact monitoring tool, the *i-Tree eco* model could be employed, thus upscaling the mass of PM removed by the vegetation per unit leaf area, to the leaf area modelled, thus taking in account an increased number of plants with certain biometric and health status conditions. In addition, NDVI, derived from multispectral remote sensing data, and calculated within proGIreg at the city and the LL district level, could be useful to spatially upscale PM abatement results. This will allow to estimate not only the PM abatement associated with specific NBS, but also with the integrated impact connected to the copresence of all the green areas at the LL district and city scale.

H: Environmental footprint

Some NBS implemented in proGIreg have the aim to provide services and products that imply a reduction of the environmental footprint of business-as-usual practices. Such a reduction is estimated through LCA.

Temporal upscale
LCA is a flexible methodology that can be applied to assess the environmental performance of any good and service, new or emergent technologies and production activities already existing or expected to penetrate in the market. In the case of NBS, which are mainly based on natural elements such as trees, life cycle manufacturing, implementation and management data collected for specific projects should be split over the lifetime of the species embedded in the solution. Such a time-dependent life cycle inventory will directly affect the calculation of environmental footprint.

Spatial upscale
The LCA method allows to account for environmental impacts at ideally any possible spatial scale pertinent for the analysis, depending on the characterised indicators. For example, the climate change impact assessed through the carbon footprint indicator (i.e., sum of direct and indirect GHGs emitted along the NBS life cycle) has typically a global relevance, and thus a global spatial scale (e.g., the GHGs emitted in the process of transporting trees to a hypothetical NBS plantation site are assumed to contribute to climate change worldwide without any specific geographical resolution). This is also the case for indicators used to characterise the impact associated with fossil or mineral/metal resource depletion, while for other natural capital elements (e.g., renewable resources such as freshwater, or biodiversity), scarcity effects and pressures potentially relevant at the regional and local scales (e.g., watershed scales) can be taken into account. The environmental footprint associated with air pollution in LCA models, which is particularly relevant at the urban scale (e.g., due to the formation of PM, NO_x,tropospheric O_3, etc.) is also typically modelled in life cycle impact assessment. For some specific indicators of ecotoxicity, impacts can eventually be calculated even at a few meters square or indoor resolution, and deployed in the LCA model in combination with all other environmental footprint metrics.
For upscaling the LCA results of NBS pilot cases, and make them representative for wider spatial scales, either a prospective or consequential LCA model can be developed. This may allow to consider the (environmental) impact associated with land use changes based on the projections of the NBS land requirements. Moreover, several impact assessment methods have been developed so far which can be used to address questions on the footprint of NBS projects at different spatial scales. In Europe, consensus has been recently found on the use of the Environmental Footprint approach and recommended by the European Commission to measure and communicate the life cycle environmental performance of products and organisations[18].

[18] https://environment.ec.europa.eu/publications/recommendation-use-environmental-footprint-methods_en

I: Biodiversity

Specific proGIreg activities are aimed at evaluating the impact on biodiversity. In particular, to assess the benefits for biodiversity, phytoplankton and zooplankton are analysed in Ningbo, while insect pollinators are monitored in Turin.

The phytoplankton and zooplankton monitoring, and biodiversity evaluation can inform the nutrient capacity of the ecosystem, predict and early deal with environmental pollution such as algal blooms and red tides, and control and solve a series of problems such as water eutrophication. Long-term biodiversity monitoring can continuously reflect the water quality status and feedback the effect of comprehensive environmental improvement, and it crucial to start the monitoring before the intervention and continuous monitoring for at least two years.

Also for the pollinator monitoring, the field surveys should begin before the interventions and being conducted during the NBS implementation and beyond. In proGIreg, this lasts for four years in total, during which the trend of the insect pollinators as bees and butterflies, and flora is evaluated in a mid-term period highlighting the benefits for biodiversity in terms of richness and abundance species (Shannon index and Evenness index as KPIs). The methodologies adopted during the study (transect walk) are recognised and shared at international level. ProGIreg transect is the first urban survey in Turin and it represents the only example of monitoring between butterflies and bees in an urban context, as suggested by Eu-PoMS[19]. This transect takes part in the Citizen Science project of the European Butterfly Monitoring Scheme (eBMS) guaranteeing the butterfly monitoring during the years thanks to the volunteer activities. The innovative multi-approach method enables to maintain the monitoring over time by researcher involved in other national and international projects and by citizens as users of these areas.

Temporal upscale

The increase in biodiversity obtained because of the realization of an NBS has a temporal evolution which depends on several factors. First, if the NBS is maintained over time or not. Also, the implementation time may play a role, since the biodiversity increase has a specific behaviour as a function of time, depending on the NBS type and on the monitored species. If the historical series of data already available are sufficient, it would be possible to preview how the biodiversity will be in the future under the hypothesis that the NBS will be maintained at its best condition.

Spatial upscale

The data collected through the biodiversity monitoring that show the effectiveness of an NBS in both specific richness and abundance, as demonstrated by KPIs, can potentially be exported and projected to other urban contexts with similar situations to the site where the NBS is realized.

[19] Potts, S. et al. (2020) Proposal for an EU Pollinator Monitoring Scheme, EUR 30416 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-23859-1, doi:10.2760/881843, JRC122225

J: Water quality

Water pollution directly or indirectly endangers human health and restricts urban sustainable development. Therefore, it is necessary to conduct long-term monitoring of urban water bodies and provide data support for water quality security. Continuous sampling and monitoring of urban water bodies is to better plan and deal with the problem of water quality deterioration. During proGIreg, the experimenters collected water samples for testing once a week, and the monitored indicators include transparency, water temperature, pH, dissolved oxygen, total suspended solids, chemical oxygen demand, total phosphorus, total nitrogen, chlorophyll, ammonia nitrogen.

Although the frequency of weekly sampling and testing is already high, and time-consuming and laborious, it is still impossible to monitor water quality in real time. Automatic water quality monitoring equipment can conduct real-time and continuous monitoring of water. It is an environmental monitoring technology that has developed rapidly in recent years, and it is of great significance for controlling the total amount of pollutants and improving environmental management capabilities. It is suggested that in the future water management, if economic conditions permit, the use of automatic water quality monitoring equipment is encouraged to save time, effort, and efficiency.

Temporal upscale

The increase in water quality obtained because of the realization of an NBS has a temporal evolution which depends on several factors. First, if the NBS is maintained over time or not. Also, the implementation time may play a role, since the water quality amelioration has a specific behaviour as a function of time, depending on the NBS type and on the type and amount of the planted species, and their growth. If the historical series of data already available are sufficient, it would be possible to preview how the water quality will be in the future under the hypothesis that the NBS will be maintained at its best condition.

Spatial upscale

The data collected through the water quality monitoring that show the effectiveness of an NBS, as demonstrated by KPIs, can potentially be exported and projected to other urban contexts with similar situations in the site where the NBS is realized.

6. Monitoring and assessment plans of upscaled proGIreg NBS implementations

6.1 Upscaling the LL district level monitoring

In the proGIreg European FRCs (Dortmund, Turin and Zagreb), all the district level monitoring tools (Table 1) are used for benefit assessment. In Ningbo, the spatial tools (i.e., the BASE and GIS data collection) are similarly applied, while the GQ is not included due to the shorter permanence of this FRC within the project and the infeasibility of planning the post-implementation questionnaire. During the data collection planning and execution, a number of barriers were encountered, and several lessons are, thus, learned. These are resumed in the following Table 3 and should be kept in mind when planning an upscaling of the district level monitoring activities.

Table 3. Barriers encountered during the implementation of the district level monitoring and lessons learned.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
GQ	Socio-cultural inclusiveness Human health and wellbeing Economic and labour market benefits	Anonymous surveys	In Ningbo GQ was not planned, due to its shorter permanence within the project and the infeasibility of planning the post-implementation questionnaire The main challenges encountered were: (a) low response rate, (b) complaining on questions and/or procedure, and (c) lack of trust in the interviewers and interviewing procedure itself. To overcome low response rate, additional sampling methods were used, such as contacting twice by letter, approaching individuals in public spaces. Advertising door-to-door and snowball sampling was also used For those uncomfortable questions, the purpose of the project was clarified. In the case of continuing to refuse answering, the question was skipped. In general, cooperation with local NGOs and associations greatly increased the likelihood of positive feedback by the respondents Despite strong efforts, Dortmund and Turin couldn't achieve the target of 600 questionnaires for the pre-implementation GQ. A power analysis will be conducted after the post-implementation evaluation data collection to evaluate if the sample size is sufficient to get statistically robust results. In case the sample size is too small, its yield will be maximized using appropriate statistical methods

BASE	Ecological and environmental restoration Socio-cultural inclusiveness Human health and wellbeing Economic and labour market benefits	Spatial data from existing administrative databases	Existing databases were not available for all the spatial data originally planned to be collected by proGIreg. For this reason, the list has been later revised and significantly reduced to ensure a homogeneous collection of spatial data for all the FRCs
GIS	Socio-cultural inclusiveness Ecological and environmental restoration	Geographic information system (GIS)-derived data Multispectral remote sensing data	The walkability index is a derived metric that requires a large number of input data. This characteristic leads to two major issues: (1) data availability and (2) data harmonization across the civil local authorities involved Another issue concerns the harmonization of data across cities. Given the nature of the input data involved in the calculation of the Walkability index, it has been found to be difficult to obtain data acquired in the same year across cities. For example, the Land Use map provided by city of Zagreb is from 2012 while the city of Dortmund provided a Land Use map generated in the first decade of the 2000s. Land Use maps are usually developed on a multiyear basis by local authorities, as the changes in land use occurring yearly, especially in European cities, are often limited. As a consequence, we will be unable to calculate a yearly walkability index, as expected initially, but rather one walkability index before the initiation of the project and, depending on the availability of the data, another walkability index at the end of the project Lesson learned: • Data collection can vary across cities and constant interaction with local authorities is needed; • Given the nature of the input data, calculating a yearly walkability index is not feasible The Normalized Difference Vegetation Index (NDVI) is a well-known remote sensing index and no particular issues were found in its calculation

Temporal upscale

If efforts in maintaining the NBS functionality are guaranteed over time, or if the NBS implementation is upscaled within the same district, it is highly recommended to temporally upscale the NBS monitoring and assessment plans at the LL district level, to be able to properly evaluate the evolution of NBS implementations and their associated impacts. To this aim and since most of the social, health and economic NBS benefits are expected to be tangible in a long-term scale, it would be necessary and highly recommended to repeat the GQ after the end of the project, with the same protocol adopted during the project. GQ interviews and data analysis should be repeated at a certain time frequency, to be able to evaluate and follow the development and temporal evolution of these benefits. For the same reason, also for spatial data (BASE and GIS), which are retrieved once a year during the project, it would be important to continue retrieving these types of data, thus allowing to keep assessing NBS benefits and to evaluate significant impacts.

Spatial upscale

In case a new district is selected for wide NBS implementation, a spatial upscale of the district level monitoring activity would be required. In this case, the same protocols previously adopted for the spatial data (BASE and GIS) can be replicated, while more attention should be paid in replicating the GQ surveys, by considering the encountered barriers and lessons learned. A proper timing should be planned, to obtain a reliable pre-post implementation evaluation. Also, a suitable control district should be identified before starting the pre-implementation survey. A reliable evaluation of the risk connected with the data collection should be performed.

6.2 Upscaling the NBS level monitoring

The three types of upscaling described in the Section 4 of this Deliverable, the *roll-out*, *expansion* and *replication*[10] are taken into account in this section to evaluate their potential applicability for upscaling the eight NBS implemented during proGIreg, and to evaluate which strategy fits the best to which solutions. To our knowledge, each of the three strategies may be potentially applied to every proGIreg NBS type, with the exception of NBS1 - Leisure activities and clean energy on former landfills and NBS2 – New regenerated soil. These types of NBS result to be extremely specific and very restricted to the intervention area. Their implementation is strongly dependent on the local availability of former landfills (or at least post-industrial abandoned areas) which can be later transformed for leisure activities and clean energy production and on contaminated soils which can be regenerated. For this reason and to our knowledge, these NBS types cannot be easily expanded or replicated in other contexts. Similarly, great attention should be paid to the replication of highly specific NBSs such as NBS7 - Local environmental compensation processes, which is based on the public-private-partnership model. These solutions may be replicated within the same city or in another one and through the same partnership or the development of new ones, but it is extremely important to take in account the complexity and peculiarity of the new context (mainly organisational and administrative). This may lead to additional efforts in the redesign of the solution, in order to be able to better adapt to the new conditions and to be able to encounter specific challenges.

However, NBS peculiar characteristics may lead to a higher or lower suitability towards each upscaling strategies. For instance, within proGIreg, the “easier” upscaling strategy, the *roll-out*, could be more easily applied to solutions such as NBS3 – Community-based gardens, urban farms, and gardens, NBS4 – Aquaponics, NBS5 – Green walls and roofs, and NBS6 – Accessible green corridors. Indeed, all these solutions are or may be based on a modular structure. This results in the possibility to utilize the solution as it is and without major modifications and adopt it within other areas of the same city, where likely identical administrative and cultural barriers may be encountered. In the specific case of NBS3, the *roll-out* strategy will especially apply when solutions as rising beds are used as the base unit for develop urban gardens or farms. For the same reason, the modularity of these solutions is also connected to their potential *expansion* upscaling, which could be adopted on a larger area with respect to that identified in the pilot implementation. Instead, when *replication* upscaling occurs, by changing the city, different administrative or cultural barriers could emerge, and thus a rearrangement of the monitoring activity could be required.

In the following sections, for each of the eight NBS types, the most suitable monitoring proGIreg tools to be adopted for their benefits assessment are described and, in order to provide the reader with a practical and tangible guide on NBS benefit assessment, for each monitoring tool, the barriers encountered, and the lesson learned during proGIreg are reported.

6.2.1 NBS1: Renaturing landfill sites for leisure use and clean energy production

This NBS is related to the renaturing of landfill sites for leisure activities and/or clean energy production. This is extremely important since landfill sites are common in post-industrial areas, but also because the same approach as per NBS1 can be extended at post-industrial abandoned sites, in general, and for all these sites there are the challenges of securing them and making use of the space when no longer in use. Their well-exposed high shapes can be an advantage; they are ideal for producing solar or wind energy, their slopes can be used for different sports, and they provide scenic views when converted into public parks. In addition to these aims (leisure activities and energy production), renaturing efforts of these sites could be also conducted, through the plantation of new specimens and the implementation of new urban forests. If this is the case, the monitoring plan could be modified accordingly, thus taking in account also benefits provided by the vegetation in terms of carbon storage/sequestration or removal of gaseous pollutants or PM removal.

In the specific case of the former Deusenberg landfill, the site has been recultivated since 1992, with a four-meter-thick isolation layer being applied to an area of around 54 hectares and up to 55 meters in height for future vegetation. About 150,000 trees have been planted for this purpose. The Deusenberg was named after the Deusen district and opened to the public in 2004. Since then, it has become a popular destination for various recreational activities such as (dog) walking, jogging, cycling, mountain biking, bird watching, etc. Access to the top of Deusenberg is mainly from the northeast side via several trails and stairs. The other exposures are "gated" or a fenced by maintenance and work facility or train tracks. Because of its uniqueness, recreational and spatial significance, the citizens of Huckarde have expressed their desire to local politicians to improve the connection of their settlements to the Deusenberg recreational area. Thus, the Deusenberg is not only be made accessible by proGIreg (NBS6, barrier-free path in the southeast side), but also will become part of the exhibition area of the International Garden Exhibition in 2027.

The NBS1 in Dortmund has been implemented and managed on the Deusenberg since 2017 by a private energy company, ENTEGRO Photovoltaik-Systeme GmbH (Figure 8). The Deusenberg site belongs to the City of Dortmund, the landfill is maintained by the Entsorgung Dortmund GmbH (waste management company). The solar park has a capacity of 3952 kWp and produces around 3,600,000 kWh per year. The harvested energy is fed into the net of the local energy supplier DSW21 (Dortmunder Stadtwerke AG). 12,735 solar modules produce the electricity, 61 inverters produce the AC voltage.

Figure 8. The solar park on Deusenberg site (image © www.entegro.eu**).**

For NBS1, the NBS level monitoring plan adopted includes the evaluation of the benefits provided to the users of the new leisure activities (by tool A and B), of the economic and labour market benefits related to the new solar plant (by the tool C), and of the environmental benefits related to the saved carbon dioxide emission (tool D).

Table 4. Monitoring tools for evaluating the benefits produced by NBS1 - Renaturing landfill sites for leisure use and energy production.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
A - NBS-visitor questionnaire	Socio-cultural inclusiveness Human health and wellbeing	Quantitative social and health status indicators collected by anonymous survey Qualitative description of social and health status by keyword and cluster analysis (in case of vulnerable users)	Sometimes a standard, validated questionnaire cannot be administered, based on the type of users of the NBS In case of vulnerable population, for example, unable to compile the NBS-visitor questionnaire, an alternative data collection might be designed. This may be of two types: (a) qualitative data collection, such as focus groups or semi-structured interviews; (2) keyword clustering. The application of the method depends on both the population characteristics and the expertise and availability of human resources for data collection
B - SOPARC	Human health and wellbeing	Number of users and type of physical activity for a specific NBS as obtained by an observational survey performed by using the “System for Observing Play and Recreation in Communities”	It may happen that there is no use of the specific area to be assessed (i.e., the NBS site) by a systematic observation protocol, specially prior to the NBS implementation. This might happen because the site: 1) it is not accessible for users (e.g., fenced), 2) it is impassable (e.g., a brownfield); 3) it is seen as an unsafe place (e.g., dark, isolated) To evaluate the use of the NBS two adaptations could be considered: 1) to plan only post-implementation assessment and repeated post-assessments over time would help to draw the dynamics in the use of the implemented NBS; 2) to avoid specific day times in the observation schedule that might feel unsafe A fieldwork diary for the observation period would be useful to complement the data collected in the observation form with qualitative information on observers’ perceptions
C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The ELMQ for the solar panel park on top of the Deusenberg landfill site was performed with the operating company without any barriers. The questions could all be answered by the company since the system is established and operating as an independent unit allowing rather easy access to reliable data.

D – Carbon impact	Ecological and environmental restoration	The saved carbon dioxide emissions are estimated by converting in CO_2 equivalent the data on energy production by photovoltaic systems	To properly assess the climate change mitigation carried out by this specific NBS, it would certainly be necessary to take in consideration also GHG emissions connected to the NBS implementation and maintenance operations decomposition rate of removed plants but also to the role of soil as natural sink or source for carbon. For this specific intervention and carbon related monitoring tool, the LCA should be applied

6.2.2 NBS2: New regenerated soil thanks to biotic compounds for urban forestry and urban farming

After decades of abandonment, the soil in post-industrial areas is often of poor quality, unfit for any use. Importing fertile soil from elsewhere is costly, both environmentally as well as economically. The aim of NBS2 is to regenerate and limit the consumption of new soil. This is connected to the potential application of carbon-neutral methods to restore soil fertility thus combining the poor-quality soil with compost from organic waste and biotic compounds. However, in some cases, as occurred in Ningbo during proGIreg, the contamination level of the soil is too high, and any remediation can't be applied. If this is not the case, and new regenerated soil can be produced, it can also be tested for sustaining and planting new specimens and implementing new urban forests close to the excavation and regeneration site. The monitoring plan can then be modified accordingly, taking into account also the benefits provided by the vegetation in terms of carbon storage/sequestration, of air temperature improvement or of the removal of gaseous and particulate atmospheric pollutants, as in the specific case of Turin NBS2.

Specifically, NBS2 in Turin is based on excavated material from local construction sites with the addition of compost from organic fraction of municipal solid waste, zeolites and innovative bio stimulants, then transported and placed along the banks of the Sangone river. The composition of the new regenerated soil has been defined with the main scope of minimizing maintenance needs. Works for this NBS were coordinated by Environment Park with the contribution of several partners: Dual Srl (realization of the construction site); UNITO (monitoring activity); ACEA (compost provider); CCS (biotic compound provider); City of Turin, Città Metropolitana di Torino and the Regional Agency for the Protection of the Environment (ARPA) Piemonte (administrative procedures).

Figure 9. The New Soil site (image © City of Turin).

For NBS2, the adopted NBS level monitoring plan includes the evaluation of the benefits provided to the users by newly planted urban forest used to test the new soil quality (by tool A and B), of the economic and labour market benefits related to the new soil production (by the tool C), and of the environmental benefits related to the carbon stored, to the air pollutants removed and to the mitigation of the air temperature due to the new planted forest (tool D, E, F and G). Also, the overall environmental footprint of the new soil regeneration is evaluated by developing a LCA model (tool H).

Table 5. Monitoring tools for evaluating the benefits produced by NBS2 - New regenerated soil thanks to biotic compounds for urban forestry and urban farming.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
A - NBS-visitor questionnaire	Socio-cultural inclusiveness Human health and wellbeing	Quantitative social and health status indicators collected by anonymous survey Qualitative description of social and health status by keyword and cluster analysis (in case of vulnerable users)	Sometimes a standard, validated questionnaire cannot be administered, based on the type of users of the NBS In case of vulnerable population, for example, unable to compile the NBS-visitor questionnaire, an alternative data collection might be designed. This may be of two types: (a) qualitative data collection, such as focus groups or semi-structured interviews; (2) keyword clustering. The application of the method depends on both the population characteristics and the expertise and availability of human resources for data collection.

B - SOPARC	Human health and wellbeing	Number of users and type of physical activity for a specific NBS as obtained by an observational survey performed by using the "System for Observing Play and Recreation in Communities"	It may happen that there is no use of the specific area to be assessed (i.e., the NBS site) by a systematic observation protocol, specially prior to the NBS implementation. This might happen because the site: 1) it is not accessible for users (e.g., fenced), 2) it is impassable (e.g., a brownfield); 3) it is seen as an unsafe place (e.g., dark, isolated) To evaluate the use of the NBS two adaptations could be considered: 1) to plan only post-implementation assessment and repeated post-assessments over time would help to draw the dynamics in the use of the implemented NBS; 2) to avoid specific day times in the observation schedule that might feel unsafe A fieldwork diary for the observation period would be useful to complement the data collected in the observation form with qualitative information on observers' perceptions
C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The Economic and Labour market questionnaire is partly challenging to be answered with precise numbers, e.g. concerning the amount of work (person months, working hours, …) dedicated to a specific NBS. The interconnectedness of NBS and partners involved allows only estimations for many of these working issues. The planning and preparatory phase is a major cost item since many activities were needed to be carried out (co-design, permissions, fine-tune the NBS planning,…); these costs can be reduced significantly when being replicated/upscaled.

D – Carbon impact	Ecological and environmental restoration	The carbon storage in specific NBS is obtained by elaboration through mathematical models of environmental, GIS or economic data	The modelling of carbon storage and sequestration through the application of the *i-Tree eco* model is highly dependent on the collection of biometric and health status data as complete as possible. In this specific NBS, this activity may result particularly challenging and time-consuming. Even if random and sample collection is admitted, great attention must be paid to the quantity and representativeness of data collected. Since NBS carbon impact can be considered a long-term benefits, monitoring on a longer temporal scale may be needed For new-planted specimens, expected outcomes in the post-implementation analysis may not be significant and therefore not easily to quantify. Attention must also be paid to the need to irrigate new plantings, in order to avoid negative effects (premature death and plant decay) related to stress from planting In addition, to properly assess the climate change mitigation carried out by this specific NBS, it is necessary to take in consideration also the GHG emissions generated by the NBS implementation and maintenance operations, as well as by the decomposition rate of the removed plants (i.e., using LCA), but also the role of soil as natural sink or source for carbon
E - Air quality	Ecological and environmental restoration	Discontinuous ozone (O_3) and nitrogen dioxide (NO_2) concentration measurements are obtained by passive diffusion tubes in the proximity of the NBS and in a control site	Depending on the size of the new planted area, and its proximity with already green areas, this tool can be redundant
F - Air temperature	Ecological and environmental restoration	Measurement of air temperature inside the NBS and in a control site	Depending on the size of the new planted area, and its proximity with already green areas, this tool can be redundant Sheltering the sensors all in comparable ways is crucial to have reliable comparison among experimental and control sites

G – Particulate biomonitoring	Ecological and environmental restoration	Particulate matter (PM) uptake by the specific NBS is obtained by quali-quantitative characterizing the leaf-deposited PM, with SEM/EDX	Great attention must be paid to the selection of an adequate number of replicate leaves for each selected species. Plants from each species must be selected at high proximity to each other. To reduce the impact of soil resuspension, branches need to be sampled at a constant height, ranging from two up to six meters from the ground. To reduce any potential influence of meteorological conditions branches must be detached after a constant rainless period For new-planted specimens, expected outcomes (canopy/leaf area growth and therefore changes in the PM leaf deposition rate) in the post-implementation analysis may not be confirmed. If this is the case, post-implementation samples and analysis may be still considered as additional statistical replicates Additional active PM samplings may be considered in parallel to the leaf sampling locations (considering costs and maintenance efforts of the instruments), to validate the PM leaf biomonitoring and achieve data on the level of pollution in the implementation area
H – Environmental footprint	Ecological and environmental restoration	Environmental data are collected to perform the LCA of the selected NBS	The LCA tool is applied rigorously in accordance with state-of-the art methodological practices compatible for NBS impact assessment and monitoring. According to those LCA guidelines, when site-specific data are not available (the life cycle model could not be fully covered due to the impossibility to retrieve industrial/process specific data for some of the inputs used by the NBS2), estimations based on literature are done An environmental footprint profile of the NBS is generated with LCA and used for comparison of the environmental performances over time and against business-as-usual practices

6.2.3 NBS3: Community-based urban farming and gardening on post-industrial sites

Post-industrial areas often lack green spaces for public use. Turning unused urban land into productive community gardens can have a positive impact on locals, contributing to improved mental and physical health through exposure to nature and healthy sources of food and a community feeling. This NBS may include in itself different types of urban farming and gardening which may be associated to the production of vegetables for consuming purposes or not, or the utilization of rising beds instead of the direct cultivation on the ground. Depending on how this type of NBS is implemented, the monitoring and assessment plan may be modified accordingly. For instance, if this NBS is also associated to the production of vegetables which can be sold to the public, economic benefits and therefore focused monitoring tools could be also employed. If social and therapeutic aspects are also expected, these benefits and focused monitoring tools may be also considered to this aim.

For instance, in Zagreb, during proGIreg, a new therapeutic garden is realized, where a previous abandoned green field was. While the project implementation started, the idea of conceiving the new garden as therapy garden came up and was welcomed by the partners and local community alike. The co-design workshops are as opportunity to gather the potential stakeholders and to include them in the planning phase, ensuring that the garden is planned adequately to cater to the needs of all possible users, including local people with various disabilities. There are plenty of potential users in the neighbouring area (including war veterans and several housing communities of people with autism). The new garden is planned in a way that it can meet the needs of all potential users in the neighbourhood and beyond.

Figure 10. The New Therapeutic Garden (image © CNR).

Figure 11. Community garden in Orti Generali, Turin (image @ University of Turin).

NBS3, in proGIreg, expresses itself in many different ways, ranging from the Zagreb therapeutic garden described above, to the Turin and Dortmund urban horticulture (Figure 11) or the Ningbo regenerated urban lake shores. Thus, the monitoring plan is time to time adapted, to meet the local needs. However, some common point can be highlighted in the adopted monitoring plans: the evaluation of the benefits provided to the users (by tool A and B), of the economic and labour market benefits related to possible economic activities (such as food production; by the tool C), and of the possible environmental benefits related to the air pollutants removed and to the mitigation of the air temperature (which are likely more important when a previous brownfield is renatured; tool D, E, F and G), to the improved biodiversity (tool I), or to the improved water quality (when blue infrastructures are included in the NBS; tool J).

Table 6. Monitoring tools for evaluating the benefits produced by NBS3 - Community-based urban farming and gardening on post-industrial sites.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
A - NBS-visitor questionnaire	Socio-cultural inclusiveness Human health and wellbeing	Quantitative social and health status indicators collected by anonymous survey Qualitative description of social and health status by keyword and cluster analysis (in case of vulnerable users)	Sometimes a standard, validated questionnaire cannot be administered, based on the type of users of the NBS In case of vulnerable population, for example, unable to compile the NBS-visitor questionnaire, an alternative data collection might be designed. This may be of two types: (1) qualitative data collection, such as focus groups or semi-structured interviews; (2) keyword clustering. The application of the method depends on both the population characteristics and the expertise and availability of human resources for data collection
B - SOPARC	Human health and wellbeing	Number of users and type of physical activity for a specific NBS as obtained by an observational survey performed by using the “System for Observing Play and Recreation in Communities”	It may happen that there is no use of the specific area to be assessed (i.e., the NBS site) by a systematic observation protocol, specially prior to the NBS implementation. This might happen because the site: (1) it is not accessible for users (e.g., fenced), (2) it is impassable (e.g., a brownfield); (3) it is seen as an unsafe place (e.g., dark, isolated) To evaluate the use of the NBS two adaptations could be considered: (1) to plan only post-implementation assessment and repeated post-assessments over time would help to draw the dynamics in the use of the implemented NBS; (2) to avoid specific day times in the observation schedule that might feel unsafe A fieldwork diary for the observation period would be useful to complement the data collected in the observation form with qualitative information on observers’ perceptions

C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The Economic and Labour market questionnaire is partly challenging to be answered with precise numbers, e.g. concerning the amount of work (person months, working hours, …) dedicated to a specific NBS. The interconnectedness of NBS and partners involved allows only estimations for many of these working issues. The planning and preparatory phase is a major cost item since many activities were needed to be carried out (co-design, permissions, fine-tune the NBS planning,…); these costs can be reduced significantly when being replicated/upscaled.
E - Air quality	Ecological and environmental restoration	Discontinuous ozone (O3) and nitrogen dioxide (NO2) concentration measurements are obtained by passive diffusion tubes in the proximity of the NBS and in a control site	Depending on the size of the new planted area, and its proximity with already green areas, this tool can be redundant
F - Air temperature	Ecological and environmental restoration	Measurement of air temperature inside the NBS and in a control site	Depending on the size of the new planted area, and its proximity with already green areas, this tool can be redundant Sheltering the sensors all in comparable ways is crucial to have reliable comparison among experimental and control sites
G – Particulate biomonitoring	Ecological and environmental restoration	Particulate matter (PM) uptake by the specific NBS is obtained by quali-quantitative characterizing the leaf-deposited PM, with SEM/EDX	Great attention must be paid to the selection of an adequate number of replicate leaves for each selected species. Plants from each species must be selected at high proximity to each other. To reduce the impact of soil resuspension, branches need to be sampled at a constant height, ranging from two up to six meters from the ground. To reduce any potential influence of meteorological conditions branches must be detached after a constant rainless period For new-planted specimens, expected outcomes (canopy/leaf area growth and therefore changes in the PM leaf deposition rate) in the post-implementation analysis may not be confirmed. If this is the case, post-implementation samples and analysis may be still considered as additional statistical replicates Additional active PM samplings may be considered in parallel to the leaf sampling locations (considering costs and maintenance efforts of the instruments), to validate the PM leaf biomonitoring and achieve data on the level of pollution in the implementation area

I - Biodiversity	Ecological and environmental restoration	Observational data are collected for the biodiversity monitoring surveys of both selected insect pollinator and plankton species, according to sampling protocols which are adapted to the NBS	Lesson learned: the co-design of community gardens in accordance with insect pollinator needs is crucial; coupled transect is an appropriate method to monitor the benefit for biodiversity. If possible; carry out the survey in the same date both for bees and butterflies transect walks is suggested to ameliorate the data comparison Barriers: Management of the areas is not always in line with the requirements of the project (e.g., grass mowing along the transect and grazing)
J – Water quality	Ecological and environmental restoration	Water samples are collected in specific sites of the NBS and then analysed to obtain: transparency, water temperature, pH, dissolved oxygen, total suspended solids, chemical oxygen demand, total phosphorus, total nitrogen, chlorophyll, ammonia nitrogen	Barriers: aquatic plants that purifies water is subject to natural (typhoon, pest) and man-made (picking) damage Lesson learned: strengthen the management of aquatic plants and set punitive measures if necessary; Pay attention to the setting of the sampling sites

6.2.4 NBS4: Aquaponics as soil-less agriculture for polluted sites

Aquaponics is the combination of raising fish (aquaculture) in tanks together with soilless cultivation of plants (hydroponics) in a symbiotic environment, whereby the fish wastewater provides the nutrients needed to feed the plants. This type of NBS is ideal for promoting local food production in areas with contaminated or poor-quality soil. Similarly to NBS3, food produced locally by locals can lead to healthier diets and contribute to community-building. Additionally, the aquaponics systems will create green job opportunities.

In Dortmund, two 200 m² large aquaponic greenhouses are realized (Figure 12). Two proGIreg partners are owners of the system (Die Urbanisten, South Westphalian University of Applied Sciences), whereas the partners Citybotanicals and AquaponikManufaktur as private enterprises support the implementation process. Building permission process for this innovative system took 10 months, as administrative (e.g., merging of plots on Hansa Coking Plant) and conceptual (scientific experiments with regards to energetic optimization and chemical analysis of harmful substances in grown food) adaptations were needed. Delays in co-design and implementation were mainly connected to 1) site identification and stipulation of contracts with the landowner (a foundation), 2) conceptual adaptation of complex legal aspects for building permission and 3) soil contamination in the implementation area. These challenges have led to a re-adaptation of the construction scheme (step-by-step realization: in a first step growing plants but so far, no fish farming is permitted which still is a pursued goal) and a significant cost increase which has been solved by a budget re-allocation of Dortmund proGIreg-partners.

Figure 12. Construction site of Dortmund NBS4, Hansa Coking Plant (image © City of Dortmund)

Being mainly a scientific and productive NBS, not open to the public access, NBS4 produced benefits that are going to be evaluated are mainly related to the economic and labour market aspects (tool C), and by its environmental footprint (tool H).

Table 7. Monitoring tools for evaluating the benefits produced by NBS4 - Aquaponics as soil-less agriculture for polluted sites.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The Economic and Labour market questionnaire is partly challenging to be answered with precise numbers, e.g. concerning the amount of work (person months, working hours, …) dedicated to a specific NBS. The interconnectedness of NBS and partners involved allows only estimations for many of these working issues. The planning and preparatory phase is a major cost item since many activities were needed to be carried out (co-design, permissions, fine-tune the NBS planning,…); these costs can be reduced significantly when being replicated/upscaled. For NBS4 especially the building permission (Dortmund), finding suitable experts (Zagreb) as well as technological innovation measures (all cities) demand many working resources.
H – Environmental footprint	Ecological and environmental restoration	Environmental and economic data are collected to perform the LCA of the selected NBS	The LCA tool is applied rigorously in accordance with state-of-the art methodological practices compatible for NBS impact assessment and monitoring An environmental footprint profile of the NBS can be generated with LCA and use for comparison of the environmental performances over time and against business-as-usual practices

6.2.5 NBS5: Capillary GI on walls and roofs

Green roofs and vertical gardens are known to be able to improve a building's insulation, reduce storm water run-off, capture CO_2, filter pollutants, and increase biodiversity. This all leads to reduced energy consumption and increased urban resilience. Available technology is advanced, but the challenge is to increase uptake by integrating it into local urban policies. Also, for this type of NBS, great variability is included in its definition. These kinds of solutions may be implemented in different situations, thus providing differentiated benefits. This can be the case of green walls which are implemented in indoor or outdoor environments or in abandoned or inhabited buildings. Differences may occur even considering the plant species selected for the implementation. Therefore, the planned monitoring tools may need to be accordingly tuned. For instance, if this type of NBS is implemented on abandoned buildings, no efforts should be place for the monitoring of KPIs such as the economic and carbon impact related ones, or the impact on the social and well-being aspects of the citizen living in its proximity. Also, if only grass species are selected for the implementation of capillary GI on walls and roofs, air quality related benefits may be less significant and difficult to evaluate, in respect to the situation where trees species are employed.

In the specific case of Turin, a green wall of 80 sqm, 3 meters high, constructed as a self-supporting structure set-off from the wall of the building, is installed outside a homeless shelter (Figure 13). In this case, most of the monitoring activities are put into action: the impact on the shelter users is evaluated (tool A), as well as its effect on the local air temperature (tool F) and on the atmospheric PM (tool G). If the impact on the air temperature is significant, this could reduce the energy demand of the building hosting the NBS and, thus, its carbon impact (tool D). The last tool suggested for this NBS type is to measure the impact on the air quality in term of gas concentration (tool E). This is not monitored in the Turin case study, since the small size and the green surrounding of the NBS likely make it undetectable. However, it could be of interest for other case studies. All the possible tools to apply to the NBS5 benefit assessment are described in Table 8.

Figure 13. The Green Wall realized in Turin (image © City of Turin).

Table 8. Monitoring tools for evaluating the benefits produced by NBS5 - Capillary GI on walls and roofs.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
A - NBS-visitor questionnaire	Socio-cultural inclusiveness Human health and wellbeing	Quantitative social and health status indicators collected by anonymous survey Qualitative description of social and health status by keyword and cluster analysis (in case of vulnerable users)	Sometimes a standard, validated questionnaire cannot be administered, based on the type of users of the NBS In case of vulnerable population, for example, unable to compile the NBS-visitor questionnaire, an alternative data collection might be designed. This may be of two types: (1) qualitative data collection, such as focus groups or semi-structured interviews; (2) keyword clustering. The application of the method depends on both the population characteristics and the expertise and availability of human resources for data collection When NBS5 are realized in schools, for children population, great attention must be paid in the collaboration with school staff. School staff, e.g., teachers, may not be confident with the research methodology. In this sense, they may not perfectly adhere to the research design. In this specific case, the exposure to the green wall was neither systematized nor controlled by number of events. It is suggested to provide a systematic intervention protocol
C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The Economic and Labour market questionnaire is partly challenging to be answered with precise numbers, e.g. concerning the amount of work (person months, working hours, …) dedicated to a specific NBS. The interconnectedness of NBS and partners involved allows only estimations for many of these working issues. The planning and preparatory phase is a major cost item since many activities were needed to be carried out (co-design, permissions, fine-tune the NBS planning,…); these costs can be reduced significantly when being replicated/upscaled. For physical implementations requiring tenders (e.g. the walls in Torino and Zagreb), the required financial resources have to be taken into account properly (preparing the tenders, working resources required to perform it, etc.).
D – Carbon impact	Ecological and environmental restoration	The saved carbon dioxide emissions are estimated by converting in CO_2 equivalent the data on building energy demand	Great attention must be paid to the collection and analysis of the building energy demand. For a proper assessment several seasons are required

E - Air quality	Ecological and environmental restoration	Discontinuous ozone (O_3) and nitrogen dioxide (NO_2) concentration measurements are obtained by passive diffusion tubes in the proximity of the NBS and in a control site	Depending on the size of the new planted area, and its proximity with already green areas, this tool can be redundant
F - Air temperature	Ecological and environmental restoration	Measurement of air temperature inside the NBS and in a control site	In this type of NBS, to different types of temperature monitoring can be done: indoor and outdoor The indoor temperature control by NBS implementation is an important impact, due to its consequence on the energetic and, thus, economic, aspects. However, indoor air temperature monitoring is not always possible in used buildings, because air conditioning alters the evaluation In the outdoor temperature monitoring, sheltering the sensors all in comparable ways is crucial to have reliable comparison among experimental and control sites
G – Particulate biomonitoring	Ecological and environmental restoration	Particulate matter (PM) uptake by the specific NBS is obtained by quali-quantitative characterizing the leaf-deposited PM, with SEM/EDX	Great attention must be paid to the selection of an adequate number of replicate leaves for each selected species. Plants from each species must be selected at high proximity to each other. To reduce the impact of soil resuspension, branches need to be sampled at a constant height, ranging from two up to six meters from the ground. To reduce any potential influence of meteorological conditions branches must be detached after a constant rainless period

6.2.6 NBS6: Making post-industrial sites and renatured river corridors accessible for local residents

In post-industrial cities, it may happen that rivers are left derelict and inaccessible for locals. While other existing projects are involved in renaturing the rivers without making them accessible or in creating green corridors in the LLs but far from the blue infrastructure, the focus of proGIreg is to improve the accessibility to the renatured river though green corridors so that the cities become more liveable, and locals can connect more to nature. However, during the project, due to administrative problems arose in connection with the creation of the NBS6, mostly related to the acquisition of the required lands from private owners, the NBS6 in Zagreb and Turin do not follow any river anymore.

Instead, in Dortmund, a 115 m long barrier-free foot and bike path is constructed, to connect the former Deusenberg landfill site with the Emscher river cycling route (Figure 14). It provides shorter access to the Deusenberg recreational areas for Huckarde citizens. This NBS is implemented by the City of Dortmund and will be maintained by its affiliated company EDG, Entsorgung Dortmund GmbH (Waste management company).

Figure 14. Construction of the footpath (image © Landschaft planen+bauen).

Being fully immersed in a green context, generally NBS6 produced benefits are only expected in connection with their users. Also, since people are expected to use such corridors to move from one place to another, observational tools are preferred. Thus, the impact on the users has been evaluated only by tool B. However, when the corridor passes across grey areas, it could also have an impact on the biodiversity (tool I), which deserves interest to be monitored (as in Turin NBS6).

Table 9. Monitoring tools for evaluating the benefits produced by NBS6 - Making post-industrial sites and renatured river corridors accessible for local residents.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
B -SOPARC	Human health and wellbeing	Number of users and type of physical activity for a specific NBS as obtained by an observational survey performed by using the “System for Observing Play and Recreation in Communities”	It may happen that there is no use of the specific area to be assessed (i.e., the NBS site) by a systematic observation protocol, specially prior to the NBS implementation. This might happen because the site: (1) it is not accessible for users (e.g., fenced), (2) it is impassable (e.g., a brownfield); (3) it is seen as an unsafe place (e.g., dark, isolated). To evaluate the use of the NBS two adaptations could be considered: (1) to plan only post-implementation assessment and repeated post-assessments over time would help to draw the dynamics in the use of the implemented NBS; (2) to avoid specific day times in the observation schedule that might feel unsafe A fieldwork diary for the observation period would be useful to complement the data collected in the observation form with qualitative information on observers’ perceptions
I - Biodiversity	Ecological and environmental restoration	Observational data are collected for the biodiversity monitoring surveys of selected pollinator species, according to sampling protocols which are adapted to the NBS	Lessons learned: a mid-term monitoring is necessary to evaluate the NBS efficacy; an improved dissemination strategy is needed to get citizens more aware about the project activities. Barriers: Management of the crop boxes by citizen and cooperatives are not always easy; vandalism; experts are needed to conduct the biodiversity monitoring survey

6.2.7 NBS7: Establishing protocols and procedures for environmental compensation at local level

This NBS type is connected to the establishment of protocols and procedures for environmental compensation. More efforts in the shape of establishing the evidence-base for NBS and unlocking funds, for example via adaptation funds, taxes or public-private partnerships are needed. As previously described, this type of NBS is extremely variable due to 1) the administrative/legislative context in which it is applied, and 2) the type of applied procedures.

Due to economic nature, NBS7 expected benefits are related to monetary benefits. For instance, in the case of Ningbo, the local government (the government of Haishu District) signed a public-private-partnership (PPP) agreement with private enterprise (Tianhe Aquatic Ecosystems Engineering Co. Ltd) to treat the Moon Lake Park. In the agreement, the governance and maintenance period of the project is ten years, and the local government compensates the private enterprises for their work in 8 instalments, for a total of 750,000 euros, on the basis of the achieved results in terms of water and greening quality. Thus, the expected benefits are evaluated mainly by the ELMQ (tool C).

Table 10. Monitoring tools for evaluating the benefits produced by NBS7 - Establishing protocols and procedures for environmental compensation at local level.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The Economic and Labour market questionnaire is partly challenging to be answered with precise numbers, e.g. concerning the amount of work (person months, working hours, …) dedicated to a specific NBS. The interconnectedness of NBS and partners involved allows only estimations for many of these working issues. For NBS7, no implementation costs are linked to it – only labour costs and possible minor cost items. However, it is beneficial to make the NBS developers aware of possible business cases of their guidelines/protocols. Other public authorities, like municipalities or regions, could be interested in learning from the Living Lab experiences and outputs, even in return for a fee or other financial compensation.

6.2.8 NBS8: Butterfly gardens for disadvantaged people

The goal of this NBS is to promote the improvement of butterflies creating a network of green areas appropriately managed with plants (food plants and nectar sources) suitable for the insect life cycle, which allow butterflies to cross the urban area, otherwise presenting a barrier to these insects. At the same time, the project aims to promote social inclusiveness for disadvantaged people through their active participation in all the NBS implementation and maintenance phases.

Turin NBS8 (Figure 15) involves people with mental diseases working in butterfly gardens co-design and focusing on the engagement of local citizens and municipality in the management of ornamental and public green spaces following pollinators needs.

Figure 15. Overview of the activities developed within NBS8 (image © City of Turin).

Due to its double aim, NBS8 produced benefits are in connection with both social and health aspect and biodiversity ones. Thus, both tool A and I can be applied. In case a productive aspect is also included (such as honey production, for instance), an economic evaluation can be also performed (tool C).

Table 11. Monitoring tools for evaluating the benefits produced by NBS8 - Pollinator biodiversity improvement activities and citizen science project.

Code - Short name	Assessing domains	Data types	Barriers and lessons learned
A - NBS-visitor questionnaire	Socio-cultural inclusiveness Human health and wellbeing	Quantitative social and health status indicators collected by anonymous survey Qualitative description of social and health status by keyword and cluster analysis (in case of vulnerable users)	Sometimes a standard, validated questionnaire cannot be administered, based on the type of users of the NBS In case of vulnerable population, for example, unable to compile the NBS-visitor questionnaire, an alternative data collection might be designed. This may be of two types: (1) qualitative data collection, such as focus groups or semi-structured interviews; (2) keyword clustering. The application of the method depends on both the population characteristics and the expertise and availability of human resources for data collection When NBS8 are realized in schools, for children population, great attention must be paid in the collaboration with school staff. School staff, e.g., teachers, may not be confident with the research methodology. In this sense, they may not perfectly adhere to the research design. In this specific case, the exposure to the green wall was neither systematized nor controlled by number of events. It is suggested to provide a systematic intervention protocol
C - Economic and labour market questionnaire	Economic and labour market benefits	Economic impact indicators of a specific NBS are obtained by a survey about economic parameters to be submitted to the organisation in charge of NBS implementation as well as to the organisation in charge of long-term management	The Economic and Labour market questionnaire is partly challenging to be answered with precise numbers, e.g. concerning the amount of work (person months, working hours, …) dedicated to a specific NBS. The interconnectedness of NBS and partners involved allows only estimations for many of these working issues. The planning and preparatory phase is a major cost item since many activities were needed to be carried out (co-design, permissions, fine-tune the NBS planning,…); these costs can be reduced significantly when being replicated/upscaled.
I - Biodiversity	Ecological and environmental restoration	Observational data are collected for the biodiversity monitoring surveys of selected pollinator species, according to sampling protocols which are adapted to the NBS	Barriers: needed expertise available to conduct this specific biodiversity monitoring survey

7. Conclusions

The monitoring and assessment of the benefits produced by an NBS implementation is a crucial aspect of the implementation itself and should be planned in parallel with the physical implementation. Indeed, Data collection for benefit assessment needs to start before the implementation, with the collection of the baseline data, which is essential for any further assessment. Then, data collection is repeated after the NBS implementation, with a time frequency that depends on the evaluation criteria but also (unfortunately) by economic of administrative reasons. Then, the data collected for the benefit assessment are converted into measurable, normalized KPIs.

All the amount of information included in the obtained KPIs is a richness that can be exploited by the stakeholders. Indeed, it provides a solid base to improve the knowledge about NBS technology, but also to strength the capability of planning (and realizing) more efficient NBS in the future.

In particular, during the project proGIreg, eight different types of NBS are realized in four LLs and their impact on different assessment domain is monitored by using already existing or newly introduced tools, both at the LL district and at the NBS level.

All the expertise accumulated during the project in connection with the application of such tools to the monitoring of the NBS types realized is resumed in the present document. In particular, instructions are provided here to the stakeholders about how to use the already assessed data with provisional aims (to help the planning of future NBS) and about how to monitor new upscaled NBS interventions by using the proGIreg tools and approach.

In particular, the information reported in this document is dedicated to the project FRC (in case they want/need to replicate the monitoring activities in future times, beyond the project duration, or to upscale the already implemented NBS or obtained results) and FC (which need to monitor and assess the impact of the NBS they are going to implement), but also to any other stakeholder that could find useful the proGIreg experience.