NBS Demonstration Site Start-Up Report

D5.4 Deliverable

30/07/2021

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European Commission

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052

Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Deliverable administration					
No & name	**D5.4 NBS Demonstration Site Start-up Report**				
Status	Final	**Due**	M48	**Date**	2021-07-30
Author(s)	**VTT**, EIN, GEN, TRE, RINA, Kuijpers, RAM, LAND				
Description of the related task and the deliverable. Extract from DoA	**WP5 Climate & Water Resilient Urban Living Labs (VTT, FHG, EIN, GEN, TRE, ENoLL, LAN, RAM, INN, IMP, RINA, IRE, TU/e, UAV, STU, LTU) M1-M66** The overall objective of WP5 is to organise and manage the implementation of NBS in accordance with the local cocreation process, including providing support for innovative governance models and business and financing models. The technical demonstrations will be planned and implemented in close collaboration between cities and local partners with additional support from the UNaLab consortium. Tasks related to this deliverable are: **T5.2 Demonstration of NBS in the City of Eindhoven (EIN, INN, IMP, ENOLL, LTU) M1-66** This task contributes to M5.3, D5.3, D5.4 and D5.5. EIN leads this task with assistance from INN, IMP, ENoLL and LTU. This task will provide regular information of the progress, outputs and potential alignment of activities to task T1.7. **T5.3 Demonstration of NBS in the City of Genova (GEN, IRE, LAN, EIN, ENOLL, RINA, LTU) M1-66** This task contributes to M5.3, D5.3, D5.4 and D5.5. GEN leads this task with technical advice/local assistance from IRE, LAN, and RINA, and support and advice from EIN, ENoLL and LTU. This task will co-operate with other SCC02 projects and will provide regular information of the progress, outputs and potential alignment of activities to task T1.7. **T5.4 Demonstration of NBS in Tampere (TRE, VTT, RAM, ENOLL, EIN, LTU) M1-66** This task contributes to M5.3, D5.3, D5.4 and D5.5. TRE leads this task with technical assistance and local support from VTT and RAM, and support and advice from ENoLL, EIN and LTU. This task will co-operate with other SCC02 projects and will provide regular information of the progress, outputs and potential alignment of activities to task T1.7. D5.4 ULL NBS demonstration site start-up report illustrates the development and implementation of the Urban Living Labs (ULLs) in the Urban Nature Labs (UNaLab) project front-runner cities (FRCs) – Tampere (FI), Eindhoven (NL) and Genova (IT).				
Participants	VTT, EIN, GEN, TRE, RAM, LAND, IRE, M3S, Kuijpers, RINA				
Comments					

V	Date	Authors	Description
0.1	16.3.2021	Arto Laikari, Maria Dubovik, Ville Rinta-Hiiro, Laura Wendling	ToC prepared
1	9.7.2021	All authors	First version of the document

1.1	12.7.2021	Spela Zalokar, Francesca Spagnoli	Cross-WP review (WP2)
2	15.7.2021	Arto Laikari, Maria Dubovik	Updates and corrections per cross-WP review and other comments
2.1	21.7.2021	Sophie Mok	Quality check
3	22.7.2021	Maria Dubovik, Arto Laikari	Updates and corrections per quality check
3.1	26.7.2021	Laura Wendling	Coordinator check and approval
4	28.7.2021	All	Final updates implemented

Dissemination level		
PU	Public	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

About UNaLab

The UNaLab project is contributing to the development of smarter, more inclusive, more resilient and more sustainable urban communities through the implementation of nature-based solutions (NBS) co-created with and for local stakeholders and citizens. Each of the UNaLab project's three Front-Runner Cities – Eindhoven (NL), Genova (IT) and Tampere (FI) – has a strong commitment to smart, citizen-driven solutions for sustainable urban development. The establishment of Urban Living Lab (ULL) innovation spaces in Eindhoven, Genova and Tampere supports on-going co-creation, demonstration, experimentation and evaluation of a range of different NBS targeting climate change mitigation and adaptation along with the sustainable management of water resources. The Front-Runner Cities actively promote knowledge- and capacity-building in the use of NBS to enhance urban climate and water resilience within a network of committed partner cities, including seven Follower Cities – Stavanger, Prague, Castellón, Cannes, Başakşehir, Hong Kong and Buenos Aires – and the Observers, Guangzhou and the Brazilian Network of Smart Cities. Collaborative knowledge production among this wide network of cities enables UNaLab project results to reflect diverse urban socio-economic realities, along with differences in the size and density of urban populations, local ecosystem characteristics and climate conditions. Evidence of NBS effectiveness to combat the negative impacts of climate change and urbanisation will be captured through a comprehensive monitoring and impact assessment framework. Further replication and up-scaling of NBS is supported by development of an ULL model and associated tools tailored to the co-creation of NBS to address climate- and water-related challenges, a range of applicable business and financing models, as well as governance-related structures and processes to support NBS uptake. The results of the project will be a robust evidence base and go-to-market environment for innovative, replicable, and locally-attuned NBS.

Partners

Table of Contents

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

1. EXECUTIVE SUMMARY

The *NBS Demonstration Site Start-Up Report* (Deliverable D5.4) is a report developed in the Urban Nature Labs (UNaLab) project. This report illustrates the development and implementation of the Urban Living Labs (ULLs) NBS demonstration sites in the UNaLab project front-runner cities (FRCs) Tampere (FI), Eindhoven (NL) and Genova (IT). The report presents the initiation of the ULLs and lessons learned, and general recommendations derived from the combined experience of the three distinct FRCs. UNaLab front-runner cities represent a cross-section of Europen cities, bringing together Southern, Central and Northern European aspects relevant for NBS implementation. While FRCs share many environmental and social challenges, NBS implementation is always specific to the local context and must be adapted to suit the local conditions. These result in varying commissioning procedures and regulations, and approaches to the structural and technical characteristics of implemented NBS.

Nature-based solutions are widely recognised for their climate change adaptation (CCA) and disaster risk reduction (DRR) potential. To highlight the cities' weak points in addressing disaster risk and thus indirectly support the NBS initiation, the disaster resilience assessment was executed in two of the UNaLab FRCs, Tampere and Genova, per United Nations Office for Disaster Risk Reduction (UNDRR) Disaster Resilience Scorecard for Cities assessment (UNDRR, 2017). The findings and summaries of these assessments are outlined in the document and the detailed scorecard results are presented in Appendix 1. In Tampere and Genova, only the Preliminary level assessment was performed as it was deemed to provide sufficient information and outcomes at the current stage. The application of the Disaster Resilience Scorecard for Cities in UNaLab front-runner cities is intended to measure resilience against the impacts of climate change (e.g., floods and droughts).

The detailed NBS descriptions from three FRCs are outlined in Appendix 2, which serve as a summary NBS catalogue describing in a compact and consistent way the basic information, addressed challenges as well as some of the technical and design parameters of implemented NBS. The monitoring strategy and defined maintenance approach are also presented for each NBS listed in Appendix 2. Monitoring constitutes an essential element of NBS implementation by providing evidence of its environmental, social and economic impacts. As an example, we have provided some early monitoring results from the FRC Tampere. Monitoring of the NBS implemented during the UNaLab project will continue throughout the project duration and beyond. These impacts and results will be analysed and further reported in the upcoming project reports to provide additional evidence in support of the widespread adoption of NBS.

Nature-based solution implementation, including planning, commissioning and realisation, proved to be inherently variable in all UNaLab FRCs given the differences in their financial and organisational structures and the procedures adopted. However, a number of outcomes and lessons learned were shared among all three cities, including but not limited to timely involvement of relevant parties at early planning stages, outlining fulfilment expectations with contractors and assigning responsibilities concerning NBS maintenance. Technical-economic documentation was an asset in selecting the suitable NBS, and frequent monitoring aided in detecting and resolving issues related to NBS performance. All three UNaLab FRCs concluded that involvement and retention of stakeholders who share a 'common vision' aided in increasing social acceptance and their involvement in NBS design, monitoring and advocating the renaturing of urban areas.

2. INTRODUCTION

2.1 Purpose and target group

The *Nature-Based Solutions Demonstration Start-Up Report* (Deliverable D5.4) aims to illustrate the development and implementation of the NBS-focused Urban Living Labs (ULLs) in the Urban Nature Labs (UNaLab) project front-runner cities (FRCs) of Tampere (FI), Eindhoven (NL) and Genova (IT). The report presents findings, good practices and lessons learned from the establishment of ULLs and NBS demonstration sites. Appendix 1 presents detailed results of the UNDRR Disaster Resilience Scorecard for Cities assessment, and a comprehensive overview of NBS and supporting measures implemented in the UNaLab FRCs. Appendix 2 contains the detailed descriptions of NBS implemented in UNaLab FRCs. Together with the final *Nature-Based Solutions Implementation Handbook* (D5.5), *NBS Demonstration Start-Up Report* will form a part of the UNaLab Replication Framework by presenting the process and the outcomes of NBS-focused ULL implementation in the FRCs. These two reports will provide guidance for NBS replication, from co-creation, through co-implementation and co-management, including social, environmental and economic data acquisition and management, and NBS impact evaluation, performance assessment and maintenance.

2.2 Contributions of partners

VTT led the preparation of D5.4 *NBS Demonstration Start-Up Report* with significant contributions to Chapters 4–6 and Appendix 2 from front-runner cities TRE, EIN, GEN, and technical partners RAM, LAND, and Kuijpers. RINA executed the UNDRR (United Nations Office for Disaster Risk Reduction) Scorecard activity in Genova, and an external consultancy Et May Oy executed the same activity in Tampere (Chapter 4).

2.3 Baseline

The present document (D5.4, *NBS Demonstration Start-Up Report*) briefly describes the baseline establishment in the UNaLab FRCs. The definition of baseline conditions for NBS impact monitoring is described in detail in UNaLab D3.1, *Performance and Impact Monitoring of Nature-Based Solutions* (Wendling et al., 2019). The document D5.3, *Preliminary Nature-Based Solutions Implementation Handbook* identifies specific cases in UNaLab front-runner cities EIN, TRE and GEN where baseline conditions are likely to have been significantly affected by COVID-19 and/or measures to mitigate the spread of the virus. Alternative approaches are outlined herein (D5.4) and in D5.3 as needed to accurately quantify the environmental, social and economic impacts of NBS implemented in the UNaLab front-runner cities in order to provide accurate, actionable information to the European Reference Base on NBS.

2.4 Relations to other activities

The *NBS Demonstration Start-Up Report* (D5.4) is a stand-alone document that provides insights and best practices related to ULL initiation and NBS implementation in the UNaLab FRCs in relation to the local administrative, financial and climatic contexts. The present document can be read in conjunction with the *Preliminary Nature-Based Solutions Implementation Handbook* (D5.3) report, the *UNaLab Living Lab Handbook* (D2.4) and the *Living Lab Handbook for Urban Living Labs Developing Nature-Based Solutions* (Habibipour

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

et al., 2020) for a comprehensive overview of ULL initiation, monitoring and evaluation of NBS. The *Nature-Based Solutions Technical Handbook* (Eisenberg & Polcher, 2018) provides an NBS catalogue, which groups a range of NBS by categories according to planning and construction terminology. The contents and findings from the present report will form a part of the UNaLab Replication framework to support wider NBS uptake and increase visibility.

3. NBS AS A WAY TO ADDRESS LOCAL CHALLENGES

Naturalising urban areas as a way to address climate change-associated challenges has been long recognised (e.g, Haase et al., 2017). A variety of efforts to mitigate and/or adapt to urban needs and challenges exist in the form of green infrastructure and other closely related concepts, e.g., Low Impact Development (LID) and Sustainable urban Drainage Systems (SuDS) (see, e.g., Fletcher et al. 2013). Nature-based solutions (NBS) comprise an 'umbrella' concept that embraces knowledge from related theories and practices to deliver multiple economic, social and environmental benefits and co-benefits. The same approach is reflected in their design, implementation and management (Dumitru & Wendling, 2021). The European Commission defines[1] nature-based solutions as *'Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.'* Thus, NBS inherently provide biodiversity benefits and support the ecosystem services.

NBS are widely recognised for their climate change adaptation (CCA) and disaster risk reduction (DRR) potential. A great deal of evidence exists regarding NBS impacts on provisioning and regulating ecosystem services, such as flood and heat mitigation, runoff management, air and water quality amelioration and increase in biodiversity (e.g., Armson et al., 2013; Carrus et al., 2015; Haase et al., 2017; Hagler et al., 2012; Mesimäki, Hauru & Lehvävirta, 2019; Nowak, Crane & Stevens, 2006; Sandström, Angelstam & Mikusiński, 2006; Yuan, Dunnett & Stovin, 2017). Citizen engagement and stakeholder participation are another distinctive NBS feature that allow for improved and potentially more transparent participatory planning and decision-making and increased cohesion and awareness among various stakeholder groups (e.g., Bonney et al. 2009; Dickinson et al. 2010; Dennis & James, 2016; Peschardt & Stigsdotter, 2013). Notwithstanding the obvious benefits, selection and design of NBS must consider potential trade-offs that influence stakeholders' choices (Dumitru & Wendling, 2021).

In this light, the UNaLab FRCs have established a set of NBS demonstration sites through a series of co-creation sessions with stakeholders that built upon the local challenges. The following sections describe the NBS implementation in UNaLab FRCs and subsequent lessons learned along with the good practices.

[1] https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en

4. DISASTER RESILIENCE ASSESSMENT IN UNALAB CITIES

The disaster resilience assessment was executed, to date, in two UNaLab FRCs, Tampere and Genova, per United Nations Office for Disaster Risk Reduction (UNDRR) Disaster Resilience Scorecard for Cities assessment (UNDRR, 2017). The UNDRR Scorecard execution in Eindhoven is underway. The Scorecard prompts identification of 'most probable' and 'most severe' risk scenarios for each of the identified city hazards, or for a potential multi-hazard event. It strives to promote resilience awareness by establishing a baseline status of disaster resilience and enabling local planning towards effective DRR.

The Disaster Resilience Scorecard provides a set of assessment criteria for the local governments that allow assessing their disaster resilience, structuring around UNDRR's Ten Essentials for Making Cities Resilient. It also helps to monitor and review progress and challenges in the implementation of the Sendai Framework for Disaster Risk Reduction: 2015-2030 and supports the baseline analysis for preparation of the disaster risk reduction and resilience strategies. The Essentials include and offer a broad coverage of topics to be considered when planning for disaster resilience (Table 1; UNDRR, 2017).

Table 1. Ten Essentials of UNDRR Disaster Resilience Scorecard for Cities (UNDRR, 2017).

Ten Essentials for Making Cities Resilient		
Governance and financial capacity	**Dimensions of planning and disaster preparation**	**Disaster response and the post-event recovery**
Essential 01: Organize for Resilience Essential 02: Identify, Understand and Use Current and Future Risk Scenarios Essential 03: Strengthen Financial Capacity for Resilience	Essential 04: Pursue Resilient Urban Development Essential 05: Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems Essential 06: Strengthen Institutional Capacity for Resilience Essential 07: Understand and Strengthen Societal Capacity for Resilience Essential 08: Increase Infrastructure Resilience	Essential 09: Ensure Effective Disaster Response Essential 10: Expedite Recovery and Build Back Better

First, the actors are identified, which should include stakeholders such as local authorities, private businesses, research centres, academia, community groups, and others. External and internal parties provide their scores and comments to the ten categories (i.e., Essentials) and their sub-categories via interviews and workshops. The scores and comments are evaluated in the MS Excel spreadsheet. The overall score of the assessment provides information on the city's overall relative disaster resilience whilst individual sub-categories support identification of specific vulnerabilities to different hazards and risks.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Two options and their respective Excel spreadsheets exist for the DRR evaluation:

- Preliminary level: responding to key Sendai Framework targets and indicators, and with some critical sub-questions. In total there are 47 question indicators, each with a 0 – 3 score.
- Detailed assessment: a multi-stakeholder exercise that can be a basis for a detailed city resilience action plan. The detailed assessment includes 117 indicator criteria, each with a score of 0 – 5.

In Tampere and Genova, only the Preliminary level assessment was performed as it was deemed to provide sufficient information and outcomes. The application of the Disaster Resilience Scorecard for Cities in UNaLab front-runner cities is intended to measure resilience against the impacts of climate change (e.g., floods and droughts). The first self-assessment of the current level of resilience of the city proves beneficial for establishing a baseline status, identifying priorities, and providing strategic indications for improvement actions within the defined time horizons. Factors such as population growth and the effects of climate change should be considered when defining the future actions, especially for medium and long-term planning. The potential use of NBS to address the urban challenges can be explicitly investigated with the UNDRR Scorecard activity.

To retrieve useful clarification about the terminology used in the tool, it is suggested to refer to the glossary included at the end of the Scorecard methodology guidelines provided by UNDRR, detailed version.

The UNaLab project partner RINA Consulting executing the UNDRR Scorecard in one of the partner cities has found that some specific terms used in the UNDRR Scorecard may leave some space for different interpretations or may be misleading. It was suggested to use the following interpretations for further terminology, which could possibly be ambiguous:

- *resource:* this term includes both financial and non-financial resources (e.g., human resources).
- *authority:* even though the Scorecard is intended to be applied at urban scale, it is often the case that authorities and institutions involved in increasing resilience exist at national level. For this reason, the term authority should be intended in a multi-level perspective, in order to avoid penalising the score at urban level whenever local authorities have the possibility and the means to access to national (or regional, or community) resources.

In general, other interpretations might be followed, but coherency should be maintained along all the Essentials analysed, and justifications for judgements must be always recorded in the comments. In this way, although the individual scores can be unavoidably subjective, the final evaluation will allow construction of a consistent overall picture of the city's level of disaster resilience.

The implementation of the Scorecard assessment enables each city to translate the acquired awareness, knowledge and vision into issuance of public documents such as urban roadmaps, adaptation strategies, and action plans, or instead generally incorporate the findings of the analysis in the overall decision-making process and development of single-target policy instruments.

4.1 Results from Genova

Prior to UNDRR Scorecard execution via the UNaLab project, the Municipality of Genova had the specific structure for urban resilience strategies (i.e., "Strategie di Resilienza Urbana"), and previous endeavours towards the compilation of a UNDRR Scorecard by internal and external stakeholders that could be used as a basis for the current assessment. Having that experience, the implementation of the scorecard was performed directly with the support of an external consultancy (RINA.C).

Owing to a large and centralised engagement process, a number of significant and well representative stakeholders were invited to participate in a clustered consultation (target groups) along three thematic roundtables: *grey* (innovative development of infrastructure, network and communication), *green* (climate change and urban regeneration) and *soft* (economic impacts on community and business). Two meetings were held per each roundtable. A variety of stakeholders participated in the thematic roundtables held by the municipality: public institutions at national and regional level (covering areas such as risk and safeguard, civil protection, coastal management, infrastructures); business representatives (including responsible companies of networks, infrastructures, port, and sectoral associations and SMEs); and, university and research centres or foundations.

In the compilation of the Scorecard in Genova, it was considered that the phenomenon of urban heat island is the most probable hazard, while the inundation of a major river in the city is the most severe hazard.

The outputs of the preliminary assessment indicate the overall score for this assessment is 84/141, which might be interpreted as a "sufficient" level of evaluation (Figure 1). The representation in the radar graph facilitates the visualization of the balance among the different "Essentials", where the grey area delimits the maximum points achievable along the ten parameters, and the blue area depicts the respective results of the self-assessment for Genova.

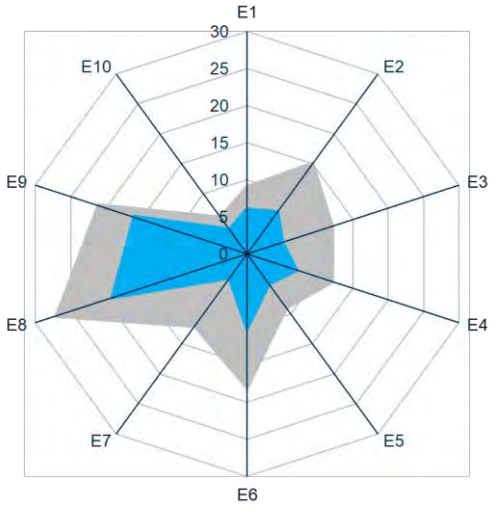

Figure 1. Overall UNDRR Preliminary Scorecard results in Genova. Grey colour denotes theme-specific maximum score (based on the number of indicators in each theme); blue colour denotes the City of Genova's results.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Neither complete satisfaction, nor grave alert is signalled for any field of observation in the Genova assessment; some margin of improvement exists for all the essentials analysed. Major bottlenecks are highlighted for all the aspects of resilience linked to:

- Understanding and strengthening the capacity of the community, with special focus on training programmes for the socially vulnerable population, engagement of private sector towards business continuity plans, and citizens' awareness and information (E7)
- Enhancement of the financial capacity for resilience, encompassing financial plan and budget, contingency fund arrangements for Disaster Risk Reduction, insurance coverage, incentives for different sectors, and segments of business and society (E3)
- Continuous risk assessment process, enabling the use and update of hazard data, and disaster scenarios towards better knowledge of city-wide exposure and vulnerability, and cascading impacts (E2)

Although less accentuated in respect to the previous points, a critical level is evidenced for:

- Delivery of courses and training in pluri-language translated material, for risk and resilience issues (E6)
- Safeguarding of natural capital for its protection potential against climate change, especially promoting green and blue infrastructures (E5)

A substantially positive result, but still deserving further progress, is revealed in the fields of:

- Organization and coordination of institutional level (E1)
- Land use, urban development and application of building codes (E4)
- Post-event recovery planning and capacity (E10)
- Infrastructure resilience in relation to the considered risks (E8)
- Plans, procedures, staffing capacity, equipment and supplied for effective disaster response and emergency operations (E9)

The detailed UNDRR Scorecard assessment for Genova is included in Appendix 1.

4.2 Results from Tampere

The UNDRR Scorecard workshop was attended by 29 City of Tampere employees and it was facilitated by the external consultancy (Et May Oy). The workshop was held remotely, at the beginning of which four experts spoke about the significance of climate change from different viewpoints. Due to time constraints, the participants were divided into four groups that were defined in advance. The workshop focused on different areas of expertise in themes 3–8. There was not enough time to respond to all indicators, so themes community (7) and infrastructure (8) had 0 results because the expert in question was unable to participate in the workshop.

Although during the workshop there was insufficient time to examine all of the indicators, the participants supplemented the data following the workshop. Overall, responses were received for 22 of 47 indicators, based upon which the final score was determined (Figure 2). Many of the indicators still require additional information or clarification, particularly in relation to allocation of responsibility. The outputs of the preliminary assessment indicate the overall score for this assessment is 37/141, however, only half of the indicators were evaluated.

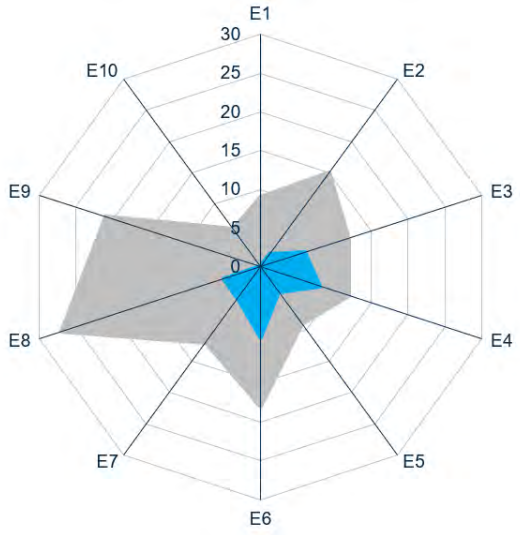

Figure 2. Overall UNDRR Preliminary Scorecard results in Tampere. Grey colour denotes theme-specific maximum score (based on the number of indicators in each theme); blue colour denotes the City of Tampere's results.

The overall results highlighted the existing strengths, including the identified on-going measures related to climate change preparations in each examined theme. One of the main findings indicated that the City of Tampere's climate goals and the related climate measures promote resilience and preparation to the impacts of climate change. Areas that needed development included appointing the responsible parties/persons and resourcing of cooperation as well as communicating climate change related concepts in an understandable manner (e.g., the differences between control, adaption and preparation).

During the assessment, particular strengths were highlighted for:

- Pilots, including participatory budgeting and innovation vouchers for city residents, and Green Deal financing opportunities (E3)
- The climate budget as an important starting point for adaption, which will enable reviewing and assessing adaption resources (E3)
- Continuous assessment of the City of Tampere's insurance portfolio (E3)
- Land use zoning and land use planning are comprehensive, systematic, and controlled (E4)
- Forthcoming local master plan round (2021–2025) that includes an impact assessment of adapting to climate change and management of climate risks, and that enables reacting to necessary changes, climate change is one of the key themes (E4)
- Implemented projects and reports increase the understanding of the role of ecosystems (E5)
- Assessment and environmental financial statement are developed (E5)
- In areas where practical climate resilience actions are implemented, awareness among residents is greater (E6)
- Aim is to increase open data: map services and data models, as data management and analysis competence exists (E6)
- Civil society is active and wants to create an impact (E7)
- Blue-green infrastructure implementation and water resources management, and there are sector-specific (such as water management) contingency plans (E8)

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Topics requiring further action and development included among others:

- Incentives for developing the financing activities (E3)
- Increasing the importance of adaption/preparation (E3)
- Developing cooperation and improving it between different planning levels (E4)
- Financial assessment of ecosystem services (E5)
- Default inclusion of blue-green solutions in urban planning (E5)
- Conveying information throughout the zoning hierarchy (E5)
- Resilience aspect should be added to the supervisor training (E6);
- Need for comprehensive cross-sectoral datasets that consider more risks, and information, competence and networks coordination improvement (E6)
- Better strategy for critical infrastructure (E8)

Although less accentuated, a development opportunity is evidenced for:

- Translating the training materials into different languages (E6)
- Greater use of networks, contacts and information channels for more cooperation opportunities (E7)

Visualisation helped recognise the plans and measures, including their strengths and weaknesses, related to the risk of the most likely and serious form of climate change. An important feature of the tool is collection and sharing of information for the joint risk management of climate change, from the viewpoint of both controlling and adapting. Instead of obtaining the highest score possible, the purpose was to understand the overall situation and the impact of climate change preparedness on society. The tool helped share relevant policies and to set the impact of the climate work in proportion within the city's own system.

Joint examination of the indicators was an excellent way to assemble parties concerned with the climate change resilience work. Forming an overall picture requires more cross-administrative cooperation, in which people learn how to set the impact of different measures more systematically and strategically. The work revealed that many of the answers call for understanding that transcends peoples' spheres of responsibility. Feedback from the workshop participants emphasised increasing cooperation related to the subject and deepening the understanding related to the subject.

The detailed UNDRR Scorecard assessment for Tampere is included in Appendix 1.

5. NBS IMPLEMENTATION IN UNALAB FRONT-RUNNER CITIES

The following sections describe how NBS and supporting measures were planned, commissioned and realised in each of the UNaLab FRCs. The UNaLab front-runner cities are geographically widespread, representing diverse climates and cultures and organisational differences. Although these differences resulted in varying approaches to co-creation, the identified local challenges were similar and so were NBS selected together with local stakeholders (Figure 3).

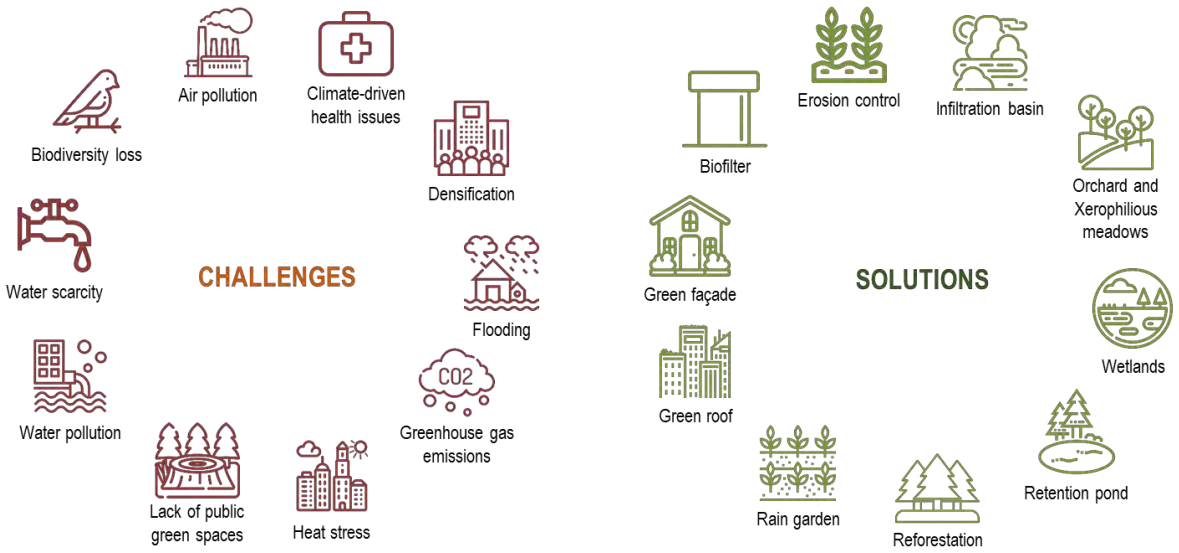

Figure 3. Identified environmental burdens and urban pressures, and examples of mitigation options (NBS and supporting measures) adopted by the UNaLab Front-Runner Cities.

Identification of local challenges, co-creation and approaches to monitoring and evaluating NBS performance has been described in more detail in the document *Preliminary Nature-Based Solutions Implementation Handbook* (D5.3). The final *Nature-Based Solutions Implementation Handbook* (D5.5) will collect the overall process and outcomes as well as guidance on NBS implementation. The selection of suitable NBS interventions considers the identified challenges and space requirements for successful NBS functioning, and their implementation typically follows the local considerations of suitability and procurement and implementation procedures. The *NBS Technical Handbook* (D5.1; Eisenberg & Polcher, 2018) created early in the UNaLab project provided the front-runner cities with accurate and topical information about potentially applicable NBS to support climate and water resilience, and facilitated informed decision-making during the NBS co-creation process. The updated version of the NBS Technical Handbook was included in the *Preliminary Nature-Based Solutions Implementation Handbook* (D5.3, Dubovik et al., 2021) and will be finalised in the *Nature-Based Solutions Implementation Handbook* (D5.5).

Originally presented in *Preliminary Nature-Based Solutions Implementation Handbook* (D5.3, Dubovik et al., 2021), Figure 4 lists all NBS and supporting measures implemented in UNaLab FRCs. The details of each intervention in all FRCs as well as their technical specifications are presented in Appendix 2.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

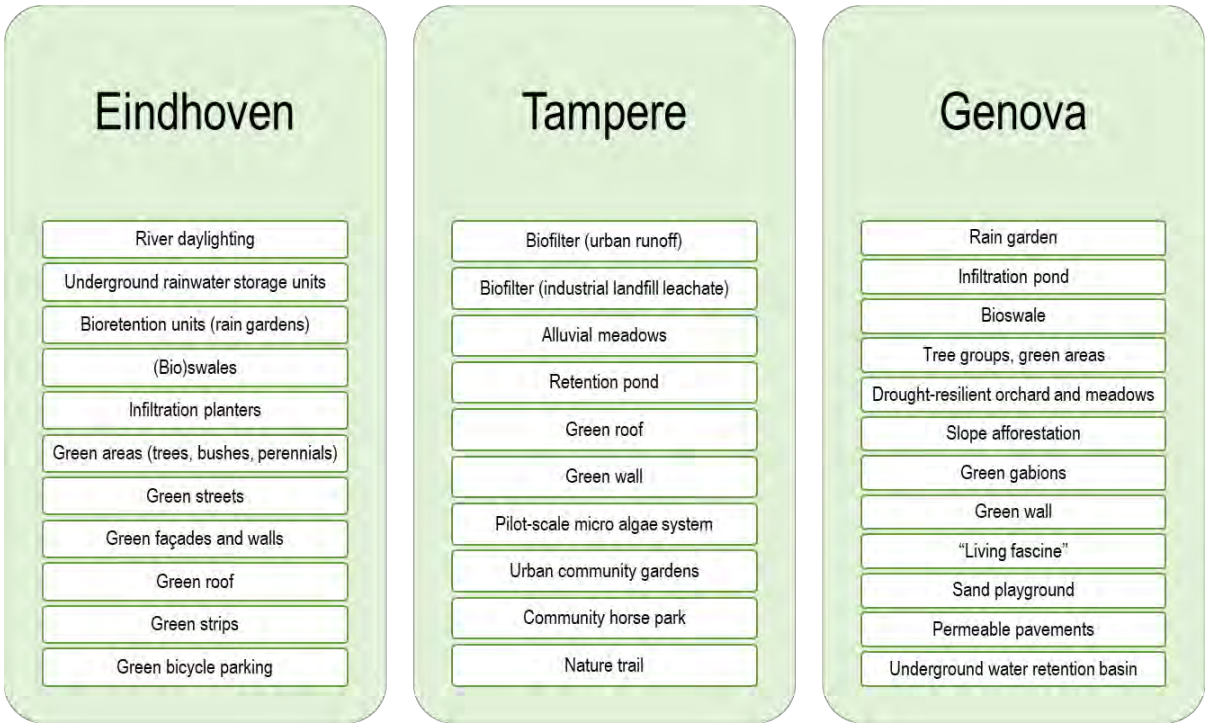
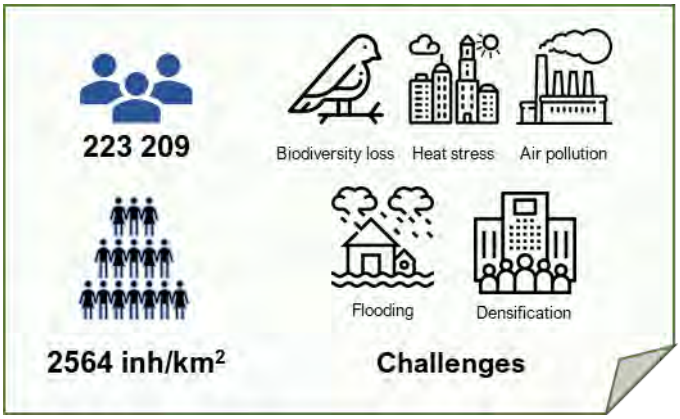


Figure 4. Nature-based solutions and supporting measures implemented in the UNaLab front-runner cities: Eindhoven (NL), Genova (IT) and Tampere (FI).

5.1 City of Eindhoven



The City of Eindhoven (51°26′N 5°29′E) is located in the southern Netherlands. The Eindhoven landscape is characterized by sand ridges and valleys formed by the Rivers Dommel, Tongelreep and Gender. The city has a high population density, which is exacerbated by lack of green spaces and high temperatures in the dense urban area. Eindhoven sought to implement NBS that are versatile and, combined with supporting measures, can deliver multiple benefits. The City of Eindhoven has selected multiple locations for NBS implementation, predominantly in the city centre, that represent a range of different urban characteristics. The focus of the NBS demonstration in Eindhoven is on effective integration of blue (water), green (flora) and grey (built environment) areas, to provide a comfortable, safe and aesthetically pleasing living environment for citizens.

5.1.1 Planning

Eindhoven has chosen a broad collection of NBS interventions, which are primarily located in the city centre (Figure 5). In most cases, the NBS interventions had been planned in combination with projects or activities that were already planned prior to the start of the UNaLab project. In that way, the finances were already organised, and the UNaLab project activities created the opportunity to add or strengthen the NBS elements in the ongoing local

activities. Some interventions had been initiated based on the possibilities created by the UNaLab project and expedited the introduction of NBS in Eindhoven. However, due to the complex organisational and financial situation, the construction of certain interventions was delayed due to unanticipated circumstances such as polluted soil and the presence of archaeological sites. Despite these challenges, the remaining NBS interventions are under construction.

Figure 5. Nature-based solutions and supporting measures in Eindhoven.

The idea to build a Community of Practice (CoP) for NBS in Eindhoven was one of the results of the UNaLab co-creation meetings in spring 2018. The group consisted of a variety of local stakeholders: experts, advisors and designers, experts in community involvement, urban greening, traffic, health or otherwise, from the municipality and other organisations (NGOs, province, health department). All of these stakeholders were connected in some way to the UNaLab project activities in Eindhoven. Some of the stakeholders participated in the co-creation workshops, others were involved in the shaping of Living Labs for NBS in Eindhoven, and new participants joined the group after learning about the CoP activities.

The most difficult project in terms of implementation was the river daylighting that should have been a joint venture with a local entrepreneur, but which had to be shifted to another location due to the different points of view which arose during the negotiations and caused additional delay for the implementation. The new river daylighting project was moved to another location that is not situated in a public space but is freely accessible. The Geestelijke Gezondheidscentrum Eindhoven (GGzE) is going to execute the daylighting of the stream on their terrain with support from the UNaLab, the waterboard and their own.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

5.1.2 Commissioning

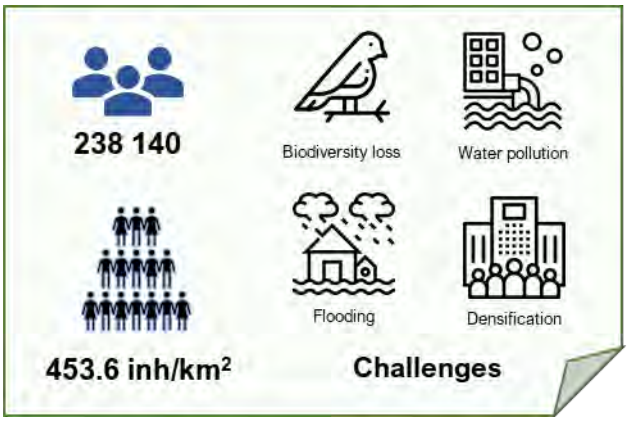
For two primary NBS locations, Vestdijk and Clausplein, the municipality worked in a 'building team'. It consisted of a process wherein the municipality described their targets and goals, and the design was executed and/or finalised and realised together with the contractor. For all NBS interventions, the City of Eindhoven created a system in which the contractor must report every step whenever it is finished. After reporting in the "borg system", the municipality may check whether the results are satisfactory. After approval, the contractor is paid for their part of the project. The GGzE river daylighting project is expected to be complete by the end of 2021. The work is commissioned by GGzE in consultation with the municipality.

5.1.3 Realisation

The realisation of some NBS interventions was challenging due to conflicts in planning and differences in other parties' interests. This resulted in the modified final version of some initially planned NBS. Planning was challenging due to the need to identify new products for incorporation within the NBS interventions. In particular, green roofs and green façades were not common for the municipality in terms of general structure and types and variety of vegetation used in designing the public spaces.

During the planning and realisation of the NBS interventions, the regulations on unexploded war time explosives and archaeological findings have changed and have become more strict. This resulted in extra investigations as well as a delay in the execution of some NBS. Together with the complex organisational and financial situation with the contractor, this caused a delay in the realisation of these NBS.

5.2 City of Tampere



The City of Tampere (61°30′N 23°46′E) is located in central Finland. Tampere is located on narrow isthmus between two large lakes, Näsijärvi and Pyhäjärvi, and it served as an important landmark of Finnish industry. Despite having multiple green areas and outdoor spaces, Tampere was concerned about preserving the water quality in the numerous surrounding lakes of varying size, which have been impacted by active urbanisation processes. Maintaining or enhancing biodiversity and addressing flooding were among other challenges identified as critical. The primary NBS demonstration sites in Tampere are located in Vuores, a newly developed green district located in the centre of a forested area and natural waterbodies. The second Tampere ULL site is located in Hiedanranta, a former industrial area transformed into a housing district. Selected Vuores NBS interventions are envisioned to be replicated in Hiedanranta.

5.2.1 Planning

Urban Living Labs in Tampere are located in Vuores and Hiedanranta districts. Vuores is a neighbourhood that was zoned for housing 14 years ago in a natural area located 7 km from the city centre. Today, it is home to ca. 5 000 people, and 14 000 more residents are expected by 2025. Hiedanranta is an old pulp mill area owned by the city and located 4 km from the city centre by the shore of Lake Näsijärvi. No citizens yet inhabit Hiedanranta, but there are plans for construction of housing for 25 000 people within the next 30 years.

The NBS planning in Tampere was performed in three phases. First, a series of three design-thinking workshops were organised during spring 2018 in each Living Lab area aiming to co-

create NBS for implementation during the project (Table 2). These workshops were attended by a total of 258 participants, the majority of whom were residents. Other stakeholders included academics, and representatives from NGOs and SMEs. The workshop participants learned together and proposed ideas for NBS on a general level. Second, after the workshops, implementation plans for each pilot site were prepared by large working groups composed of relevant experts. Technical planning was performed mostly by Ramboll as separate engineering projects. Although the main engineering discipline involved was stormwater planning, green area managers and ecological planners were closely involved in the projects, and geotechnical challenges were duly considered. Third, multiple smaller events were organised in the Living Labs that form parts of co-creation. For example, such events included sparring events for innovation voucher applicants; presenting the pilot sites and NBS to visitor groups; and an online survey on NBS in Vuores.

Based on the original project plans, with an emphasis on stormwater management, and the multiphase process of co-creation, various NBS were designed for the Tampere Living Labs, including: biofilter, retention pond, alluvial meadows, small-scale NBS (Vuores area), biofilter for seepage waters, microalgae pilot (Hiedanranta area) and green roof/wall (city centre). In addition, supporting measures such as duckboards to enhance accessibility of a nature trail and information signs (Vuores), and measurement stations for monitoring, were planned alongside the actual NBS. In the co-creation process, recreational aspects and awareness raising were highlighted as important.

Table 2. Co-creation workshops in Tampere Living Labs.

	Hiedanranta pilot area	Vuores pilot area
Official co-creation workshops in spring 2018	Three workshops: • Expert workshop as part of the seminar on open customership and inclusiveness • Expert workshop as part of the seminar on nature-based solutions • Guided city walks for the residents of the nearby areas after an urban planning event	Three workshops: • Evening event for the resident and experts with presentations and nature-based solutions design game • Presentations for schoolchildren and designing nature-based solutions at school • Field trip for residents and info tent as part of the Vuores Day event
	The activities were organised around three themes: water, biodiversity and recreation. The objective was to have a shared vision, generate ideas for nature-based solutions and choose the pilot sites.	The activities were organised according to the existing nature-based storm water solutions of the area. The objective was to have a shared vision, to gather development needs and ideas and to learn.

5.2.2 Commissioning and Realisation

The NBS were realised following the standard methods of the City of Tampere. Procurement guidelines of the city were followed: the largest investment of measurement stations and water monitoring required a formal tendering process organised by Tuomi Logistics (Partner of Tampere in procurement). EHP Oy won the tendering and realised the water monitoring systems. Most of the NBS were implemented by Tampere Infra, which has the framework

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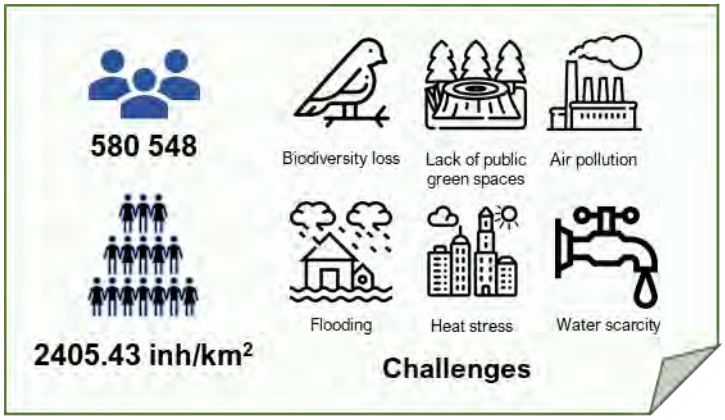
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

agreement with the city regarding the construction of green areas. Tampere Infra realised the NBS according to the detailed plans made by Tampere technical partner Ramboll. Smaller procurements not realised by Tampere Infra (green wall structures by ProInfra, nature trail duckboards by Ecofellows) followed a relatively less involved tendering process. In some cases, materials or solutions were not widely available (e.g., green wall vegetation) and in those cases the supplier was chosen based on product availability. In the case of small-scale NBS, materials were funded via innovation voucher program and residents implemented the NBS themselves (voluntary work). In the case of the microalgae demo, the local university (Tampere University) was selected as a realisation partner due to their long-term algae research knowledge and implementation expertise. The university also received additional (external) project funds to run the microalgae demo.



5.3 City of Genova

The City of Genova (44°24′40″N 8°55′58″E) is located in the northern Italy. Genova has historically been one of the most important ports in the Mediterranean region and its port is currently the busiest in the Mediterranean Sea. The city experiences acute densification and lack of public green spaces, making urban heat stress a pronounced challenge. Air pollution and biodiversity loss are among the other challenges Genova targeted to address through NBS implementation. The NBS in Genova primarily target amelioration of the urban heat island effect, flooding and droughts, and air pollution. The distinguishing feature of NBS in Genova is their combination in a multifunctional public green space. Here, NBS are combined with other supporting measures to deliver benefits and co-benefits, such as enhanced biodiversity and drought resilience via reclamation of rainwater for irrigation purposes.

5.3.1 Planning

The use of NBS for the realisation of the pilot project of the urban park in Genova was a decision motivated by the desire to extend the use of techniques already applied in the suburban area to the urban environment, which would enable evaluation of the similarities and differences. The overall objective was to organise and manage the implementation of NBS in accordance with the local co-creation process, including the support for innovative governance models and business and financing models. The technical demonstrations were planned and implemented in close collaboration between the City and local partners with additional support from the UNaLab consortium.

The co-creation process served to further define the project and the inclusion of the NBS to implement the various functions of the park, verifying its compatibility with the urban plans. Based on a program already defined by the Public Administration, where the park is an important piece of a more complex redevelopment project, the partners IRE and LAND joined the City of Genova by contributing the detailed design and executive activities. The choice of a site with a history of industrial activity has led to a particular complexity and the need to execute in-depth land reclamation analyses. The preventive analysis activities required more than six months, in addition to the architectural design of the area, which significantly affected the timing of the project.

The actions (NBS and supporting measures) initially planned for Genova included (Figure 6):

- Action 1 – Unseal soil through targeted demolitions (around 46 000 m^3 of existing buildings on 4 500 m^2), thus increasing soil drainage capacity and enabling groundwater recharge (draining surfaces on site will be increased of nearly 30%)
- Action 2 – Increasing green areas within the city
- Action 3 – Reshaping of Lagaccio's Cinque Santi river, which runs under the area and could potentially be subject to flooding
- Action 4 – Improve water management and quality on site through innovative collection, disposal, depuration, and reuse of rainwater from roofs and sealed surfaces
- Action 5 – Draining features – Creating a framework of a new recreational public space (ca. 3 600 m^2), that will represent a new centre for the neighbourhood and an aggregation area (draining hardscape surfaces through paved landscape terraces, green patches, trees, playgrounds). First, innovative draining hardscape surfaces including improving soil performance with geogrid reinforcement and welded gabions are designed and deployed. Secondly, ponds and wetlands are constructed to collect, store and clean water before gradual release into watercourses. Third, permeable surfaces are designed and deployed in hard landscape construction to provide aquifer recharge. Innovative permeable surfaces such as concrete formulation capable of draining water or restore natural soils are utilised, estimated size 1 800 m^2.
- Action 6 – Rain gardens allowing runoff from impervious urban areas to infiltrate. Indicative actions: allow runoff from impervious urban areas to infiltration, with the aid of riparian vegetation, phyto-purification vegetation, rows and bunch of trees, shrubbery zones, ornamental lawn used in ca. 3 700 m^2, use of balancing ponds to contain surges and release water slowly, balancing ponds 800 m^2. Increase co-creative and citizen activate biodiverse tree planting inside the demo area after the co-creation process.
- Action 7 – Community gardens offering productive 1 500 m^2 of green open space involving inhabitants, by including urban farming and rest areas, to increase awareness of flood risk and limit the potential damage of flooding.
- Action 8 – Enhance biodiversity. The new green spaces will be reconnected to the existing nearby green areas (such as Peralto Naturalistic Park and the forts) and this conjunction will create a green corridor in which it will be possible to develop and increase biodiversity and decrease urban heat stress, ensuring a well-functioning ecosystem.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Figure 6. Landscape plan of the Gavoglio park.

During the co-creation phase, the emerged proposals served to modify the project actions proposed in the preliminary phase.

The role of green areas

Since the redeveloped area is a public park, the theme of greenness was of great importance because the neighbouring districts lack public green spaces. In particular, it required that the green areas dedicated to various functions, including relaxing, playing, picnics and sports, are created on the top of the demolished buildings. This approach already forms a part of the approved feasibility study. For instance, the area under Via Ventotene creates an appealing design approach as it offers the opportunity to give particular meaning to the encounter between the natural elements (rocks, trees) and the artificial element (the retaining wall), transforming a negative event (a collapse occurred years ago) into a new hallmark of intervention. Further wooded areas are planned for slope securing in some sectors of the River Cinque Santi valley, where the terrain appears particularly steep.

Urban gardens are another topic of interest; however, according to the Municipality their location must be subject to further assessments according to the area availability and their optimal location. The proposal to include urban gardens in the River Cinque Santi valley did not appear feasible given the non-optimal conditions, although a piece of land owned by the City adjacent to the area but at a higher altitude has been identified and in the future may accommodate this functionality as well as being linked to the park. The part to the north-east of the River Cinque Santi valley appears problematic due to its strong acclivity and rocky soil. For this reason, terraced areas are proposed, the usability of which must be carefully evaluated

because the morphology does not allow construction of slopes suitable for a truly universal accessibility. It was requested that the garden areas allow rest along the paths and are close to the areas for children. The areas most exposed to the prevailing winds should be equipped with vegetation to mitigate this condition: the resolution of this theme does not appear simple due to the narrowness of space which prevents adopting the truly effective solutions. The inclusion of a dog area has been requested, for which the area of Piazza Papacino was identified. However, this area appears unsuitable for such use, so it is necessary to identify an alternative site (for example, in the River Cinque Santi valley).

Additional services and functions

Services and functions related to the green areas have been considered. It was requested to equip the area with one or more information points. It is noted that, first of all, it is necessary to enhance the role of the Neighbourhood House, which is already an active and appreciated presence on the territory. As a possible integration to the role of the house of the District it would be possible to install the panels (interactive or traditional) that show useful information for park users. For example, panels can inform about the solutions adopted against climate change, urban biodiversity, and the water cycle to encourage school visits to the park.

The request to prepare an "amphitheatre" space for public shows and recreation appears in line with the product feasibility study, given that the project includes a grading that, in addition to allowing the existing difference in level, it is designed to be a public space. Another request included the establishment of a neighbourhood library, which would require restoration of the historical buildings.

The area under Via Ventotene (Piazzale Duca D'Aosta) has been the subject of several proposals including the establishment of collective gardens and a sports area. This area, being one of the few flat and sheltered, seems more appropriate for children's or elderly, which require spaces with particular characteristics. Other parts of the park envisaged to be dedicated to other activities must consider steep slopes which significantly limit accessibility. Hygienic services have been requested at various points in the park, and other requests concern the installation of a collective oven, the provision of drinking water fountains, and the inclusion of small wooden artefacts for educational activities with children. All requests and design considerations have been evaluated carefully.

The challenge of accessibility

The park is difficult to access especially from the north, so it is necessary to find ways to overcome this obstacle. In this regard, there have been some proposals, which in part reflect the solutions already envisaged by the “Valorisation Program”:

a. Lift equipment (on Via Bari, Via Napoli, Via Ventotene). For lift implementation, it is necessary to consider the cost-benefit assessment in relation to the existing roads, for which complex procedures are required to activate various forms of public use. It is necessary to evaluate the passage through municipal properties to establish the connections with the park and the areas to the north.

b. Restore access and path from via Napoli. This appears to be an approach to be explored and possibly implemented within the project. It would be a pedestrian path, and might not be viable for people with reduced mobility. In this case, however, the issue of public use of private areas remains to be resolved.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

c. In the first phase, foresee closure at certain times for security reasons and prevention of vandalism.

Concerning the 'Action 3 – Reshaping of Lagaccio's Cinque Santi river', following more detailed analyses on site, it was decided not to proceed with renaturalisation as the conditions were not favourable. The river has become a full-fledged sewage collector, and it receives rainwater only through manhole covers and road grills. To date, it is not possible to consider separating the Cinque Santi river from the sewer network given the urban complexity of the area. In this regard, an assessment was requested from the Liguria Region, which is responsible for watercourses and which confirmed that the Cinque Santi river is no longer considered a watercourse because it is not relevant for the purposes of calculating the hydraulic flow rates of the Rio Lagaccio basin.

5.3.2 Commissioning

The public procurement aimed at sourcing a supplier that could redevelop the former military barrack area into an urban park incorporating NBS. The project incorporates the creation of new green spaces, while ensuring their connectivity to the existing green infrastructure (Figure 7). It additionally aims to include urban gardening elements as well as water management measures.

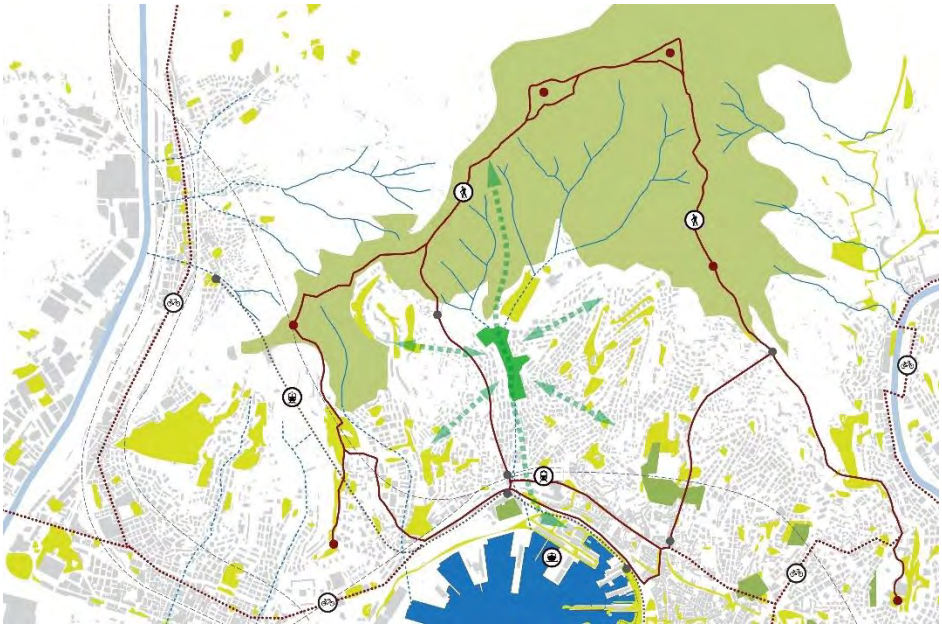

Figure 7. Connectivity of the Lagaccio area (dark green) to surrounding natural areas.

The public procurement of NBS is executed similarly as for other public works in Genova, hence open tender procedure was chosen. Around 40% of the contract value was foreseen for the NBS interventions and urban furniture, in addition to construction, engineering and area reshaping works. The contract includes all the works, services, and supplies necessary to redevelop the Gavoglio area. The tender was published in 2019, and it listed technical, qualitative and quantitative characteristics. Prior market consultation with the private sector was not held. However, the tender itself followed an open, digital procedure pursuant to Article 60 of Legislative Decree no. 50 of 18/4/2016. Any company satisfying the tender requirements could compete for the contract.

Environmental and sustainability considerations were likewise included in the special tender specifications. They refer to the stringent regulation concerning Minimum Environmental Criteria (MECs) for services and works for the new construction, renovation and maintenance of public buildings, purchase of the street furniture, and public lighting systems, as well as environmental criteria for the soil, and plants procured. It includes requirements for the management of the waste generated during construction and "directly and/or indirectly generated by all the activities covered by the contract". The MECs were developed as part of the National Action Plan for Green Public Procurement in Italy. The MECs are "fully applied" to the contract, meaning they need to be incorporated in the offers. In addition, ISO and UNI standards must be followed for the construction materials.

While the technical specification document required the submitted offers to fulfil the MECs, the prevailing award criteria in this tender is the lowest cost. Additionally, the contractor is required to provide maintenance of green elements until the standard criteria-based approval test is performed by the municipality. Upon the successful completion of the approval test, the city assumes the maintenance operations.

The tender was successful and there were 24 bidders, out of which one was selected according to the lowest cost criterion. The awarded contract duration is 360 days. Even though the type of works procured could be deemed as 'rather unusual' by the local supplier ecosystem, the relatively high number of participants would suggest that the awareness and the capability to deliver NBS is increasing.

5.3.3 Realisation

The works began in November 2019, starting with the reclamation of the site to remove waste and metal residues, carried out throughout the area. At the beginning of 2020, the Covid-19 pandemic led to a slowdown in work which lasted until May 2020. Environmental remediation works continued, and the demolition of industrial buildings began, which however, following the discovery of war-time explosives, suffered further slowdowns. The construction site set up to carry out the hydraulic risk mitigation work of the Rio Lagaccio has been suspended due to the need for a partial redesign.

In autumn 2020, the campaign to crush the debris deriving from the demolition of industrial buildings began and the asbestos remediation work on the last buildings under demolition was subsequently completed.

In the meantime, structural works are carried out for accessibility to the construction site (ramp on via Sobrero, lift on via Bari). Currently (April 2021) the NBS relating to the Valletta of the Rio Cinque Santi are under construction, while the preparatory works on the Rio Lagaccio remain suspended.

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6. GOOD PRACTICES AND LESSONS LEARNED

This section describes and discusses successes as well as lessons learned from joint and local perspectives. General guidance is given to advance NBS implementation based on the FRCs' experience.

6.1 Joint outcomes

The project provided a priceless occasion for the different municipal agencies and departments to collaborate, and it highlighted the need to facilitate design processes with particular attention to the implementation of natural solutions for urban resilience. Table 3 lists the joint outcomes and lessons learned from three UNaLab FRCs under relevant categories, including building upon outcomes discussed in Hawxwell et al. (2018).

Table 3. Joint outcomes from NBS implementation in UNaLab FRCs.

Category	Joint outcomes
Public acceptance	• Citizens generally react positively to green spaces, but disseminating positive outcomes of NBS to citizens is valuable for attracting a wider audience • Awareness raising and dissemination among citizens aid in accepting less neatly looking areas (i.e., introduction of more natural habitats instead of regular lawns) • Citizens are willing to actively participate in co-creation and co-monitoring if tools and means of participant retention are carefully considered and applied • Sharing solutions with stakeholders is essential for creating a 'common vision' and a sense of involvement • Establishing joint initiatives (e.g., Communities of Practice or through other collaborative NBS effort) aid in overcoming reluctance to accepting NBS and establishing cohesion
Cooperation within and between municipal units and decision-makers	• Nature-based solutions offer an integrative direction for multidisciplinary cooperation, but the cooperation must be facilitated carefully • A multidisciplinary approach is critical for defining the most relevant solutions and identifying challenges at early planning stages • Aiding decision-makers in understanding the importance and value of adopting NBS facilitate the wider NBS adoption and acceptance • Land-use trade-offs
Financing & procurement	• Conflicts between parties should be anticipated at any stage of NBS planning and implementation • Private actors can be integrated into NBS financing, but it requires more careful planning and discussion among parties • It is critical to outline the expectations and fulfilment criteria between the parties, especially when involving private financing
Technical & construction considerations	• Technical-economic documentation helps selecting the suitable NBS instead of conventional technologies and approaches • Locally-specific NBS guidelines and good practices aid in selecting appropriate interventions • Evidence from the implemented NBS interventions should aid in the future design processes • Training technical staff on the use and value of NBS proved beneficial for planning and implementation

	• Certain NBS require considerable space for successful implementation and functioning, so involving a multidisciplinary planning team is critical • Green roofs and façades comprised one of the most demanding NBS to implement, so they must be subject to a more thorough planning and realisation, and cooperation between green and construction sectors
Monitoring & evaluation of monitoring outcomes	• Frequent monitoring aids in detecting issues in NBS functioning and supports in solving them • Monitoring provides information for the future planning and NBS value facilitating replication and upscaling • Division of responsibilities for NBS monitoring should be clearly emphasised during the planning stages • Interpreting monitoring data and outcomes may be challenging, so appropriate baseline data, evaluation techniques and expertise are required • Challenges in the evaluation of monitoring outcomes often relate to poor or non-existent reference data • Data management strategy and data governance should be defined during the planning stage. Ownership of data between municipal units generated via monitoring
Maintenance	• Need of maintenance should be emphasised, and maintenance responsibilities and their execution should be carefully considered at the early stages of NBS planning • Maintenance costs and implementation should be planned at the early stages of NBS planning and implementation • Regular maintenance provides greater and longer lifecycle of the NBS interventions
Policies and regulations	• Targeted tendering aids in attracting investors for urban zoning that supports NBS implementation • City zoning and a local master plan for urban development creates opportunities for integrating NBS in the urban planning and replication potential, including upscaling of NBS • Forthcoming and existing EU-level regulations, e.g., the EU Biodiversity strategy, creates opportunities for greater NBS integration in planning and implementation • Local incentives that support NBS integration could introduce supportive regulations • Mainstreaming sustainable development aids in greater acceptance and lesser administrative burden that limits wider implementation • Urban resilience strategies reflected in local master plans create a solid ground for incorporating NBS into local climate-change adaption strategies

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

6.2 Locally specific outcomes

6.2.1 City of Eindhoven

Nature-based solutions proved to be helpful to make the city more climate-robust and more liveable at the same time. During the construction of the NBS, the maintenance department has been involved to provide comments on the chosen solutions. This appeared to be a suitable approach because some improvements were made during the construction phase. For example, the soil in Eindhoven lacks sufficient infiltration capacity in some places, which complicates the growing of plants. Adding some extra organic material improved the vegetation development and growth, and it additionally resulted in an improved infiltration capacity.

At first, the shop owners disapproved the idea of planting trees in front of their stores. This was overcome by "planting" temporary trees in the shopping street, so citizens and the shop owners had an opportunity to adapt to the street trees and could observe the ways the public responded to the inclusion of trees. Most citizens prefer the green solutions, which form the greater part of the NBS interventions. Although some people expressed their dissatisfaction with urban greening, most people greatly appreciate the NBS and perceive them as enriching the city. A beneficial undertaking, which expanded the NBS acceptance, was to appoint ambassadors – people who are enthusiastic about NBS and urban greening. Creating a CoP to share ideas and successes helped NBS advocates in Eindhoven to support and inspire one another. Such allies were beneficial for spreading information about the purposes and implementation of NBS.

In certain cases, green façades and green roofs require extra considerations for their implementation. For example, the construction of one of the green façades required considerable time to evaluate means of its attachment to the building as it was constructed with concrete flaps in front of the building. The implementation of green roofs, particularity on existing buildings, was not straightforward for several reasons. One of the reasons includes the bearing capacity of the existing buildings, which may not be constructed to carry the additional load of a green roof. If a building was identified as a (municipal) monument, it added more complications for green roof implementation, especially if the building was situated in the city centre. However, more attention is attracted if a green roof can be combined with solar panels. Although there are currently relatively few applicable examples of combined green and solar roofs, future developments may further illustrate the added value of integrating green roofs with solar panels.

Green façades, pergolas and green roof require regular maintenance. An important question during green façade, pergola and green roof implementation included determining who is responsible for the maintenance and who pays. During the NBS design, the challenge is to keep the maintenance costs as low as possible. It was ascertained that one should not choose the fast-growing plants for a quick result but choose the slow growing plants instead as they typically require less maintenance.

Monitoring proved to be essential for demonstrating the ways NBS perform, and it additionally aided in convincing the colleagues and other parties about the NBS value and compelled them to consider way of improving the local NBS.

Incorporating private funds in an NBS project requires fine-tuning between the municipality and the private partners. It is critical to outline the expectations between the parties. Due to the municipality regulations, which include the procurement rules, the timeframe for a municipality to realise an NBS project is different from that of an entrepreneur, and that must be considered during the planning stage.

6.2.2 City of Tampere

Co-creation and planning of NBS

In the City of Tampere, mutual learning was the most important objective and achievement of co-creation because it enabled equal encounters between the participants. Making mutual learning an objective provides space for managing the complexity of NBS. If co-creation focuses greatly on practical implementation planning, experts' views become relatively more emphasised, and citizens' views marginalised. Meetings of urban planners (experts) and citizens on site (NBS sites and the whole residential area) were fruitful and served to develop a common understanding and commitment. An additional learning point was that giving more space and power to other actors than municipality can result in interesting and surprising new ideas of ways to bring more nature to the city.

In practice, experimenting with novel solutions and resident participation works best for small sites and relatively small groups. Trying to get a very large group of individuals engaged hinders realisation of the demonstrations. In this kind of multiphase interactive planning, lack of resources is challenging. However, in this case, UNaLab project resources enabled various Living Lab activities that are not normally possible with municipal funding. Giving more power to other actors than municipality has the potential to save municipal resources, but one needs to be careful with equality and fulfilment of municipal democracy.

To improve detailed/implementation planning of the complex NBS, which require multi-sectoral knowledge, Tampere proposes the process presented in Figure 8. Process development targets to information exchange between various actors and phases (planning – implementation – maintenance). It is important to visit the NBS site (1 year) after the implementation and examine whether it performs as planned. It is equally important that planner and implementer communicate during the realisation to see whether the plans need to be adjusted due to circumstances on site.

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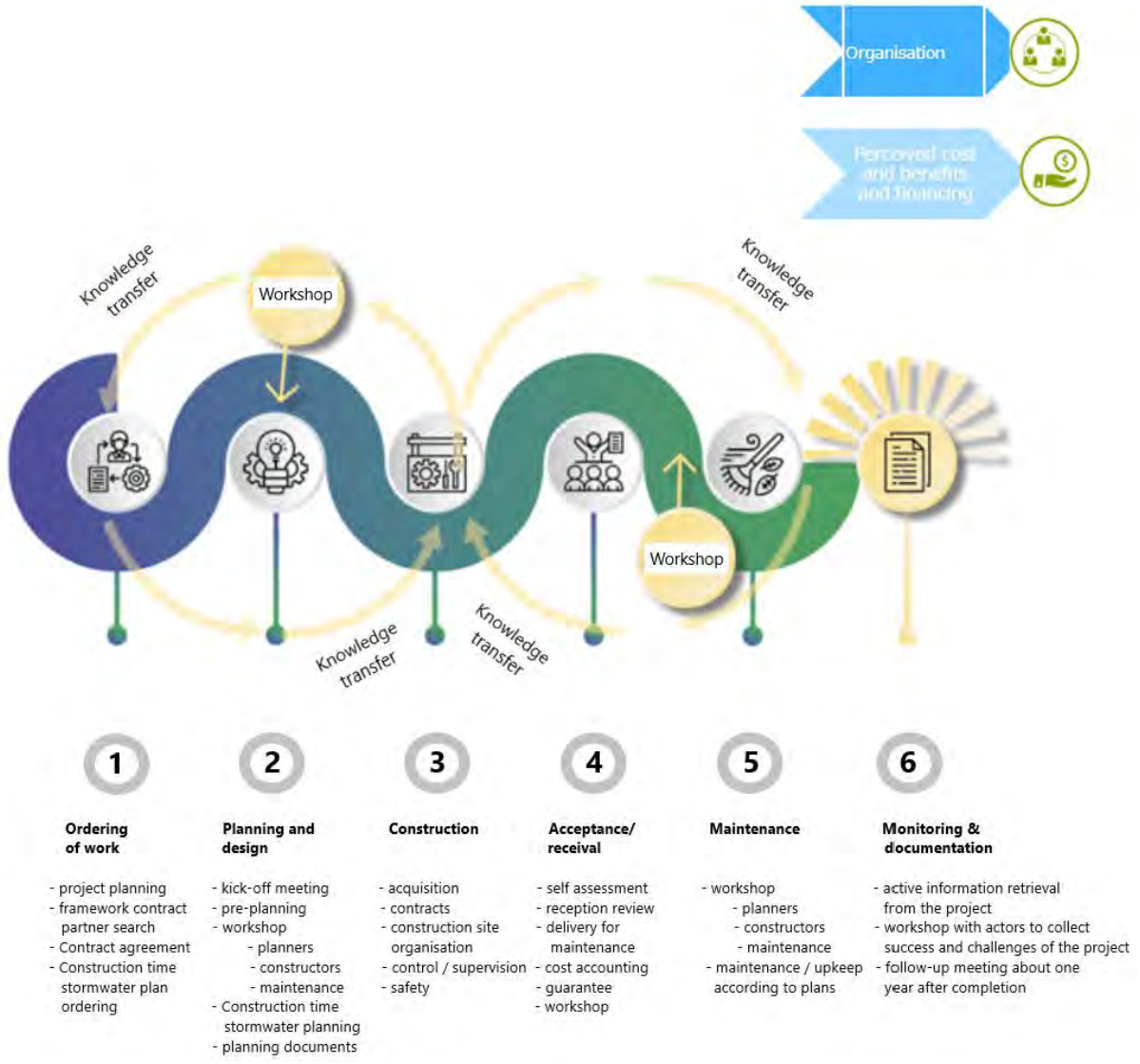

Figure 8. Development of planning-implementation-maintenance chain of nature-based (storm water management) solutions (Luhtaniemi, 2020).

Demonstrations and supportive actions in Vuores: Biofilter, retention pond, alluvial meadows, nature trail and information signs

NBS for stormwater management – biofilter, retention pond, alluvial meadows – in Vuores were the most straightforward demonstrations in Tampere, because the city has experience with similar NBS, and they proved to be reliable. The planning process was smooth as these NBS were already considered the adequate solutions especially in greenfield development.

Co-creation in Tampere highlighted the possibility for an accessible local recreation and awareness raising regarding NBS and biodiversity. As a result of co-creation, duckboards to make a nature trail more accessible and information signs were added to Tampere's demonstration plans.

Reflections:

- The decentralised, hybrid (grey, blue and green infrastructure) **stormwater management system of Vuores performs well for retention and purification of urban runoff**, and it will perform at the same level when Vuores has expanded to its full size (5 000 residents at present, and projected 14 000 more in the future).

- Original aim of the Vuores project to maintain the areas' moisture conditions has been achieved.
- These kind of **NBS require space**, which was not problem in Vuores, but could be an obstacle in more dense urban areas.
- **The Vuores school is built very low and there is risk of water damages at times of flooding**. School area is continuously kept dry by pumping water from school grounds to Virolaistenoja ditch.
- **The interpretation of water monitoring data is challenging** as the Vuores stormwater system is complicated and runoff passes through a small lake at one location. Therefore, it was challenging to determine a starting point to measure quantity and quality of the incoming water.
- Comparing water quality before construction of the stormwater management system to the quality after the system was built is misleading, because changed soil masses (swamp to rock) during the area construction might have resulted in clearer waters, upon which NBS might have less impact.
- When co-creating multifunctional NBS, **residents highlight access to nature** near their homes.
- The UNaLab project showed that residents in Vuores did not fully understand the multifunctional NBS in the area. The idea of stormwater retention and purification as well as biodiversity aims were not clear, and therefore acceptance of "new urban aesthetics" such as meadows and bushes instead of grass and neat garden was not as high as it could have been.
- The UNaLab project has been successful in **awareness raising** via Living Lab activities and information signs.

Small-scale NBS (innovation voucher funding, Vuores)

Three small-scale NBS projects were awarded innovation vouchers in summer 2019 by the City of Tampere. Two of the vouchers were used to develop garden areas near residential housing whilst the third voucher was used for the creation of a community horse park in the Vuores Central Park.

The innovation vouchers represent an interesting approach to enable residents to co-design and co-implement small-scale NBS. Through this initiative, encouraged citizens to take the initiative to plan and implement the NBS that they find useful for their environment. The city organised an official information session for interested citizens and the information was also disseminated through the city's communication channels. Three applications were received, and all the applied projects were funded.

The garden areas funded by the innovation vouchers implemented trees and bushes, planter boxes for the residents to use, fruit trees and berry bushes, perennials and summer flowers, as well as areas to compost gardening waste and structures to harvest rainwater for garden irrigation. The aim was to create safer, more inclusive and pleasant, and more communal areas for all residents to use and enjoy.

The residents of the buildings adjacent to the garden areas did most of the work themselves and used the funds from the innovation vouchers to purchase materials and transportation services needed for the construction work. Both housing cooperatives were very pleased with the end results and agreed that these collective projects have further enhanced the relations between the residents.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

The third innovation voucher was used to establish a community horse park in the Vuores Central Park managed by the local Annisto stable. The horse park represents an example of how a green space can be managed for multipurpose use. The aim of the horse park is to promote citizen engagement (social wellbeing) in a natural setting and encourage outdoor recreation, while enabling residents to participate in and learn about the cultural heritage of the Vuores area. The horse park aims to increase residents' accessibility to outdoor activities, which otherwise may not be within their reach due to financial or social reasons. Interaction with horses has also been shown to enhance residents' well-being and general health, which was one of the objectives of the horse park. The UNaLab partners will continue to examine land use and management impacts on biodiversity in this multi-use green space.

The inclusion of innovation vouchers in the Tampere NBS business model proved a successful approach and solution to engage citizens to a greater extent in the city's efforts to implement NBS and supporting measures. This solution can easily be replicated in other cities or contexts, where small- or medium-scale NBS are implemented.

Reflections:

- Innovation vouchers **encourage residents and other city actors** than municipality ideate and implement novel nature-based solutions in the city.
- Nature based solutions created were **feasible: DIY-type** rather than professional/engineered solutions.
- Participants enjoyed working with neighbours – **social aspect** was highlighted.
- Living Lab was a new area and there were little applications received. In the future, **targeting such funding to older/more dense areas** with less nature and resources is recommended.

Biofilter for seepage waters

In autumn 2018, Tampere Infra constructed a biofilter at Hiedanranta to clean strong leachate (containing mean N_{tot} = 22 mg/L and P_{tot} = 0.9 mg/L) from the old pulp mill landfill. The landfill leachate is filtered through an area of ca. 100 m^2 and 3 m deep consisting, for example, of biochar, peat and expanded clay aggregate. Deep-rooted bushes and perennials native to the area were planted on top of the filter to retain water and nutrients. For the removal of odours caused by the water from the landfill, an activated char filter was installed on the manhole cover.

The biofilter was not included in the original project plan but was co-created with stakeholders during the project. The reasons behind the initiative include the city's intent to develop the qualitative management of stormwater, the reports of disturbing odours from users of the area and the interest of a biochar factory in Hiedanranta to promote the use of biochar in stormwater management.

After the co-creation events, a wide group of experts with expertise in water treatment and/or challenging demonstration site, continued demonstration planning. A shared vision formed around the demonstration, even though some contradictory views and interests were also highlighted. For example, the Centre for Economic Development, Transport and the Environment highlighted the need to treat all seepage water from the landfill, while the demonstration filter was planned only for half of the landfill and waters. The biochar manufacturer would have preferred to use iron-biochar to achieve the best possible cleaning result and to have a reference case, whereas Ramboll, who was responsible for the implementation plans, estimated basic biochar to be sufficient as part of the other structure.

These are examples of the conflicting views regarding NBS, which complicate addressing the complex environmental problems in multi-sectoral cooperation. While NBS offer an integrated approach, the cooperation between parties must be carefully facilitated.

Initially, the biofilter seemed to function effectively in cleaning the landfill leachate (N removal 90% and P removal 60–70%), but capacity problems soon became evident. Monitoring revealed that the efficiency decreased, and nutrients began to leach from the filter to the lake. In addition, a greater share of urban runoff from the upstream catchment area was entering the filter than was estimated based on historical stormwater network data and previous flow rate measurements. Subsequently, overflowing runoff water bypassed the filter and entered the lake directly.

The first improvement was to channel the large share of urban runoff past the filter into a nearby stormwater basin. The next problem was leakage, which was noticed as the volume of filter effluent was four times greater than the measured filter inflow. In other words, large portion of inflow was entering the filter from underground, although the filter's bentonite layer was supposed to make it waterproof. At the same time, traces of bentonite started to appear in a post-filter monitoring well. After the leakage detection, it was not possible to evaluate the leachate purification performance of the biofilter as it was impossible to determine the quality of the incoming water from underground and thus calculate influent nutrient loads. Isotope analyses demonstrated that leaking water is rainwater, rather than lake water or groundwater. The observed capacity issue reflects well the complexity of NBS. In this case, monitoring has been invaluable in detecting and diagnosing the problems.

Some issues arose during the construction of the biofilter, and better exchange of information between the constructer and planner at early stages may have helped to avoid the resultant performance issues, e.g., by making changes to implementation plans. When construction was finished at the edge of the landfill, the excavations revealed car tyres and contaminated soil. Landfill gases and low oxygen content prevailed at the worksite and measuring wells, which resulted in health check-ups and the use of protective equipment at the building site and while working in the measurement wells. Installation of an insulating mat in the foundations failed the first time and had to be re-done. Leachate from the old landfill accumulated in holes on the worksite, and removal of the leachate by pumping slowed the construction work. It is important to leave space for learning in such demonstrations. Repair rounds are common in trials of innovations, but they are highlighted even more with NBS that exhibit performance issues and are co-managed by multiple stakeholders.

Reflections:

- Biofilters utilising novel filtering materials to purify landfill leachate is a good example of a **complex nature-based solution** where the implementation requires the use of multidisciplinary expertise.
- Nature-based solutions offer an integrative direction for **multidisciplinary cooperation**, but the cooperation must be facilitated carefully.
- In a **real-life context**, water flow analyses contain uncertainty.
- Biochar has potential to remove nutrients.
- Nutrient rich waters can cause biofilm growth and subsequent filter blocking.
- When biochar is used as filtering material, the fine fraction of biochar needs to be removed to mitigate clogging issues.
- **Frequent monitoring** detects problems and supports the diagnosis and resolution of issues.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

- The landfill site turned out to be very **challenging site** for a large-scale underground biofilter pilot. Performance impacts and possible problems would have been easier to observe and solve if visible in, e.g., a container type reactor.
- **More R&D and experimentation is needed** with dedicated partners to demonstrate the long-term reliability of engineered NBS, including nutrient attenuation capacities of filter materials under changing environmental conditions (e.g., pH, oxidative-reductive potential, temperature, or other).
- If these kinds of systems are proved to be reliable, **scaling and replication potential** is high (e.g., for closed landfills and to support wastewater treatment).

Microalgae pilot (Hiedanranta)

This was an unusual demo, which was closer to research than the other "close to urban development" demonstrations in Tampere, because the local university was responsible for operating, monitoring and assessment. The aim was to create NBS for sustainable urban development in the future city district (and current ULL) of Hiedanranta. In this case, UNaLab was one of many projects supporting the microalgae demonstration in Hiedanranta. The demonstration was built and initiated with the UNaLab resources, and other funding sources supported the work of researchers on the site to operate and monitor the performance of the microalgae pilot. Due to the close cooperation with academia, the results of this demonstration are published in peer-reviewed scientific journal articles.

In their publication based on the microalgae pilot in Heidanranta, Chatterjee et al. (2019) highlight that "[h]uman urine contributes approximately 80% of nitrogen and 50% of phosphorous in urban wastewaters while having a volume of only 1-1.5 L/d per capita compared to 150-200 L/d per capita of wastewater generated". This alone has led to global interest in source separation of urine and the development of efficient and economical methods to recover nutrients from urine. In the microalgae pilot in Heidanranta, nutrients from source separated urine were used for outdoor cultivation of microalgae in a Nordic climate. The freshwater green microalga *Scenedesmus acuminatus* was grown in different dilutions of source separated human urine, in a semi-continuously operated outdoor raceway pond. The microalgae were able to remove 52% of the total nitrogen and 38% of the total phosphorus from source separated urine under the experimental conditions applied, even at culture temperatures as low as 5 °C (Chatterjee et al., 2019).

Green roof/wall (City centre)

At present (spring 2021), a green wall remains the only demonstration yet to be implemented in Tampere. Since 2017, it has been a great effort to integrate a green roof and/or wall demonstration to one of the building construction projects in Tampere. Although during the years, plans have changed many times, the implementation has currently been initiated and a green wall will be implemented as the UNaLab demonstration in 2021–2022. In addition to the green wall, a green roof will be implemented later by the City of Tampere (Water Utility). Although the construction of the green roof will happen after the project end, the UNaLab project has had a great impact on the green roof plans. The green roof will be a meadow type (enhancing biodiversity) with a 10 cm layer (providing water retention) of recycled soil (targeting carbon emissions).

The green wall/roof demonstration was first initiated in the Living Lab Hiedanranta, as the initial plan was to demonstrate a green roof on one of the old industrial buildings in the brownfield area. At first, the old Hiedanranta water treatment plant was selected as a suitable building for the green roof demonstration. This was one of the oldest buildings in the area, at

risk of collapsing and thus in need of renovation. Preliminary plans for a garden roof and a cost estimate were prepared for the site. Then, the city received an offer to buy the water treatment plant and the green roof plan was abandoned. Thereafter, preliminary plans and cost estimates were done for two more old halls in the area. However, the conclusion was that it is too expensive to build a green roof on the old factory buildings in Hiedanranta, because it would have meant demolishing the old roof and building whole new roof that can support the additional weight of a green roof. The lack of plans for future use of the brownfield buildings hindered green roof implementation in Hiedanranta.

Then, in spring 2019, after multiple-stage negotiations, the officials from different units of municipality decided to add a green roof demonstration to the project plan for the service building of the Kauppi outdoor recreation area. The service building was a suitable pilot site because it will be heated similarly to residential buildings but visits to the building will be of short duration. A heated building would be a step forward from green roofs of carports which are already a common feature in Tampere. People stay in the changing rooms of the service building only for a short time, which made the risks associated with a green roof acceptable, namely building humidity and air quality problems. In addition, the construction timetable of the service building fitted the UNaLab project. In the end, this demonstration was rejected by municipal decision-makers in autumn 2019. The green roof was removed from the plans of the service building because it was deemed expensive and remote. However, well-prepared plans for the green roof advanced the public discussion and leaders promised to locate better sites for green roofs in Tampere.

Finally, the suitable demonstration site was found slightly outside the core city organisation. The Water Utility of the City of Tampere is currently constructing new wastewater treatment plant (WWTP) outside the city centre. The old WWTP located in the city centre (Viinikanlahti) will be closed and replaced by a large wastewater pumping station (900 m^2) surrounded by a dense city district. The design requirements for a pumping station were high, because it will be located in the middle of the apartment buildings and along an ecological corridor and walking/bicycling path heading south from the city centre. The “City landscape board” decided that a green roof and wall are obligatory for the building project. Municipal staff from the UNaLab project then became involved with the planning of the pumping station and incorporated green roof and wall plans together with other planning. However, the implementation was shifted somewhat because the pumping station construction was delayed beyond the UNaLab project timeframe. The solution was to build a modular green wall in a temporary location (old WWTP) and monitor it. When the pumping station is constructed, the wall will be relocated to the station and the Water Utility is building a green roof as planned by the UNaLab partners.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Reflections on the planning phase:

- Green roofs/walls are the exceptionally demanding pilots because they require **cooperation of green and construction sectors**.
- The building sector is used to diverting water away from buildings and the **idea of 'wet soil on a roof' is not easily accepted.** There are concerns that construction mistakes such as leakage are hidden under the soil and moisture in the building structures will cause indoor air quality problems.
- It is important to create a **shared vision and engage all key stakeholders before the NBS project starts.**
- The City of Tampere is now considering making **a green roof strategy** to systematically guide green roof/wall implementation.

6.2.3 City of Genova

The requalification of the former Gavoglio barracks area comprises a new connection of the area of the former Gavoglio barracks to the neighbourhood as a potential **urban hinge** between the landscape system of the historic forts and the dense urban context of the consolidated city. The project site thus becomes a demonstration for a redevelopment strategy that combines the recovery of historical heritage and the creation of new connections with the Lagaccio district (in relation, for example, to the historical roots of the "crose") for the reintegration and enhancement of the former barracks. The increased connectivity through redevelopment at neighbourhood level can trigger processes to limit the strong social contrasts present in the Lagaccio neighbourhood, characterised by problems deriving from low-middle income population and immigration.

The creation of new **green infrastructure** is an opportunity for the highly urbanised Lagaccio neighbourhood to re-establish ecosystem services and enhance the quality of the urban environment, and to promote new community green spaces for socialisation, such as an urban orchard. Different species of bushes and trees (including varieties of oak) could be found in the area before the start of the project; however, they were very poorly maintained. The city aims to preserve the already present native species with gradual thinning and adoption of a naturalistic forestry approach without unnecessary vegetation replacements. The expectation is for a gradual recovery of the local ecosystem, particularly in terms of pest control and limiting the presence invasive species. The increase of green surfaces and tree-lined spaces, with consequent reduction of the impermeable surface areas, allow increasing the environmental protection of the area by reducing the hydrological risk and by increasing the geotechnical stability of the slopes, allowing for groundwater recharge and providing stormwater storage capacity in a large drainage area. The constrained watercourses in the underground pipes will be addressed, and this will consequently reduce the reliance solely on conventional sewer type infrastructure to ameliorate flooding and landscape instability phenomena along the Lagaccio river basin as a result of the increasingly frequent heavy rainfall events. The resulting damage to buildings and people will also be reduced in central city districts. The recovery and reuse of rainwater reduces the use of groundwater for irrigation purposes, enhancing water security. The increase of green areas and trees favours the reduction of atmospheric pollutants, supporting carbon sequestration and a subsequent improvement of the local microclimate, contributing to the overall reduction of urban temperatures.

Indicators for the quantification of expected benefits:

- Increase in green and blue space (ca. 2 754 m^2)
- Reduced stormwater runoff (ca. 31%)
- Increased carbon sequestration
- Demolition materials reused on site (ca. 4 925 m^3)
- Biodiversity increase (based upon numbers of native/naturalised species)

The increased **accessibility and inclusiveness** of public (green) spaces is aimed at solving the issues that currently characterise the area, addressing the fragmentation and inadequacy of the road network, improving pedestrian mobility, and promoting slow mobility to the detriment of vehicular mobility. The result is the creation of inclusive, multifunctional, and flexible public spaces that are suited to the topography of the area, create an interruption to the excessive residential urbanisation and increase the attractiveness of the area, making it a strategic hub between the "Piazza Principe" station to the south and the "Parco dei Forti" to the north.

Indicators for the quantification of expected benefits:

- Increased area for pedestrians (ca. 124%)
- Increased access to urban public outdoor recreation space (ca. 5 313 m^2)

6.3 Impacts

Genova

Environmental impacts: The project has highlighted the importance of using natural solutions to increase urban resilience and the need to direct future urban interventions towards promoting more efficient, inclusive and climate resilient urban communities. This can be achieved through innovative renaturation measures, proper stormwater management, unsealing of urban surfaces, open space design that improve urban environmental performance with a reduction of local temperature (microclimate moderation), reduced air and water pollution and mitigation of the urban heat island effect. This results in a better quality of life for the citizens and improved community well-being. With this project, the municipality addresses Genova's needs of improving the local connectivity and pedestrian mobility and increasing perceptions of the district and landscape. The project highlights the importance of protecting the surrounding historical and cultural heritage and the characteristics of landscape typical of the Ligurian region, concomitant with environmental improvement, increasing awareness of adopting a new approach to natural risk management.

The UNaLab project has inspired the city administration to include NBS among the requirements for the design of another urban park for the city of Genova. Subject to an international design competition, 'The Park of the Bridge' is located in the area affected by the infamous collapse of the Morandi highway bridge, which is being redeveloped. Experience gained through the UNaLab project was an important source of inspiration for drafting the guidelines set by the city administration at the basis for the design competition, and these guidelines were implemented extensively by the winning project.

Social impacts: Complementary to the positive impacts from an overall increase in accessibility and social cohesion, the involvement of the stakeholders through the co-creation process enabled the active engagement of citizens in the process of reclamation of the degraded areas. The project contributed to raising awareness on urban and social regeneration,

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

environmental sustainability, promotion of the historical and cultural heritage and protection and enhancement of the natural components and ecosystems. In this regard, an indicator for the evaluation of the active involvement of citizens has been defined, which will make it possible to quantify the number citizens actively involved in the project.

The project highlights the importance of creating accessible spaces and offering services for all age groups, encouraging physical activity as well as socialisation and interaction between the residents of the district and city visitors, as a result of the sharing and the synergy between citizens and the entire Administration.

Economic impact: Enhanced biodiversity will enable the creation of a new attractive base for investments, real estate development, and commercial activities. The reduced hydrogeological risk is expected to lead to decreased flooding occurrence and/or damage caused by flooding, with an associated decrease of economic and social costs, including water treatment costs. Local businesses such as shops, real estate agencies, and professional associations could increase their earnings due to the requalification of the area and improvement of the quality of life for residents. Currently, the area is closed to the public; its requalification and the availability of recreational opportunities will attract more people from the surrounding areas, potentially leading to increased commercial opportunities.

Eindhoven

Eindhoven is characterised by a high population density, with high temperatures in the dense urban areas exacerbated by lack of green spaces. In Eindhoven, public spaces in the inner city are changing from the traditional paved areas with little space for, and around, trees into greener public spaces with greater vegetation extent which will enhance local biodiversity. The citizens appreciate the changes to public spaces. Liveability is becoming an essential part of the design of public spaces and the available space for cars is declining in favour of space for cyclists and pedestrians. Climate resilience and water management have improved due to increases in the infiltration capacity and the introduction of water retention at several locations.

Activities and meetings within the established CoP around NBS contribute to defining further actions concerning the ecological cycle of green areas, identifying barriers to NBS implementation, and defining and discussing progress of NBS monitoring and maintenance.

Tampere

First monitoring results in City of Tampere

As climate change projects increased precipitation in the Nordic regions, stormwater retention and purification are clearly emphasised in the multifunctional NBS demonstrations in Tampere. According to monitoring data from **online water quality monitoring stations**, the Vuores stormwater system operates as expected, retaining solids and nutrients and buffering rates of runoff flow to receiving waterbodies. The present rates of surface water flow to receiving waterbodies are considerably lesser than before NBS construction in the area, although measuring of flow rates was previously based on infrequent sampling. The elevated nitrogen contents due to explosive residues detected in previous years are no longer observed, and the nutrient content corresponds to that of an uncontaminated runoff water. Runoff from the Vuores area does not contribute to eutrophication of the receiving water bodies. Decentralised stormwater systems such as those implemented in the Vuores area seem to improve stormwater management reliability and decrease the requisite size of a single system, and are therefore recommended in dense urban areas.

The Tervaslammenpuisto construction site stormwater system (settling basin and sand filter) retained solids well, but nutrients were only retained to a satisfactory degree. The purification system retained a very limited quantity of total nitrogen. For total phosphorus, the performance of the purification system was somewhat better than for nitrogen. The purification efficiency averaged 45%. The system performed well in terms of solids with the purification efficiency averaging 80%. This is likely due primarily to the characteristics of the filter materials; pure sand has no capacity for chemical retention of nutrients and, as such, sand filters are reliant upon physical filtering processes. A substantial proportion of phosphorus is associated with particulate material and can be removed by physical filtration, whereas nitrogen is primarily present in dissolved form and cannot be removed by physical filtration. The settling basin and sand filter worked relatively well to control rates of runoff flow, but the flow rates were relatively low. The general guideline for treatment of construction site water is that the system size must be 5 % of the drainage basin size. Due to lack of space, the system volume had to be reduced to 2.5 % of the drainage basin size, which is inevitably reflected in the results.

As a part of the UNaLab project, **a pollinator survey** in the city of Tampere has been conducted annually since 2019 in the districts of Vuores, Hiedanranta and Viinikanlahti. Pollinators were chosen as an indicator species group for monitoring the NBS effects on biodiversity as they are expected to be most impacted by the NBS. Due the decline in pollinators worldwide, it is essential to monitor the abundance and diversity of the key pollinator species including beetles, bees, and butterflies.

Since the implementation of the UNaLab NBS, the pollinators surveyed were observed to benefit from the diverse plant communities in the study areas. The pollinator species surveyed favour the lush meadows and especially the biofilter area of Hiedanranta as these provide a wide range of different flowering plants. The survey demonstrated an expected increasing trend in the abundance of the pollinators during summer due the naturally increasing pollinator activity. In addition to pollinator surveys, vegetation and insect diversity is monitored during the summers of 2020 and 2021 to obtain information about the role of NBS in biodiversity protection in the cities. Initial results indicate that the implementation of the horse paddock has changed the meadow biotope to promote the living conditions for species common in endangered cultural habitats (ancient agricultural habitats that are endangered in Finland), like grazed meadows, thus promoting biodiversity.

In addition to the pollinator monitoring done by professional ecologists, the city collects citizen observations of pollinators through the iNaturalist application (iNaturalist, 2021). iNaturalist is a global application that allows people to report and identify their observations, and the results can be collected to a specific project where they can be analysed by the public and researchers. A pollinator Biobliz -a pollinator monitoring challenge/competition - will also be organised in August 2021 to activate and inform citizens about the importance of pollinators and NBS.

In spring 2020, the city performed a **survey among the residents** of Vuores. Results of the survey suggest that Vuores residents appreciate the NBS in the area and think that they increase attractiveness and unique characteristics of the area (Figure 9). Residents enjoy the area's multifunctional and easily accessible NBS.

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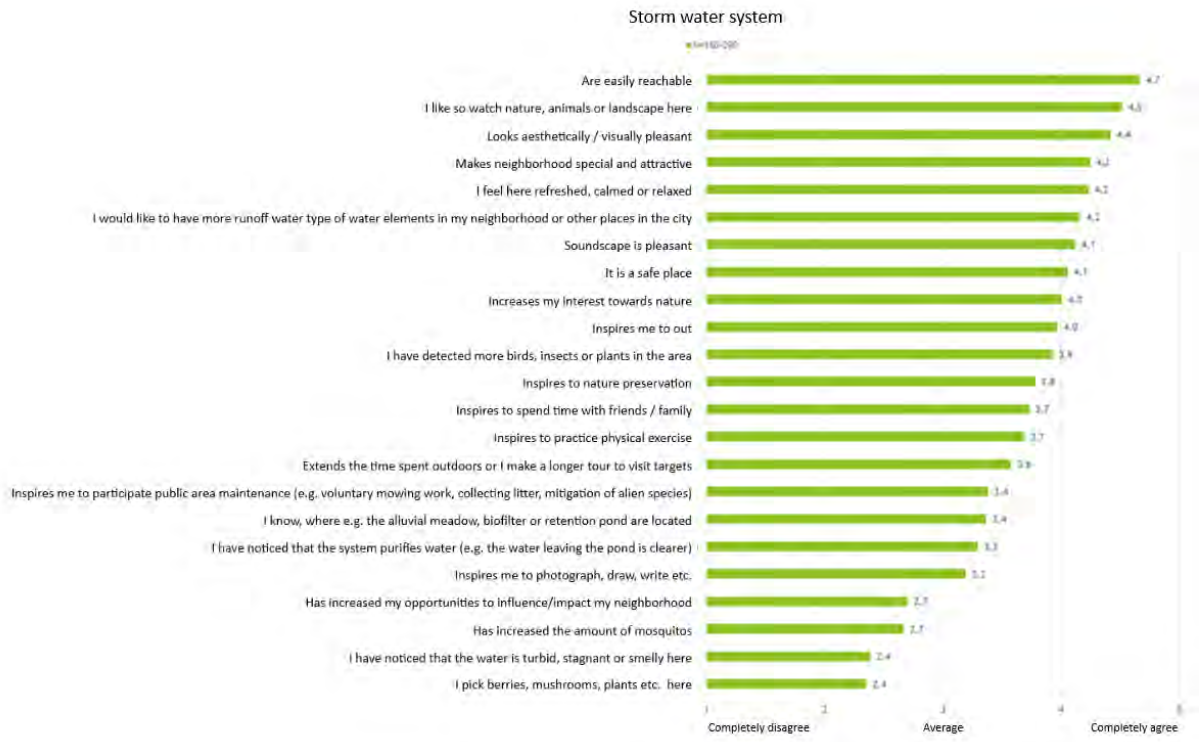

Figure 9. Results of Vuores resident survey in spring 2020.

Carbon emissions are rather interesting for Tampere, as the city aims to be carbon neutral by 2030. In Table 4 and Figure 10, calculations for carbon footprint of the biofilter in Hiedanranta are presented. Materials are the most significant source of carbon emissions followed by transport (Figure 10). Implementation causes relative fewer carbon emissions. Among the materials, carbon emissions of plastic products, Leca-gravel (produced with a thermal process) and bentonite (imported) for waterproofing the filter are highlighted in yellow. Note that the potential sequestration of carbon by biofilter soil and vegetation is not included in the following carbon footprint calculation.

Table 4. Carbon footprint of Hiedanranta biofilter. All units in kgCO_2-e.

Product	Material	Transportation	Installation	Total
Plastic products	1544,3	477,2		2021,6
Mounting platform from gravel	21,0	62,6	33,0	116,6
Leca®-gravel	1580,8	364,7	28,0	1973,5
Macadam	23,4	62,6	39,0	125,0
Bentonite carpet	220,0	725,8	27,0	972,8
Growing medium	175,0	247,6	0,0	422,6
Biochar	197,4	152,2	0,0	349,6
Woodchip mulch	12,0	366,0	0,0	378,0
Shrubs	11,6	58,2	0,0	69,8
Perennials	46,6	63,7	0,0	110,3
Sampling wells	786,4	62,1	0,0	848,5
Soil profiles	0	0,1	422	422,1
Pipeline trenches	0	0,01	44	44,0
In total	4618,5	2642,8	593,0	**7854,3**

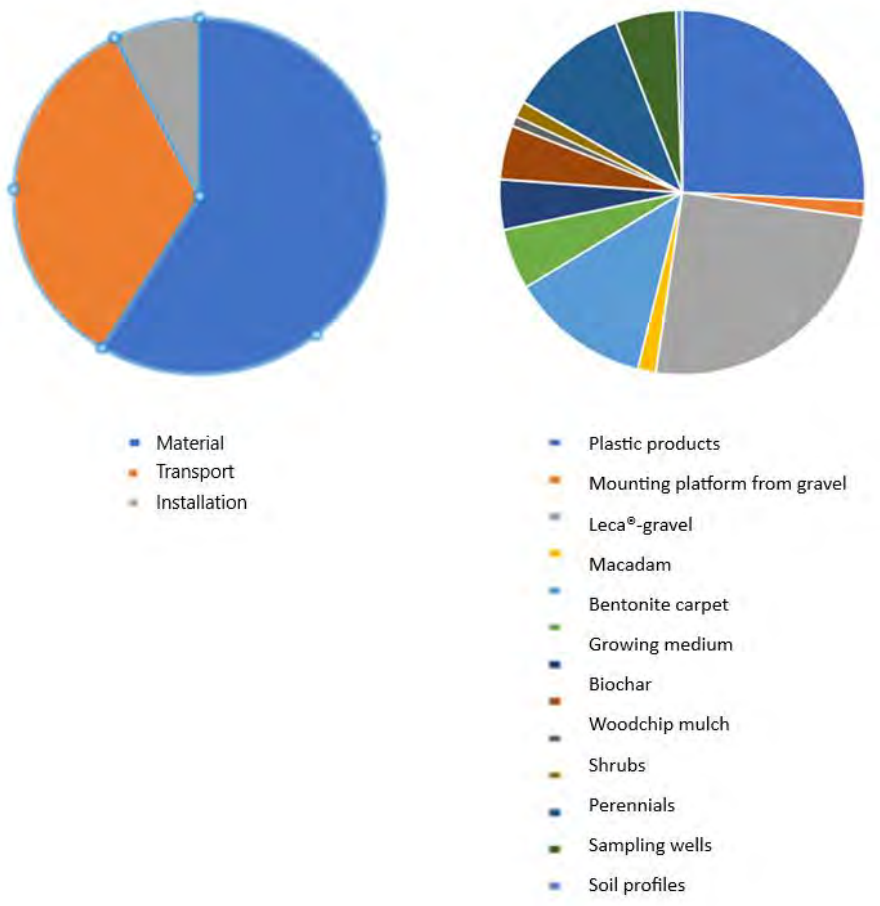

Figure 10. Proportions of (left) of materials, transport and implementation of the carbon footprint, and (right) of different materials of the carbon footprint of the Hiedanranta biofilter.

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Citizen science monitoring activities (water and biodiversity) have been implemented in cooperation with schoolchildren from Vuores, and, inspired by UNaLab demonstrations, the City of Tampere is planning a biofilter implementation, several river restoration projects throughout the city, and replication of the online water quality and quantity monitoring system for the main streams running through the city. The core UNaLab Tampere team additionally contributed to preparing a City roadmap for green areas and stormwater, and other municipal programs.

6.4 Guidance on NBS implementation

Changing urban landscapes and attitudes requires time, and, similarly, municipalities and citizens require time to adjust to the changes. Implementing changes gradually will enable creation of alliances, finding enthusiastic people within and beyond the municipality, and private investors and citizens that share similar ideas. Nature-based solutions create an opportunity to make cities more climate resilient. However, embedding NBS within the regulations and the work processes has proven to be challenging. Gradual implementation and regular monitoring and dissemination will change attitudes and generate the evidence necessary for NBS upscaling and replication. Figure 11 illustrates the typical lifecycle of an NBS project centred around the 'cornerstones' that were highlighted as essential by UNaLab FRCs. Shared vision and values developed via facilitated cooperation aids in building trust among the stakeholders involved in all stages, from planning to realisation and maintenance. Commitment of participants and dissemination of outcomes to a wider audience build strong, enduring networks and output new financing, procurement and decision-making approaches that facilitate green initiatives.

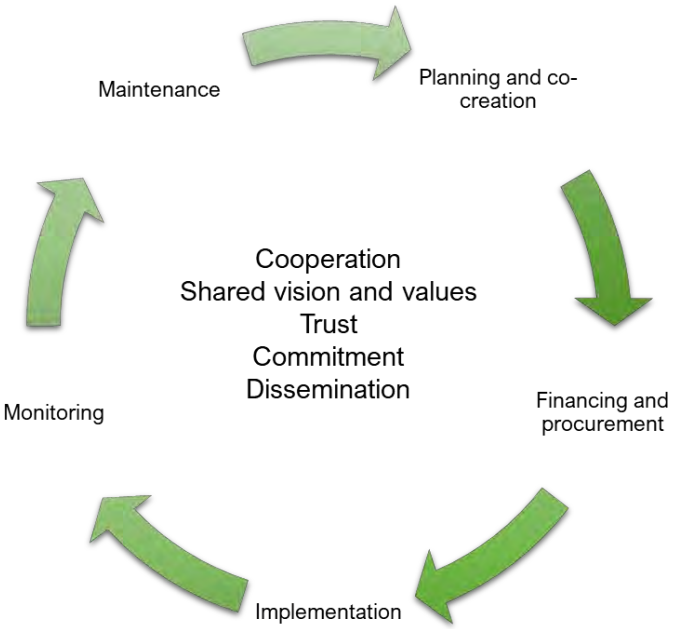

Figure 11. Cornerstones of locally attuned NBS implementation.

Tools, models and methods developed within UNaLab aid in initiating planning, identifying key resources and possible cost structures, and determining key beneficiaries and stakeholders and appropriate financing strategies for each type of NBS (Mačiulyte et al., 2019). Challenges related to NBS governance and facilitating the uptake of NBS in cities can be addressed by, e.g., introducing alternative procurement practices and certification schemes that foster greater cooperation and drive the uptake and replication (Hawxwell et al., 2018).

7. CONCLUSIONS

The *Nature-Based Solutions Demonstration Site Start-Up Report* discusses and demonstrates the various dimensions of highlights and lessons learned regarding NBS implementation in the UNaLab FRCs. Nature-based solution implementation requires careful planning and involvement of a variety of actors. Development of a shared vision and raising of awareness contribute to the successful implementation of selected NBS interventions. The overall outcomes of NBS implementation in UNaLab FRCs revealed that citizens and stakeholders generally react positively to NBS and disseminating the positive outcomes of NBS is valuable for wider outreach and uptake. A multidisciplinary approach proved beneficial for defining the most relevant solutions and identifying challenges at early planning stages and during NBS co-creation. Complementary disaster risk assessment per UNDRR Scorecard for cities in Tampere and Genova highlighted the strong points of local disaster risk reduction, such as incorporation of risks in urban planning, and points for improvement, including expanding the financial capacity and continuous risk assessment processes. Tools, methods and practices developed in UNaLab can aid in introducing alternative procurement and financing practices that drive the great involvement of private actors and facilitate NBS uptake.

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8. ACRONYMS AND TERMS

CCA	Climate change adaptation
CoP	Community of Practice
DO	Dissolved oxygen
DRR	Disaster Risk Reduction
EC	Electrical conductivity or European Commission (see content)
EIN	City of Eindhoven
FRC	Front-runner city
GEN	City of Genova
GGzE	Geestelijke Gezondheidscentrum Eindhoven
HRT	Hydraulic retention time
ISO	International Organization for Standardization
LID	Low impact development
MEC	Minimum Environmental Criteria
NBS	Nature-based solution
NGO	Non-governmental organisation
N_{tot} or TN	Total nitrogen
OD	Optical density
P_{tot} or TP	Total phosphorus
SME	Small or medium size enterprise
SuDS	Sustainable urban drainage systems
TIA	Total impervious area
TRE	City of Tampere
TSS	Total suspended solids
ULL	Urban Living Lab
UNDRR	UN Office for Disaster Risk Reduction
UNI	Ente Nazionale Italiano di Unificazione
VSS	Volatile suspended solids
WWTP	Wastewater treatment plant

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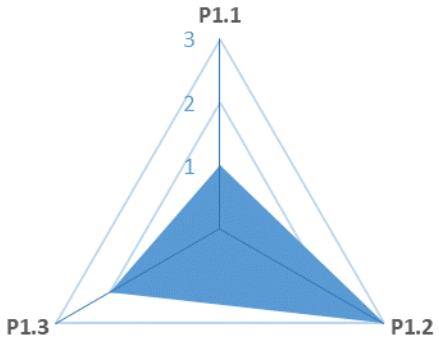
10. APPENDIX 1: RESULTS OF UNDRR DISASTER RESILIENCE SCORECARD FOR CITIES

10.1 Genova

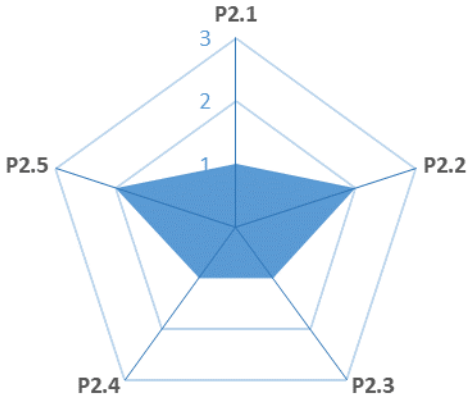
Essential 01: Organize for Resilience

P1.1	Does the City master plan (or relevant strategy/plan) adopt the Sendai Framework?	1
P1.2	Is there a multi-agency/sectoral mechanism with appropriate authority and resources to address disaster risk reduction?	3
P1.3	Is resilience properly integrated with other key city functions / portfolios?	2



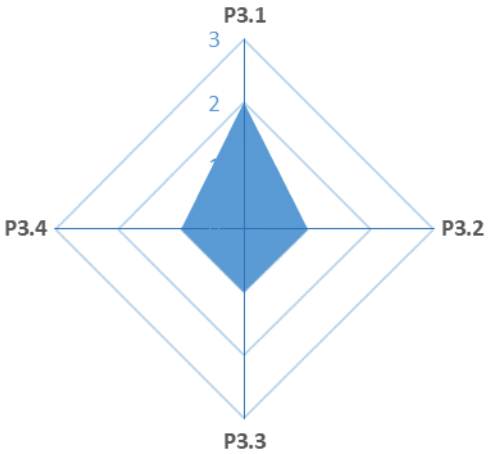
Essential 02: Identify, Understand and Use Current and Future Risk Scenarios

P2.1	Does the city have knowledge of the key hazards that the city faces, and their likelihood of occurrence?	1
P2.2	Is there a shared understanding of risks between the city and various utility providers and other regional and national agencies that have a role in managing infrastructure such as power, water, roads and trains, of the points of stress on the system and city scale risks?	2
P2.3	Are their agreed scenarios setting out city-wide exposure and vulnerability from each hazard, or groups of hazards (see above)?	1
P2.4	Is there a collective understanding of potentially cascading failures between different city and infrastructure systems, under different scenarios?	1
P2.5	Do clear hazard maps and data on risk exist? Are these regularly updated?	2



Essential 03: Strengthen Financial Capacity for Resilience

P3.1	The city / lead agencies understand all sources of funding, and the "resilience dividends", are well connected, understand all available routes to attract external funding and are actively pursuing funds for major resilience investments.	2
P3.2	Does the city have in place a specific 'ring fenced' (protected) budget, the necessary resources and contingency fund arrangements for local disaster risk reduction (mitigation, prevention, response and recovery)?	1
P3.3	What level of insurance cover exists in the city, across all sectors – business and community?	1
P3.4	What incentives exist for different sectors and segments of business and society to support resilience building?	1



Essential 04: Pursue Resilient Urban Development

P4.1	Is the city appropriately zoned considering, for example, the impact from key risk scenarios on economic activity, agricultural production, and population centres?	2
P4.2	Are approaches promoted through the design and development of new urban development to promote resilience?	1

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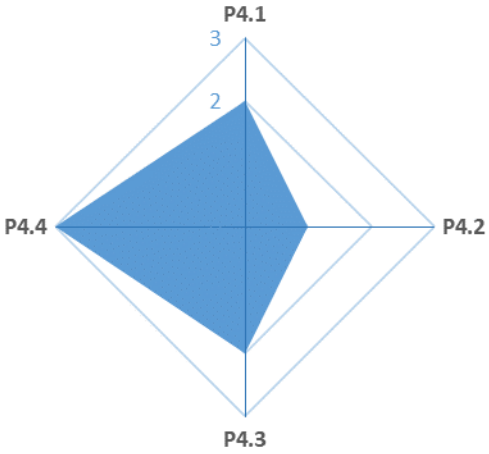
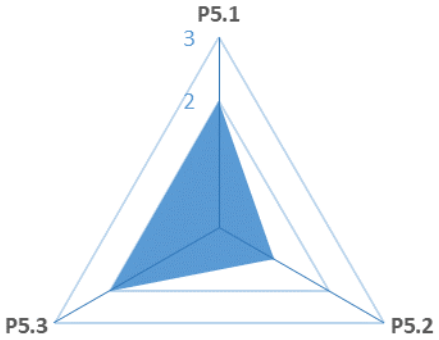
P4.3	Do building codes or standards exist, and do they address specific known hazards and risks for the city? Are these standards regularly updated?	2
P4.4	Are zoning rules, building codes and standards widely applied, properly enforced and verified?	3



Essential 05: Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems

P5.1	Beyond just an awareness of the natural assets, does the city understand the functions (or services) that this natural capital provides for the city?	2
P5.2	Is green and blue infrastructure being promoted on major urban development and infrastructure projects through policy?	1
P5.3	Is the city aware of ecosystem services being provided to the city from natural capital beyond its administrative borders? Are agreements in place with neighbouring administrations to support the protection and management of these assets?	2



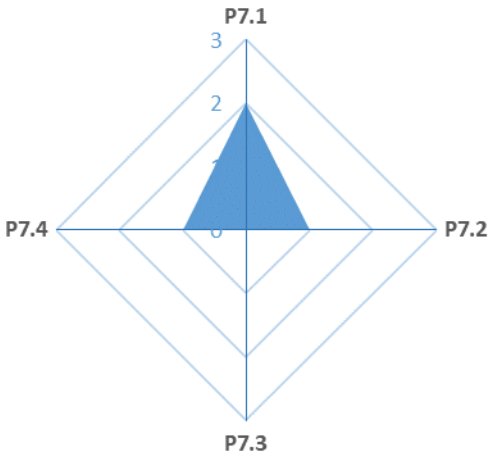
Essential 06: Strengthen Institutional Capacity for Resilience

P6.1	Does the city have clear access to all the skills and experience it believes it would need to respond to reduce risks and respond to identified disaster scenarios?	2
P6.2	Does a co-ordinated public relations and education campaign exist, with structured messaging and channels to ensure hazard, risk and	3

	disaster information (that can be understood and used) are properly disseminated to the public?	
P6.3	Extent to which data on the city's resilience context is shared with other organizations involved with the city's resilience.	2
P6.4	Are there training courses covering risk and resilience issues offered to all sectors of the city including government, business, NGOs and community?	0
P6.5	Are training materials available in the majority of languages in common use in the city?	0
P6.6	Is the city proactively seeking to exchange knowledge and learn from other cities facing similar challenges?	3

Essential 07: Understand and Strengthen Societal Capacity for Resilience

P7.1	Are "grassroots" or community organizations participating in risk reduction and post-event response for each neighbourhood in the city?	2
P7.2	Are there regular training programmes provided to the most vulnerable populations in the city?	1
P7.3	What proportion of businesses have a documented business continuity plan that has been reviewed within the last 18 months?	0
P7.4	How effective is the city at citizen engagement and communications in relation to DRR?	1



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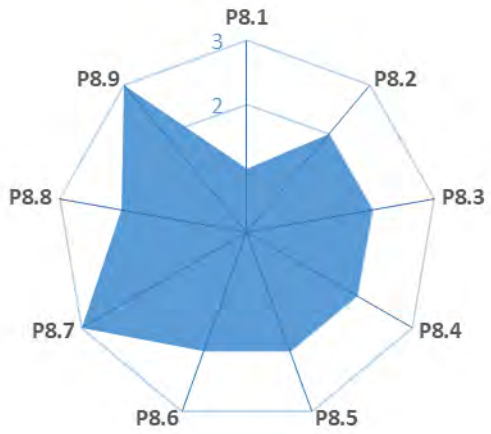
Essential 08: Increase Infrastructure Resilience

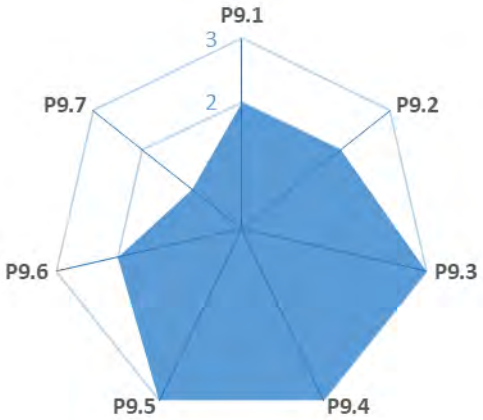
P8.1	Is critical infrastructure resilience a city priority, does the city own and implement a critical infrastructure plan or strategy?	1
P8.2	Is existing protective infrastructure well-designed and well-built based on risk information?	2
P8.3	Would a significant loss of service for these two essential services be expected for a significant proportion of the city under the agreed disaster scenarios?	2
P8.4	Would a significant loss of service be expected for a significant proportion of the city in the 'worst case' scenario event? In the event of failure would energy infrastructure corridors remain safe (i.e. free from risk of leaks, electrocution hazards etc.)?	2
P8.5	Would a significant loss of service be expected for a significant proportion of the city in the 'worst case' scenario event? In the event of failure would transport infrastructure corridors remain safe (i.e. free from risk of flood, shocks etc) and passable?	2
P8.6	Would a significant loss of service be expected for a significant proportion of the city in the 'worst case' scenario event?	2
P8.7	Would there be sufficient acute healthcare capabilities to deal with expected major injuries in 'worst case' scenario?	3
P8.8	% of education structures at risk of damage from "most probable" and "most severe" scenarios	2
P8.9	Will there be sufficient first responder equipment, with military or civilian back up as required?	3



Essential 09: Ensure Effective Disaster Response

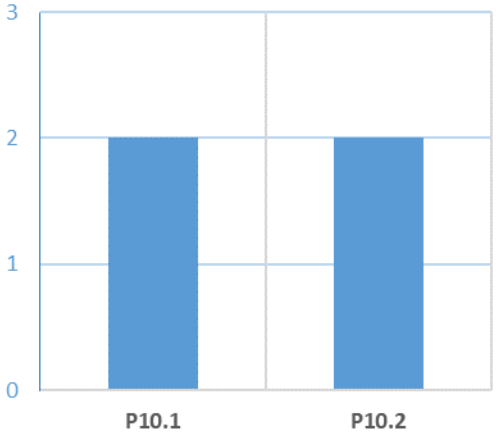
P9.1	Does the city have a plan or standard operating procedure to act on early warnings and forecasts? What proportion of the population is reachable by early warning system?	2
P9.2	Is there a disaster management / preparedness / emergency response plan outlining city mitigation, preparedness and response to local emergencies?	2
P9.3	Does the responsible disaster management authority have sufficient staffing capacity to support first responder duties in surge event scenario?	3

P9.4	Are equipment and supply needs, as well as the availability of equipment, clearly defined?	3
P9.5	Would the city be able to continue to feed and shelter its population post-event?	3
P9.6	Is there an emergency operations centre, with participation from all agencies, automating standard operating procedures specifically designed to deal with “most probable” and “most severe” scenarios?	2
P9.7	Do practices and drills involve both the public and professionals?	1



Essential 10: Expedite Recovery and Build Back Better

P10.1	Is there a strategy or process in place for post-event recovery and reconstruction, including economic reboot, societal aspects etc.?	2
P10.2	Do post-event assessment processes incorporate failure analyses and the ability to capture lessons learned that then feed into design and delivery of rebuilding projects?	2



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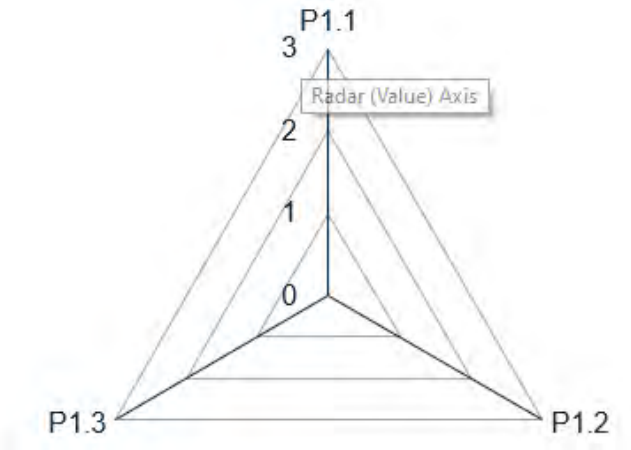
10.2 Tampere

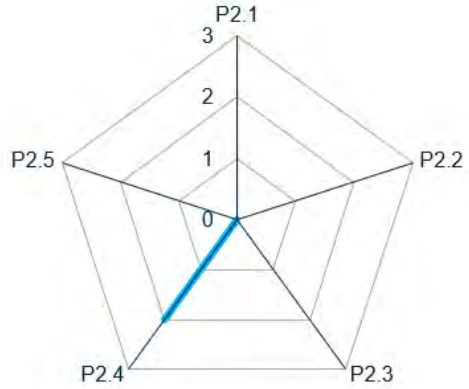
Essential 01: Organize for Resilience

P1.1	Does the City master plan (or relevant strategy/plan) adopt the Sendai Framework?	0
P1.2	Is there a multi-agency/sectoral mechanism with appropriate authority and resources to address disaster risk reduction?	0
P1.3	Is resilience properly integrated with other key city functions / portfolios?	0



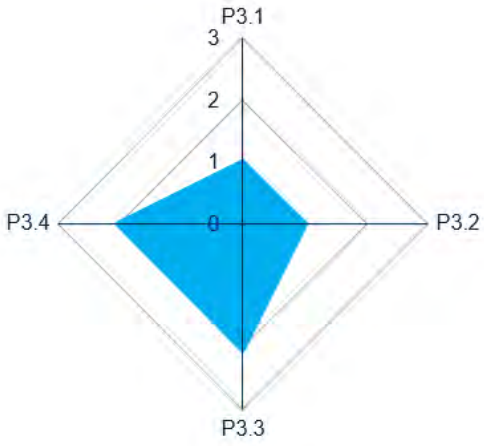
Essential 02: Identify, Understand and Use Current and Future Risk Scenarios

P2.1	Does the city have knowledge of the key hazards that the city faces, and their likelihood of occurrence?	0
P2.2	Is there a shared understanding of risks between the city and various utility providers and other regional and national agencies that have a role in managing infrastructure such as power, water, roads and trains, of the points of stress on the system and city scale risks?	0
P2.3	Are their agreed scenarios setting out city-wide exposure and vulnerability from each hazard, or groups of hazards (see above)?	0
P2.4	Is there a collective understanding of potentially cascading failures between different city and infrastructure systems, under different scenarios?	2
P2.5	Do clear hazard maps and data on risk exist? Are these regularly updated?	0



Essential 03: Strengthen Financial Capacity for Resilience

P3.1	The city / lead agencies understand all sources of funding, and the "resilience dividends", are well connected, understand all available routes to attract external funding and are actively pursuing funds for major resilience investments.	1
P3.2	Does the city have in place a specific 'ring fenced' (protected) budget, the necessary resources and contingency fund arrangements for local disaster risk reduction (mitigation, prevention, response and recovery)?	1
P3.3	What level of insurance cover exists in the city, across all sectors – business and community?	2
P3.4	What incentives exist for different sectors and segments of business and society to support resilience building?	2



Essential 04: Pursue Resilient Urban Development

P4.1	Is the city appropriately zoned considering, for example, the impact from key risk scenarios on economic activity, agricultural production, and population centres?	2
P4.2	Are approaches promoted through the design and development of new urban development to promote resilience?	1

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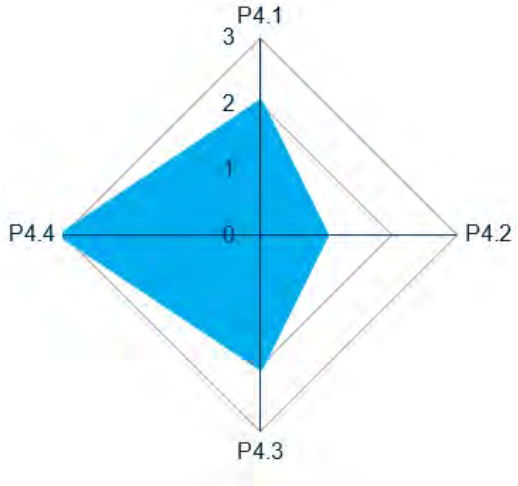
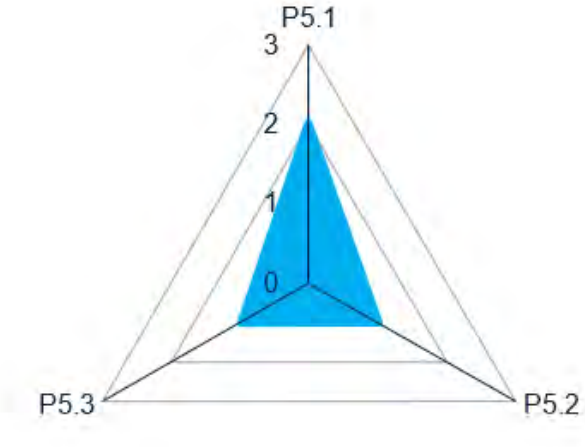
P4.3	Do building codes or standards exist, and do they address specific known hazards and risks for the city? Are these standards regularly updated?	2
P4.4	Are zoning rules, building codes and standards widely applied, properly enforced and verified?	3



Essential 05: Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems

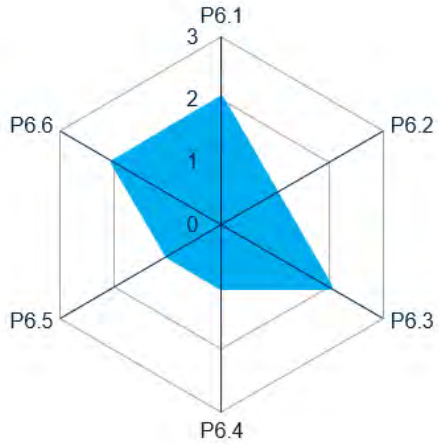
P5.1	Beyond just an awareness of the natural assets, does the city understand the functions (or services) that this natural capital provides for the city?	2
P5.2	Is green and blue infrastructure being promoted on major urban development and infrastructure projects through policy?	1
P5.3	Is the city aware of ecosystem services being provided to the city from natural capital beyond its administrative borders? Are agreements in place with neighbouring administrations to support the protection and management of these assets?	1



Essential 06: Strengthen Institutional Capacity for Resilience

P6.1	Does the city have clear access to all the skills and experience it believes it would need to respond to reduce risks and respond to identified disaster scenarios?	2

P6.2	Does a co-ordinated public relations and education campaign exist, with structured messaging and channels to ensure hazard, risk and disaster information (that can be understood and used) are properly disseminated to the public?	1
P6.3	Extent to which data on the city's resilience context is shared with other organizations involved with the city's resilience.	2
P6.4	Are there training courses covering risk and resilience issues offered to all sectors of the city including government, business, NGOs and community?	1
P6.5	Are training materials available in the majority of languages in common use in the city?	1
P6.6	Is the city proactively seeking to exchange knowledge and learn from other cities facing similar challenges?	2



Essential 07: Understand and Strengthen Societal Capacity for Resilience

P7.1	Are "grassroots" or community organizations participating in risk reduction and post-event response for each neighbourhood in the city?	3
P7.2	Are there regular training programmes provided to the most vulnerable populations in the city?	1
P7.3	What proportion of businesses have a documented business continuity plan that has been reviewed within the last 18 months?	0
P7.4	How effective is the city at citizen engagement and communications in relation to DRR?	1

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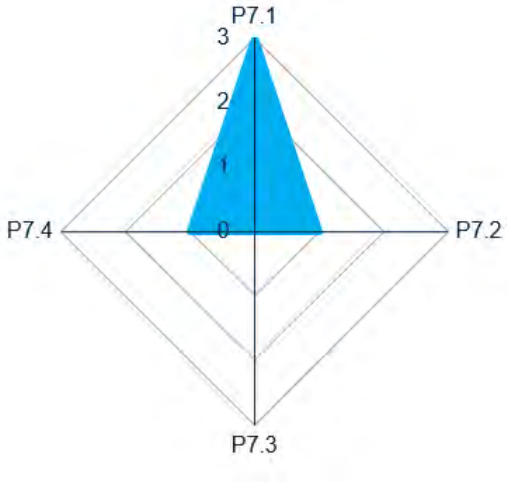
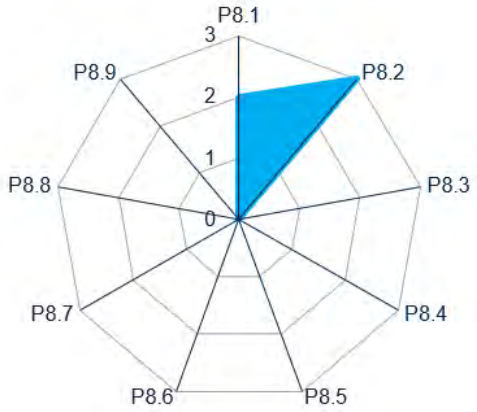


Essential 08: Increase Infrastructure Resilience

P8.1	Is critical infrastructure resilience a city priority, does the city own and implement a critical infrastructure plan or strategy?	2
P8.2	Is existing protective infrastructure well-designed and well-built based on risk information?	3
P8.3	Would a significant loss of service for these two essential services be expected for a significant proportion of the city under the agreed disaster scenarios?	0
P8.4	Would a significant loss of service be expected for a significant proportion of the city in the 'worst case' scenario event? In the event of failure would energy infrastructure corridors remain safe (i.e. free from risk of leaks, electrocution hazards etc.)?	0
P8.5	Would a significant loss of service be expected for a significant proportion of the city in the 'worst case' scenario event? In the event of failure would transport infrastructure corridors remain safe (i.e. free from risk of flood, shocks etc) and passable?	0
P8.6	Would a significant loss of service be expected for a significant proportion of the city in the 'worst case' scenario event?	0
P8.7	Would there be sufficient acute healthcare capabilities to deal with expected major injuries in 'worst case' scenario?	0
P8.8	% of education structures at risk of damage from "most probable" and "most severe" scenarios	0
P8.9	Will there be sufficient first responder equipment, with military or civilian back up as required?	0



Essential 09: Ensure Effective Disaster Response

P9.1	Does the city have a plan or standard operating procedure to act on early warnings and forecasts? What proportion of the population is reachable by early warning system?	0
P9.2	Is there a disaster management / preparedness / emergency response plan outlining city mitigation, preparedness and response to local emergencies?	0
P9.3	Does the responsible disaster management authority have sufficient staffing capacity to support first responder duties in surge event scenario?	0
P9.4	Are equipment and supply needs, as well as the availability of equipment, clearly defined?	0
P9.5	Would the city be able to continue to feed and shelter its population post-event?	0
P9.6	Is there an emergency operations centre, with participation from all agencies, automating standard operating procedures specifically designed to deal with “most probable” and “most severe” scenarios?	0
P9.7	Do practices and drills involve both the public and professionals?	0

Essential 10: Expedite Recovery and Build Back Better

P10.1	Is there a strategy or process in place for post-event recovery and reconstruction, including economic reboot, societal aspects etc.?	0

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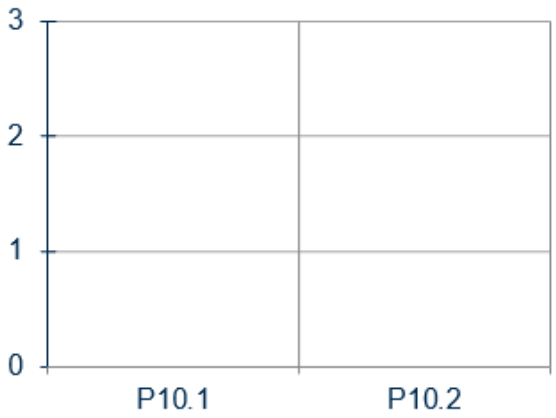
P10.2	Do post-event assessment processes incorporate failure analyses and the ability to capture lessons learned that then feed into design and delivery of rebuilding projects?	0



11. APPENDIX 2: NBS AND SUPPORTING MEASURES IN UNALAB FRONT-RUNNER CITIES

11.1 NBS and supporting measures in Eindhoven

Vestdijk: Street trees, bioretention units (rain gardens)

i. NBS description

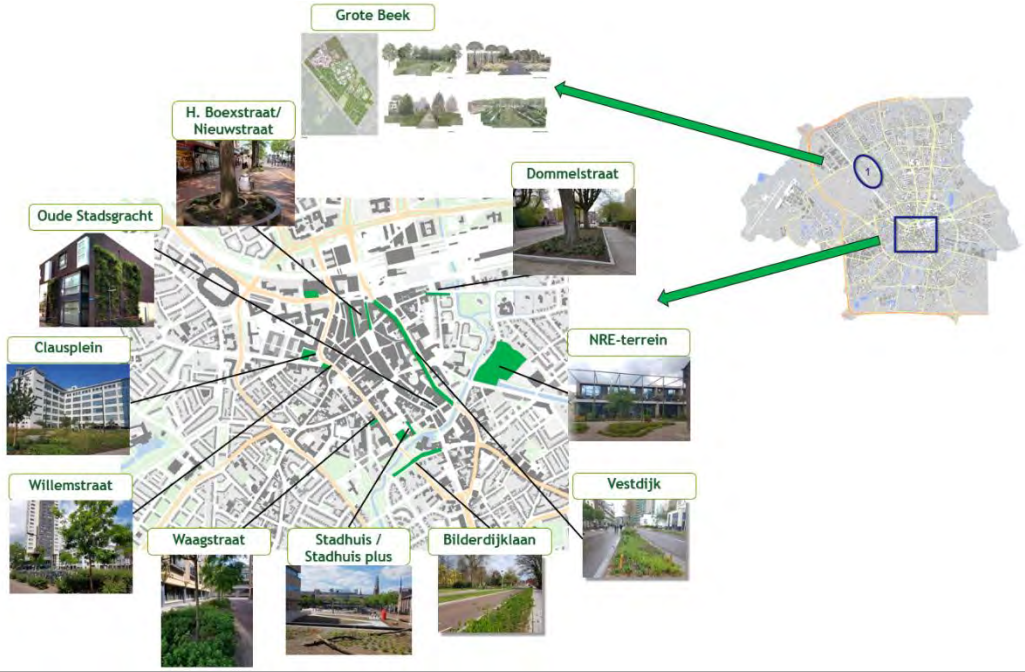
Vestdijk has been transformed from a busy street mostly serving for transportation from one point to another. It is now a greener street with an underground water retention basin and space for pedestrians. It features street trees, bioretention units (rain gardens), green strips with perennials, mixed grasses.

Before transformation

After transformation

ii. Basic information

Location



Type[1]	1	2	3	Size	2000 m² /1000 m³	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality

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	X	X		X	X	X
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
						X

iii. Specific challenges targeted

Heat stress, air quality, attractiveness for pedestrians and cyclists, air quality and flooding after a heavy rainfall event

iv. Technical and design parameters

v. Potential for replication and upscaling

The design has already been extended to other streets with adjustments due to local requirements

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Mean or peak daytime local temperatures	Satellite data Spatial resolution 30 m, temporal resolution 8 days
Climate resilience	Mean or peak daytime local temperatures	Sensors (mobile equipment) Data collection frequency to be decided Monitoring begins Q4 2020 together with the newly installed air quality equipment
Climate resilience	Heat stress: temperature, radiation, wind speed	Evaluated based on temperature measurements Frequency 2-4 times/year

Water management	Infiltration capacity	Field tests (manual measurements) Data collection frequency 1-2 times
Water management	Runoff in relation to precipitation quantity/Rainwater available for irrigation purposes	Sensor (Eijkelkamp) Water level in the retention unit (1/hr or adjusted based on experience)
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data
Biodiversity enhancement	Changes in numbers of birds, butterflies, bees… Change in habitat	Field survey Data collection frequency approx. 4 times/year
Air quality	Concentration of PM_{10}, $PM_{2.5}$, NO_2, and O_3 in ambient air	Draeger/RIVM/Intemo sensors (Aireas) Data collection frequency 1/day? Continuous monitoring begins Q4 2020
New economic opportunities and green jobs	Land and property value	Modelling of scenarios Evaluated once during the project

vii. Maintenance strategy

In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is the functioning as intended, it will be monitored

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Stadhuis/Stadhuis plus: green roof, green entrance and green terrace

i. NBS description

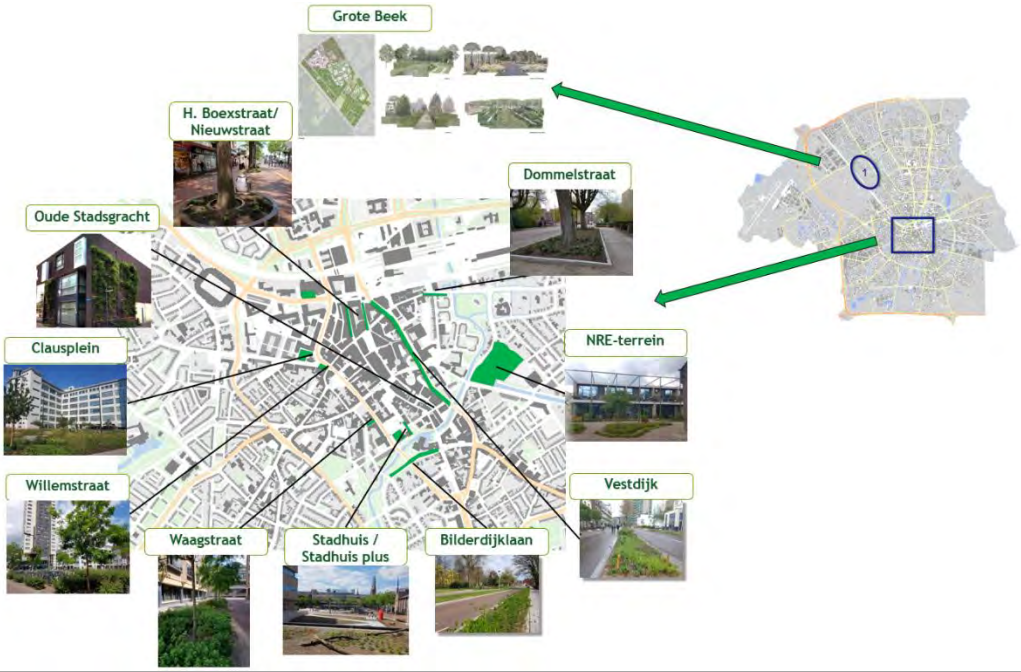
The river Dommel side of the city hall has been improved and changed into a more natural and attractive environment for enhancing biodiversity. The new plan is designed to fit and connect to the design and the ecological function of the Dommel area. Green terrace (trees, perennials and grasses, e.g., *Alnus glutinosa, Alnus incana Aurea, Betula pubescens, Salix Alba, Filipendula ulmaria, Typha angustifolia, Iris pseudacorus*); Native plant species planting along the Dommel River, and a green roof at the City Hall building.

Green roof entrance

Green terrace

ii. Basic information

Location



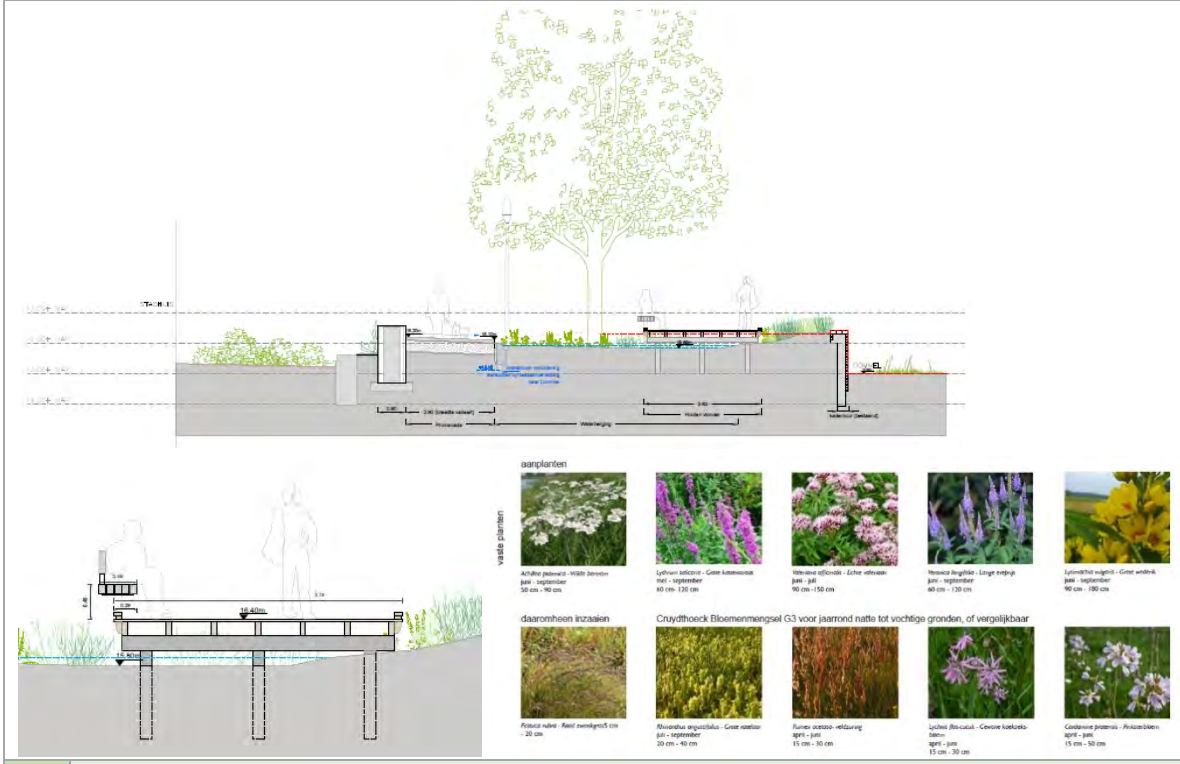
Type[1]	1	2	3	Size	350m²/450 m²/120 m³/220m³ /150m²

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X	X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X					

iii. Specific challenges targeted

Heat stress, potential flooding at location in the surrounding of the city hall. Little space for biodiversity except for the Dommel River zone. In addition, water quality and energy use management.

iv. Technical and design parameters



v. Potential for replication and upscaling

The idea of creating more green areas and NBS which enhance biodiversity has already been used at more locations.

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data
Biodiversity enhancement	Changes in numbers of birds, butterflies, bees; Change in habitat	Field survey Data collection frequency 4 times/year
Water management	Infiltration capacity	Field tests (manual measurements) Data collection frequency 1-2 times
Green space management (green roof)	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Climate resilience (green roof)	Heat stress: temperature, radiation, wind speed	Sensor: reference and NBS 25 cm above the green roof vs. ordinary roof (not fixed measurements points; mobile equipment measuring every minute for 10-15 minutes; several measurements)
Green space management (green entrance)	Proportion of natural areas within a defined urban zone	Modelling Once per project duration

vii. Maintenance strategy

European Commission

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In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is the functioning will be monitored

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

NRE terrein: Green façade and new green space, street trees, bioretention units (rain gardens)

i. NBS description

The NRE terrain is an old industrial area at which the old buildings are declared to be a monument. People who live and will live in this area form a community and want to transfer the area into a green and liveable area. The UNaLab project facilitates these green initiatives with a big green façade, greening the area and adding some special elements like big water barrels, worm hotels and pergolas. Green façade with plantings such as *Actinidia deliciosa, Akebia quinata, Aristolochla macrophylia, Clematis amandli, Lonicera periclymenum, Perhenocissus quinquefolia, wisteria sinensis*. New green space in developing area: trees, perennials, grasses (e.g., *Parthenocissus quinquefolia, Wisteria sinensis, Alnus glutinosa, Crataegus persimilis, Sophora japonica, Nothofagus Antarctica*).

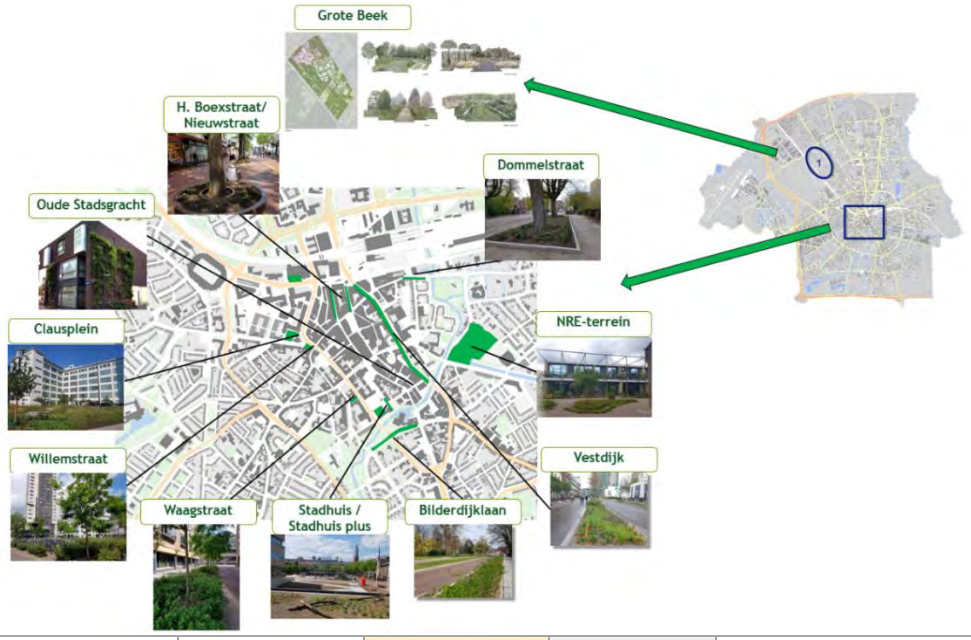
Green façade

Water barrel

Worm hotel

ii. Basic information

Location



Type[1]	1	2	3	Size	300 m² /100 m² / 5 pieces	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X				X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

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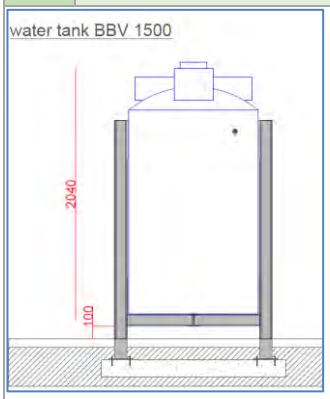
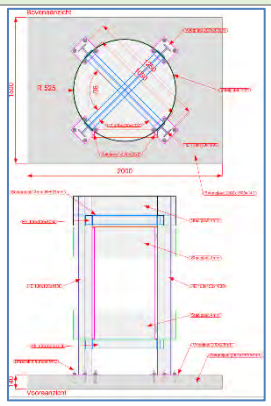
		X	X		X	

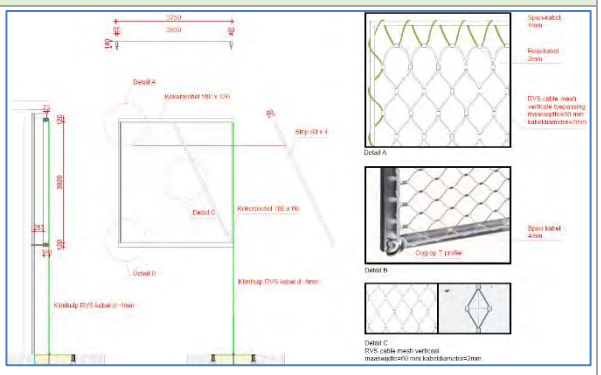
iii. Specific challenges targeted

An old industrial area with little or no climate measures. Heat stress and potential flooding due to heavy rainfall, lack of biodiversity, heat stress, green space accessibility & distribution.

iv. Technical and design parameters







v. Potential for replication and upscaling

To date, there have been no discussions for upscaling. When the project is finalised, several elements may prove to be attractive and function as intended, and will be used in other projects.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Heat stress: temperature, radiation, wind speed	Evaluated based on temperature measurements Frequency 2-4 times/year Sensor: reference and NBS 25 cm in front of the green façade vs. ordinary façade (not fixed measurements points; mobile equipment measuring every minute for 10-15 minutes; several measurements)
Knowledge and social capacity building for sustainable urban transformation	Awareness of citizens regarding urban nature & ecosystem services	Survey Evaluated once during the project
Participatory planning and governance	Sense of involvement	Survey Evaluated once during the project
Knowledge and social capacity building for sustainable urban transformation	Awareness of citizens regarding urban nature & ecosystem services	Survey Evaluated once during the project
Participatory planning and governance	Sense of involvement	Survey Evaluated once during the project
Participatory planning and governance	Sense of participation in governance	Survey Evaluated once during the project
Health and wellbeing	Encouraging a healthy lifestyle	Survey Evaluated once during the project
Health and wellbeing	Attraction of people	Measured as number of visitors per year and increase in average residence time
Health and wellbeing	Satisfaction rate	Survey Evaluated once during the project

vii. Maintenance strategy

In principle the standard maintenance should be enough to ensure the functioning of the NBS together with the maintenance done by the community. For this, a contract will ensure that the responsibility for the maintenance is a job of the community. To make sure that the maintenance is enough functioning will be monitored.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Clausplein: Green areas + rainwater storage

i. NBS description

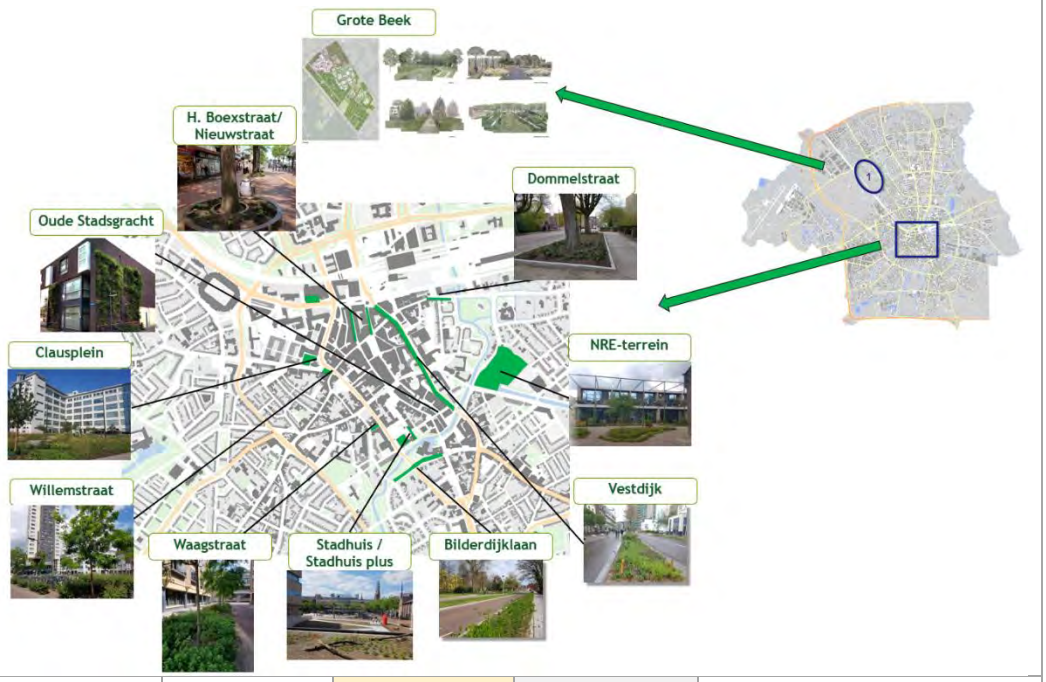
Clausplein used to be a stony square with little to no trees. After reconstruction, it has become a small park with an underground water retention basin, which additionally serves as water supply for the vegetation. Green space: Trees, perennials and grasses.

Before transformation

After transformation

ii. Basic information

Location

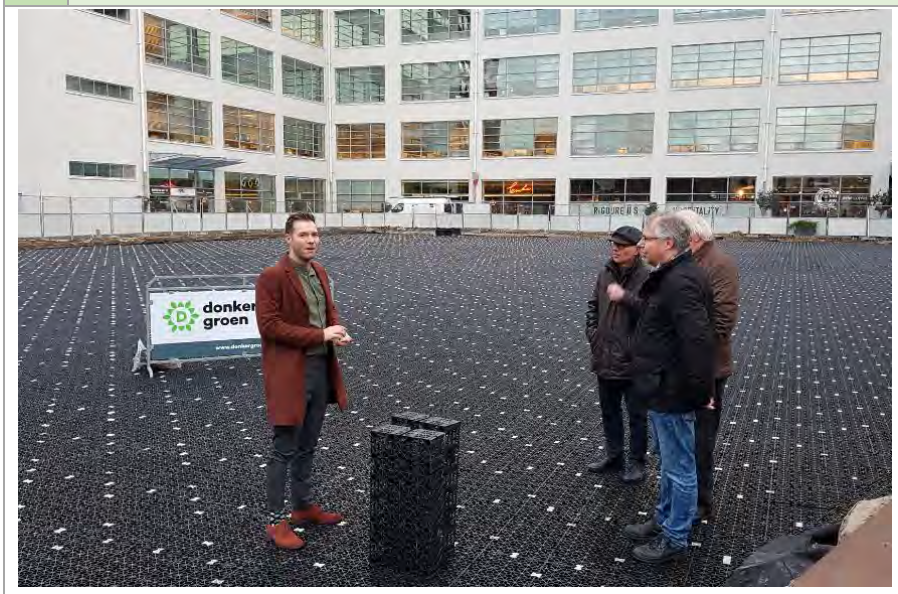


Type[1]	1	2	3	Size	2000 m^2 /1000 m^3	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X	X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		X	X		X	X

iii. Specific challenges targeted

Heat stress, flooding, air pollution, biodiversity, green space accessibility & distribution, social cohesion

iv. Technical and design parameters



Installation of the crate system is finalised

v. Potential for replication and upscaling

The design has been a good example for future developments. Although, the area with a parking garage underneath a square and the possibility to green this area is unique, parts of the system can be replicated.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Mean or peak daytime local temperatures	Satellite data Spatial resolution 30 m, temporal resolution 8 days
Climate resilience	Heat stress: temperature, radiation, wind speed	Evaluated based on temperature measurements Frequency: 2-4 times/year
Water management	Infiltration capacity	Manual measurements 1-2 times/year
Water management	Runoff in relation to precipitation quantity/Rainwater available for irrigation purposes	Water level in the retention unit Sensor (Eijkelkamp/Telecontrol)
Water management	Moisture in soil	Sensor (Eijkelkamp/Telecontrol) Data collection frequency 1/hr?
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data
Biodiversity enhancement	Changes in numbers of birds, butterflies, bees; Change in habitat	Field survey Data collection frequency approx. 4 times/year
Knowledge and social capacity building for sustainable urban transformation	Awareness of citizens regarding urban nature & ecosystem services	Surveys Evaluated at least 2 times during the project
Participatory planning and governance	New forms of financing	Evaluated once per project
Health and wellbeing	Attraction of people	Interviewing several times per project
Health and wellbeing	Satisfaction rate	Survey Evaluated 1 time during the project

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New economic opportunities and green jobs	Land and property value	Modelling of scenarios Evaluated once during the project

vii.	Maintenance strategy
In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is the functioning as intended, it will be monitored.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Waagstraat: Grassed swale, street trees and grasses

i. NBS description

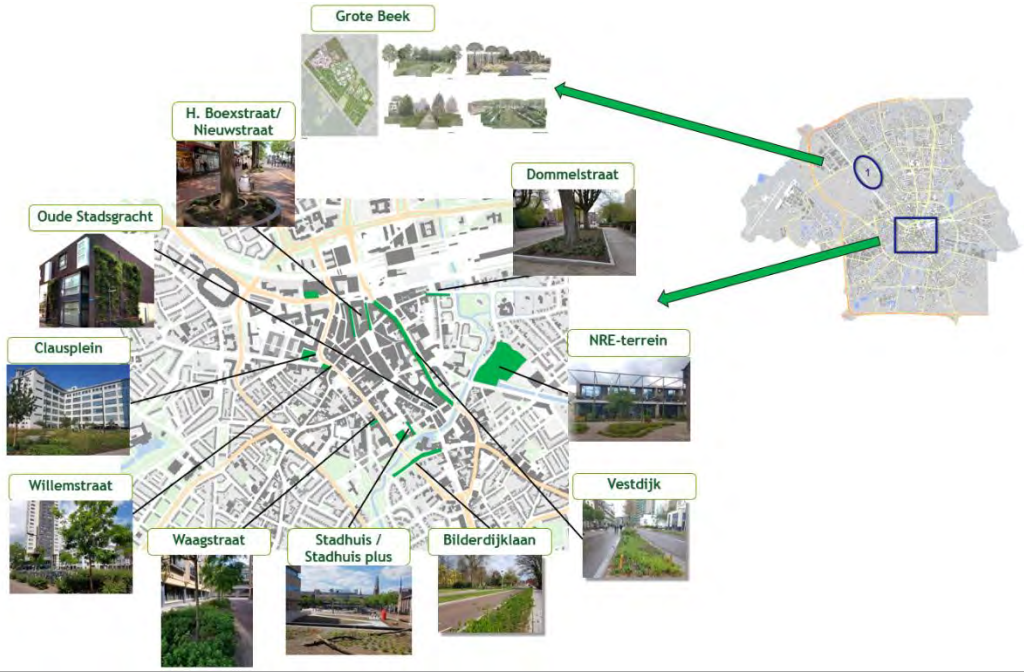
Small street for pedestrians and cyclists very stony with a few small trees redeveloped to feature grassed swale, street trees and grasses.

Before transformation

After transformation

ii. Basic information

Location



Type[1]	1	2	3	Size	250 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X			X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X					

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iii. Specific challenges targeted

Attractiveness for pedestrians and cyclists, heat stress and no water retention or infiltration (flooding), biodiversity

iv. Technical and design parameters

Removing pavement, improvement of soil conditions and infiltration capacity as well as the growing conditions for trees

v. Potential for replication and upscaling

The design has already been extended to other streets with adjustments due to local requirements

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data
Biodiversity enhancement	Changes in numbers of birds, butterflies, bees… Change in habitat	Field survey Data collection frequency approx. 4 times/year
Climate resilience	Heat stress: temperature, radiation, wind speed	Evaluated based on temperature measurements Frequency 2-4 times/year

vii. Maintenance strategy

In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is the functioning will be monitored. As a result, from the monitoring already some adjustments have been made to improve the quality of the soil.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Bilderdijklaan: Larger street with trees, bushes and shrubs

i. NBS description

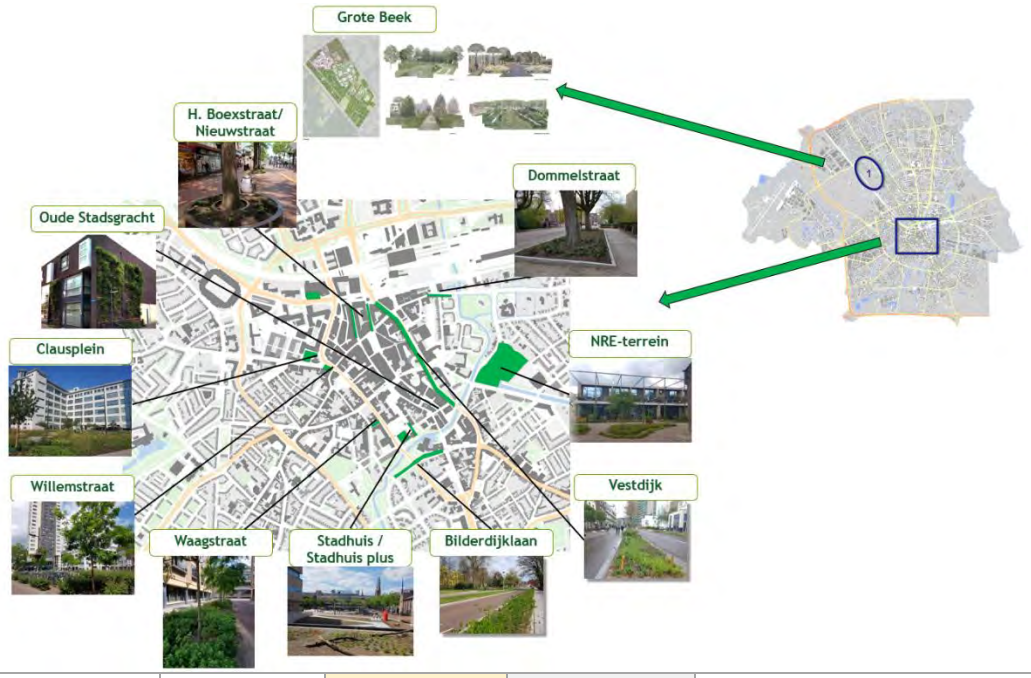
Small street for pedestrians and cyclists very stony with a few small trees redeveloped into a street with trees, bushes, and shrubs.

Before transformation

After transformation

ii. Basic information

Location



Type[1]	1	2	3	Size	600 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

iii. Specific challenges targeted

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Heat stress, drought, flooding, biodiversity

iv. Technical and design parameters

Removing pavement, improvement of soil conditions and infiltration capacity as well as the growing conditions for trees

v. Potential for replication and upscaling

The design has already been extended to other streets with adjustments due to local requirements

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data
Biodiversity enhancement	Changes in numbers of birds, butterflies, bees; Change in habitat	Field survey Data collection frequency approx. 4 times/year
Water management	Infiltration capacity	Field tests (manual measurements) Data collection frequency 1-2 times

vii. Maintenance strategy

In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is the functioning as intended, it will be monitored.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Vestdijk, Oude Stadsgracht: Green façades

i. NBS description

Creating green façades to make the city more attractive and address heat stress.

Oude Stadgracht green façade

Vestdijk green façade

ii. Basic information

Location

Type[1]	1	2	3	Size	Appr. 50 m² / 50 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X					
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

iii. Specific challenges targeted

Reducing heat stress and making the street more attractive

iv. Technical and design parameters

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

v. Potential for replication and upscaling

The design has already been extended to other streets with adjustments due to local requirements

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Heat stress: temperature, radiation, wind speed	Evaluated based on temperature measurements Frequency 2-4 times/year in front of and next to the green façade Sensor: reference and NBS 25 cm in front of the green façade vs. ordinary façade (not fixed measurements points; mobile equipment measuring every minute for 10-15 minutes; several measurements)

vii. Maintenance strategy

Maintenance will be done by the owner of the building the municipality made a contract to make sure that the owner will do this. To make sure that the maintenance is done as intended, the functioning will be monitored.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Willemstraat, green bicycle parking with trees and bushes

i. NBS description

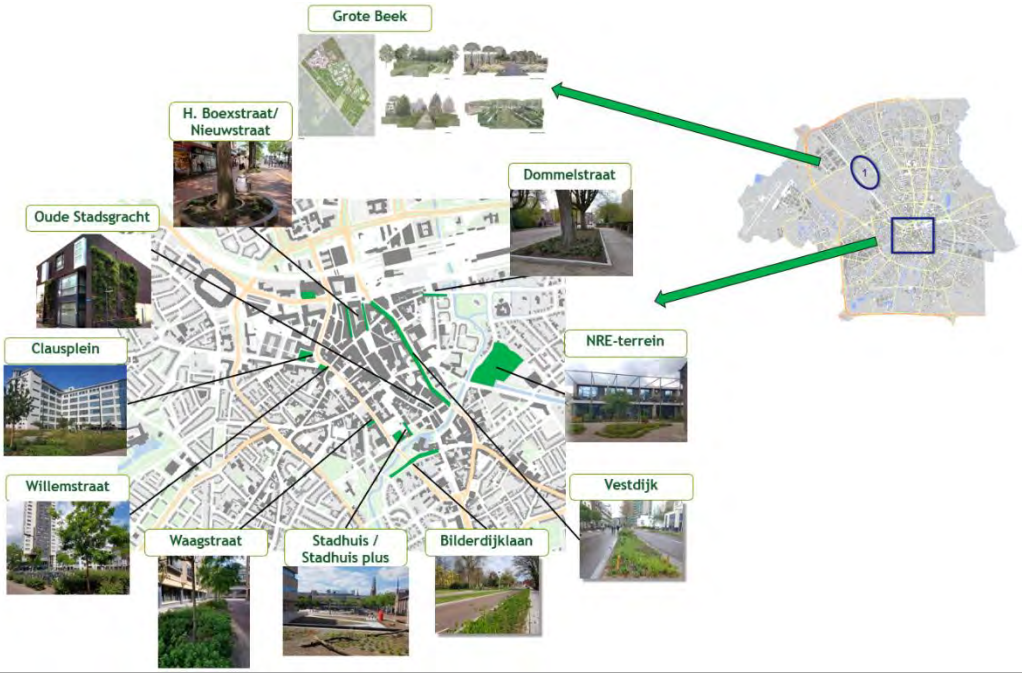
Greening a paved bicycle parking place, to make it more attractive and to enhance biodiversity.

Before reconstruction

After reconstruction

ii. Basic information

Location



Type[1]	1	2	3	Size	135 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
				X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

iii. Specific challenges targeted

Biodiversity enhancement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

iv.	Technical and design parameters
Removing pavement, improvement of soil conditions and infiltration capacity as well as the growing conditions for trees and planting bushes	

v.	Potential for replication and upscaling
The design has already been extended to other streets with adjustments due to local requirements	

vi.	Monitoring strategy	
Challenge	**Indicator**	**Details**
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data

vii.	Maintenance strategy
In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is functioning as intended, it will be monitored.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

H.Boexstraat and Dommelstraat: infiltration planters

i. NBS description

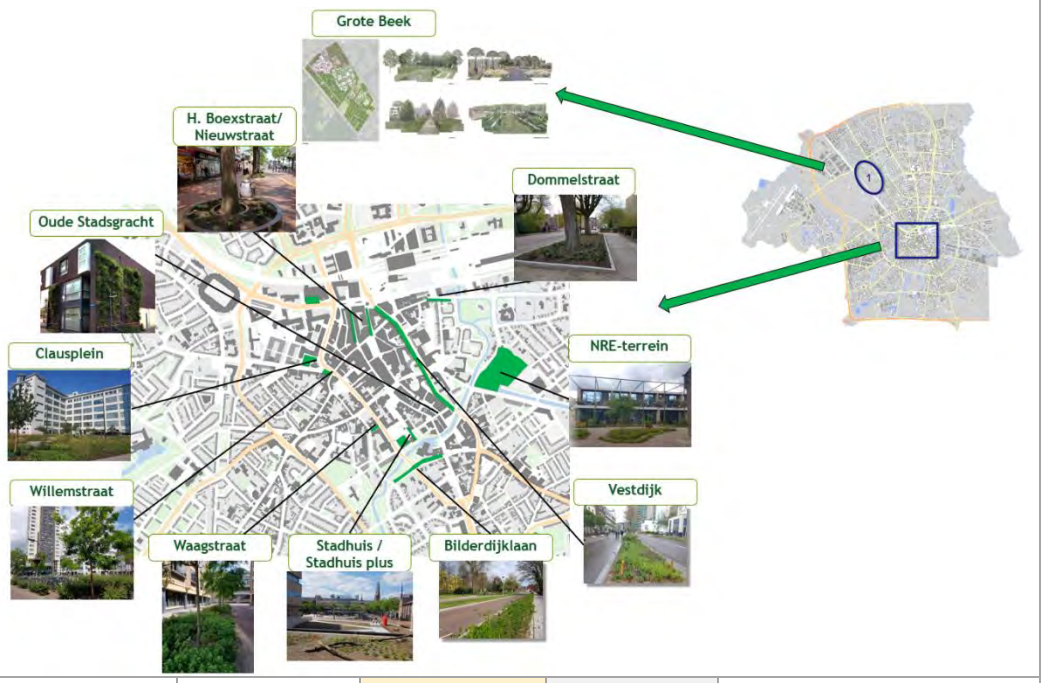
Enhancement of street trees that grew in limited spaces with densified soil. Infiltration planters to improve water retention and infiltration, create space for trees, and create new attractive spaces for citizens' everyday life.

Dommelstraat

H.Boexstraat

ii. Basic information

Location



Type[1]	1	2	3	Size	57 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X		X		
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

iii. Specific challenges targeted

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Improving growing conditions of the trees, enhancing biodiversity as well as bringing shade and infiltration.	
iv.	**Technical and design parameters**
Removing pavement, improvement of soil conditions and infiltration capacity as well as the growing conditions for trees	
v.	**Potential for replication and upscaling**
The design has already been extended to other streets with adjustments due to local requirements	
vi.	**Monitoring strategy**

Challenge	**Indicator**	**Details**
Water management	Infiltration capacity	Field tests (manual measurements) Data collection frequency 1-2 times
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration

vii.	**Maintenance strategy**
In principle the standard maintenance should be enough to ensure the functioning of the NBS. To make sure that it is functioning as intended, it will be monitored.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

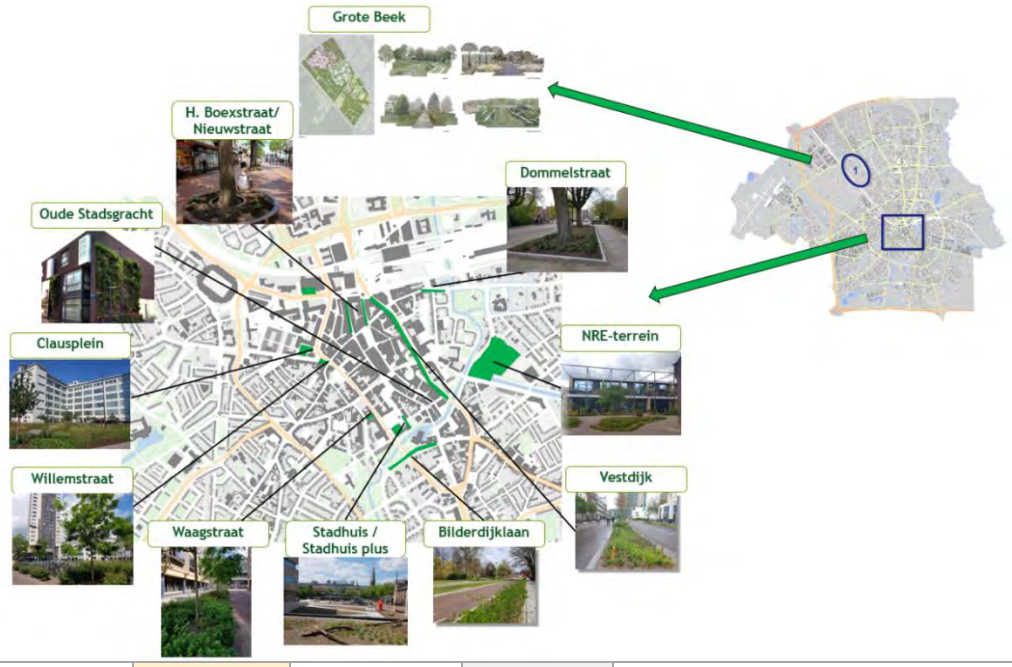
River daylighting: Grote Beek

i. NBS description

The "Grote Beek" is a health institute in a green area. In the past, the stream which ran through this area has been partly removed and the water lead around the area in a pipe. The reconstruction of this stream in a natural setting will be the result of this project. The stream will only be running full after a rainfall event.

ii. Basic information

Location



Type[1]	1	2	3	Size	Depends on design

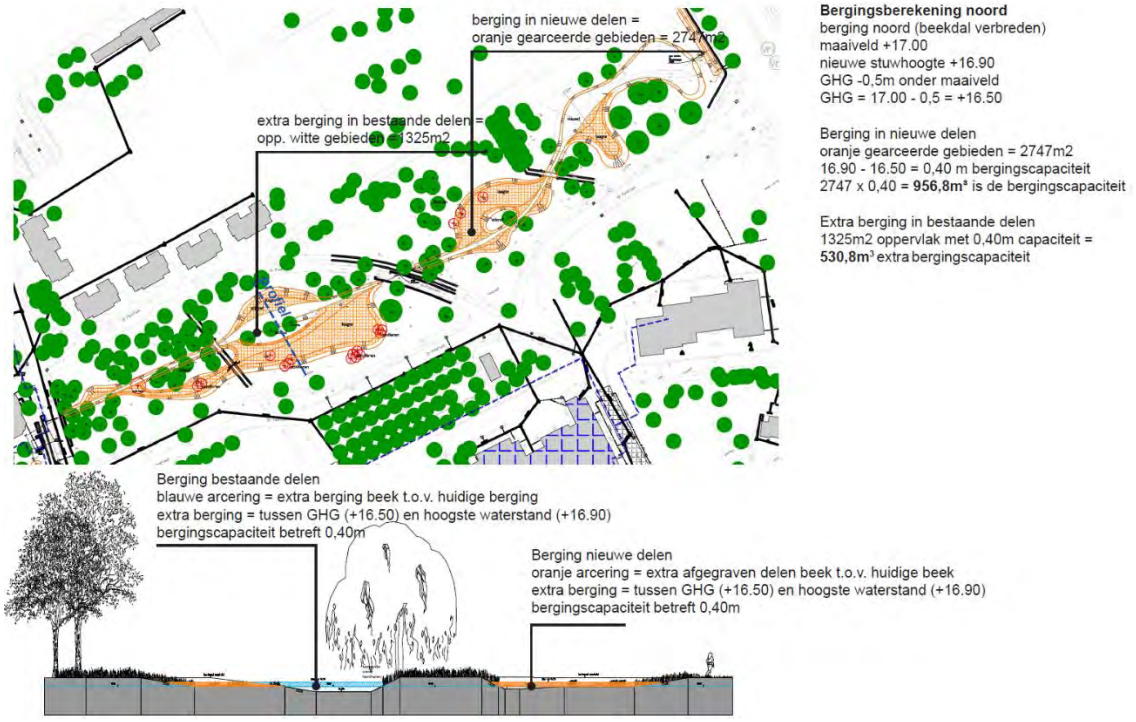
This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X	X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
				X		X

iii. Specific challenges targeted

Reconstructing a watercourse on private property for addressing flooding, heat stress, water quality, biodiversity, social cohesion

iv. Technical and design parameters



v. Potential for replication and upscaling

The design has already been extended to other streets with adjustments due to local requirements

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Total amount of carbon stored in vegetation	i-Tree modelling (first, at one location; then could be expanded to other areas)
Climate resilience	Total amount of carbon stored in soil	i-Tree modelling (first, at one location; then could be expanded to other areas)
Climate resilience	Carbon removed or stored per unit area per unit time	i-Tree modelling (first, at one location; then could be expanded to other areas)
Biodiversity enhancement	Structural and functional connectivity	Evaluation from the maps or satellite data
Biodiversity enhancement	Changes in numbers of birds, butterflies, bees; Change in habitat	Field survey Data collection frequency 4 times/year
Health and wellbeing	Attraction of people	Measured as number of visitors per year and increase in average residence time
Green space management	Proportion of natural areas within a defined urban zone	Modelling Once per project duration

New economic opportunities and green jobs	Land and property value	Modelling

vii. Maintenance strategy

Maintenance will be done by the GGzE together with their clients. Monitoring will be done by several NGO's as well as (for the first year) by a consulting company.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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11.2 NBS and supporting measures in Genova

Draining pavements

viii. NBS description

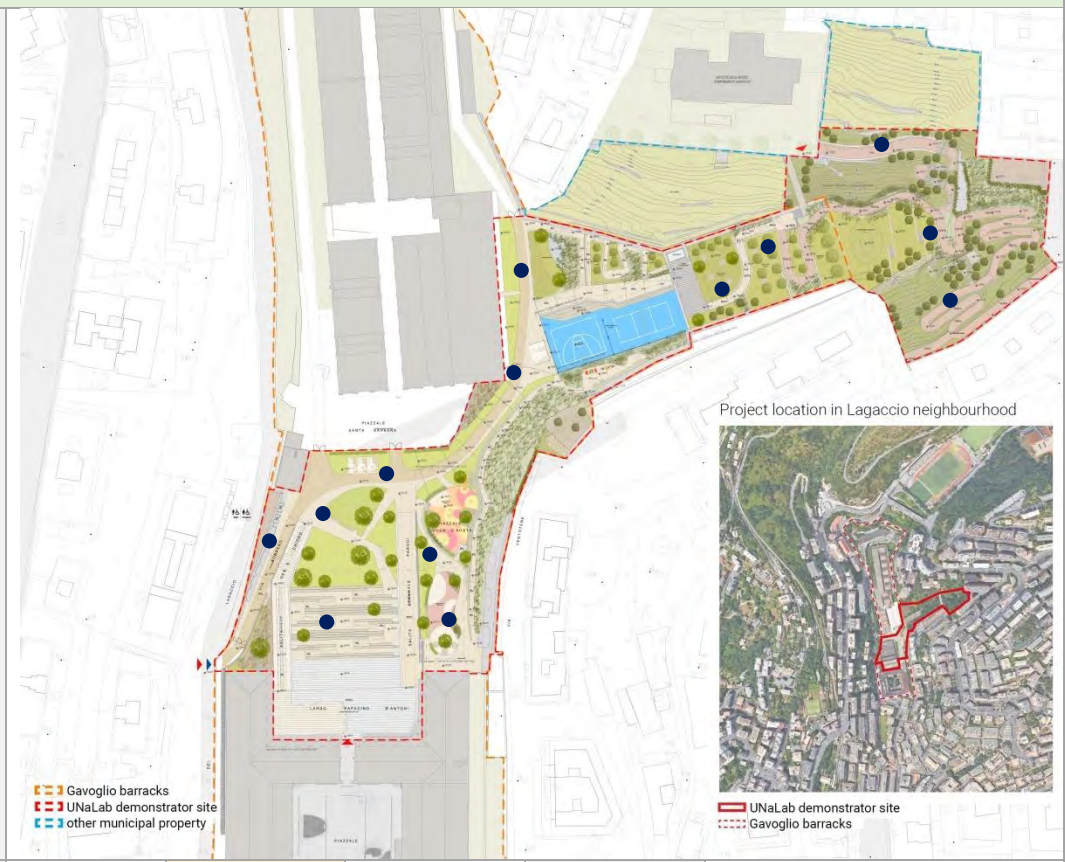
Draining pavements are hardscape surfaces whose main purpose is reducing water runoff and enable rainwater infiltration. Paving materials such as porous blocks, clinkers, open-joint clinkers, resin bound gravel, beaten heart, shells, and concrete or plastic grid can be used. Draining pavements can be deployed for different purposes such as footpaths, playgrounds, fire service roads and recreational areas. Furthermore, green pavers, such as reinforced grass, can reduce pollutants in rainwater. In the project following draining pavements have been selected: open-joint stone slabs for squares, resin bound gravel for most paths and driveways, reinforced grass on highly accessible meadows, beaten earth for trails in the upper part of the park. The reinforced grass uses a mix of *Festuca rubra, Lolium perenne e Poa pratensis*.

Parco via Keplero, Pero (LAND)

HQ Diesel, Breganze (LAND)

ix. Basic information

Location



Type[1]	1	2	3	Size	4751 m²

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X	X	X		
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X					

x. Specific challenges targeted

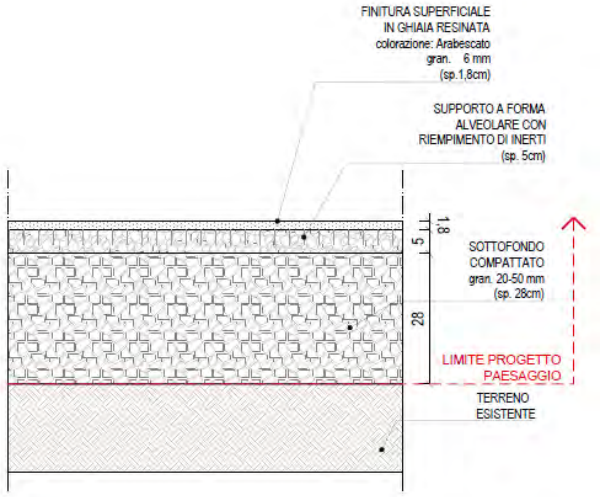
Harsh topography and impervious soil in the area have been causing several damages during extreme meteorological events, such as slides and flooding. Moreover, the neighbourhood lacks accessible pedestrian connections and safe public spaces.

Benefits:

- Reduce stormwater runoff by direct infiltration into the ground
- Delay runoff release into the drainage system
- Increase area for pedestrian and access to urban public outdoor recreational spaces

xi. Technical and design parameters

Resin-gravel with a thickness of 1.8 cm has been used for continuous paving. The mixture has draining characteristics and a high percentage of voids. The polyurethane-based binding product shall be solvent-free. Honeycomb support with 5 cm thick layer of inerts and a 28 cm layer of compacted subfloor filled with split quarry. Different gravel combinations are available and shall be adapted to local architectural context and climate.



Beaten earth.

The surface layer of beaten earth is 10 cm thick, composed of a mixture of monogranular hooks bound by eco-compatible binder. Under it a layer of compacted ground (approximately 30 cm) allows the stabilization of the surface. The pavement should be protected against premature drying of the surface with anti-evaporation protection after paving and compaction, performed by suitable means.

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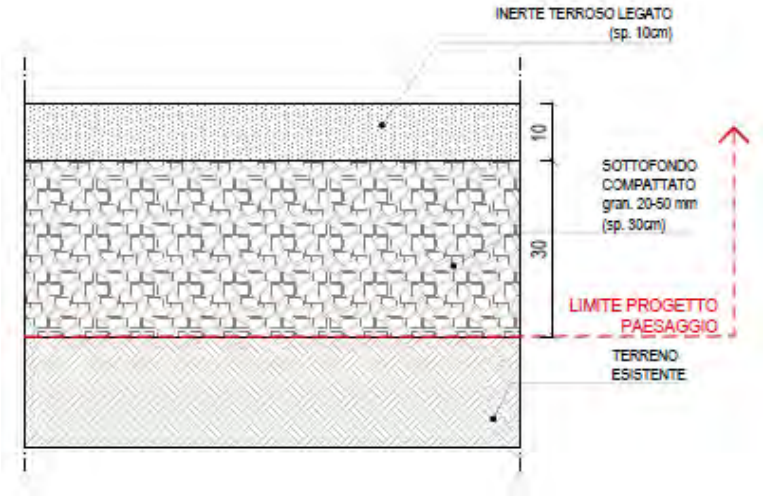
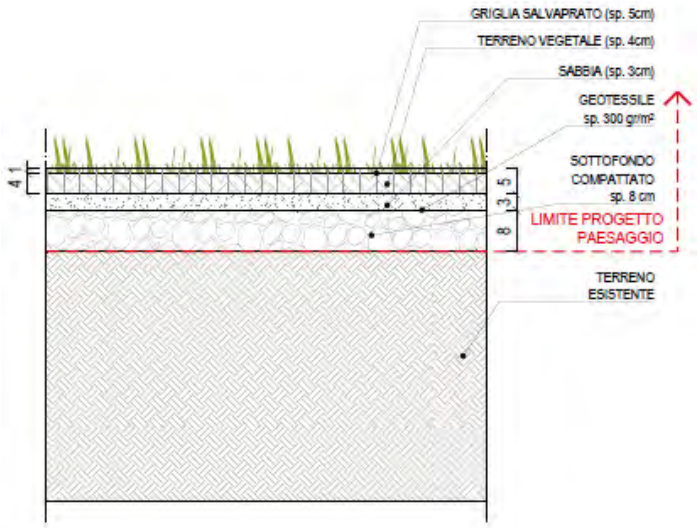


Reinforced grass

The grass seeds are planted in a plastic grid which allow water infiltration across the entire surface. The grid is made of thermoplastic resin (virgin UV-stabilised heterophasic PP), with excellent elastic properties that ensure long-term resistance to temperature changes and atmospheric agents. The grid assures indeed an excellent response to extremely harsh environmental conditions (-20°C) and a non-deformability under load at very high temperatures; it has also an interchangeable double profile (vehicular and pedestrian) and an interlocking modularity that ensures stability and a uniform distribution of loads. The seeds supplied must be of excellent quality, in original sealed packages and provided with a certificate of identity, indicating the level of purity and germinability and expiry date, and must be certified in accordance with the law.



xii. Potential for replication and upscaling

One of the main challenges of the city of Genova is the high sealing rate of soil which, combined with a morphology often characterized by steep slopes, causes many problems in the disposal of rainwater. Draining pavings easily absorb rainwater and distribute it in the substrate over a large surface ("lawn effect"). They guarantee the natural maintenance of the aquifers and improve road safety during meteorological events. They create a "favourable microclimate" as they do not form an impermeable layer and allow the earth to "breathe" by accumulating less heat during exposure to the sun and consequently radiating less heat at sunset. They improve the quality of life in compliance with the basic principles of green building.

The use of various types of drainage pavements could help to address many of these problems and slow down the flow of rainwater, which could be conveyed to the sewer pipes more slowly, as well as infiltrating the ground, where possible. Pavements deployed in the park have medium realisation costs, require easy maintenance activities and low construction layers, and can tolerate steep slopes. Therefore, they are suitable to be replicated in other public areas in Genova as well as Mediterranean cities with similar morphology.

xiii. Monitoring strategy

Challenge	Indicator	Details
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Total amount and percentage of water (per unit surface area) retained in laboratory testing of the design stratigraphy in a dedicated test plot where artificial rain events of selected magnitude are simulated.
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Green space management	Increased area for pedestrians	Proportion of area devoted to roads and paths for pedestrian. Data from project in [%]
Green space management	Increased access to urban public outdoor recreation space	Ratio of open spaces to build form / reclamation of contaminated land (brownfields) available for recreation purposes. Data from project in [m^2]
Participatory planning and governance	Active involvement of citizens	Overall evaluation considering: 1) activities implemented by the Urban Living Lab; 2) data collection (survey) to evaluate the willing of citizens to participate in the management of NbS in the Gavoglio Park. [number of people]

xiv. Maintenance strategy

They require little maintenance and have a long life. In the case of maintenance to the sub-layer or to the underground services, the typical surface patches of asphalt pavements are not created. With the drainage elements, if suitable design of the substrate layers is carried out, it is possible to carry out urbanizations without traditional rainwater collection systems with considerable savings in immediate economic terms (lower urbanization costs) and in the long term (lower maintenance costs).

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Sand playground

i. NBS description

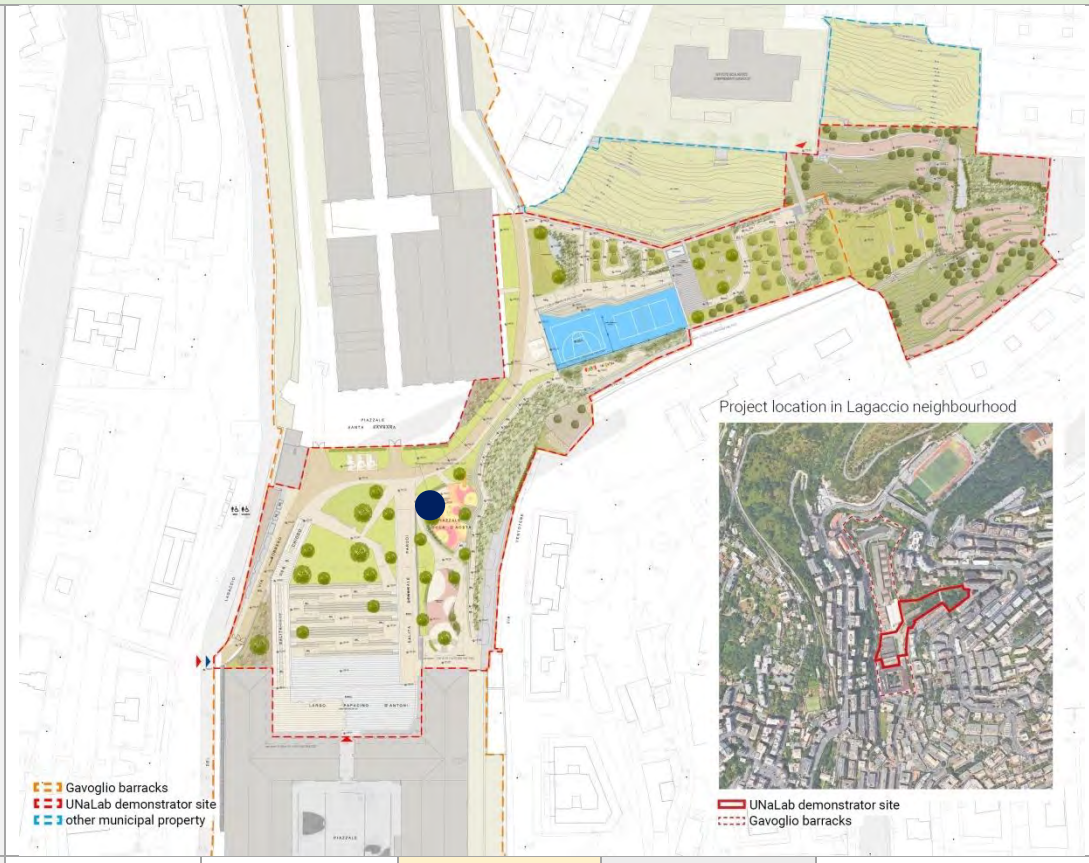
Sand playgrounds are smooth basins filled with sand in order to create a safe soft surface for recreational purposes. In the park the play area is composed by different interventions integrating anti-shock rubber surfaces with sand pools. The use of sand aims to offer a playful experiential surface in connection to natural elements.

Thyssen Krupp Kindergarden, Essen (LAND)

Krupp Park, Essen (LAND)

ii. Basic information

Location



Type[1]	1	2	3	Size	27 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X		X		
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X				X	

iii. Specific challenges targeted

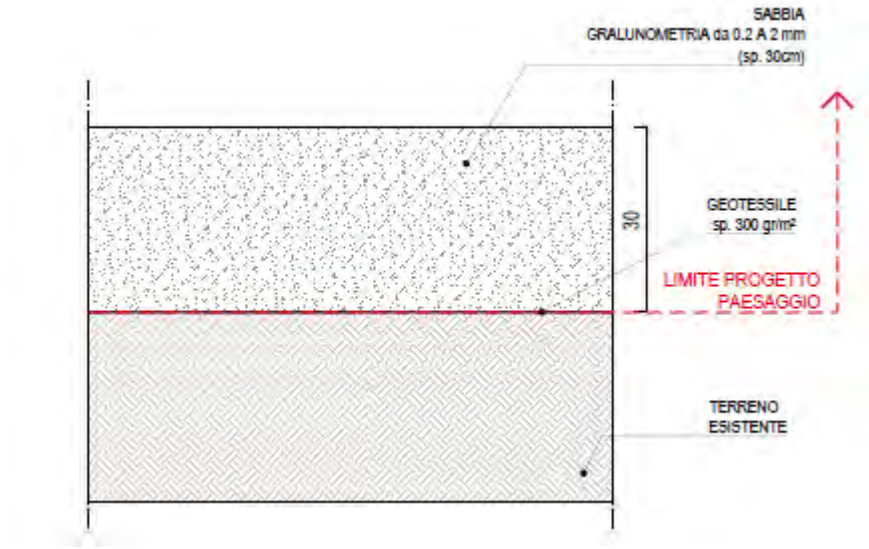
The whole park was designed to meet the needs of the neighbourhood; thus, the sand playground is a recreational as well as social meeting space where, especially children, play with each other. Since the project is sensitive to climate resilience, the area also helps increasing stormwater infiltration.

Benefits:

- Citizen wellbeing
- Reduced stormwater runoff

iv. Technical and design parameters

This paving consists of a sand layer on a geotextile sheet. The geotextile gives a higher stability to the overlying layer but still provides a high-water permeability. The sand layer, 30 cm, provides anti-shock features and is made with rounded sand grains ranging in size from 0 to 3mm.



v. Potential for replication and upscaling

Sand is a natural anti-shock material with which it is possible to shape stimulating and funny playgrounds for children. It is also an inexpensive and easily available material; much appreciated for the possibility of manipulation and use to give free rein to creativity.

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Increased access to urban public outdoor recreation space	Ratio of open spaces to build form / reclamation of contaminated land (brownfields) available for recreation purposes. Data from project in [m^2]
Green space management	Increased area for pedestrians	Proportion of area devoted to roads and paths for pedestrian. Data from project in [%]
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Water management	Increased stormwater retention	Total amount and percentage of water (per unit surface area) retained in laboratory testing of the design stratigraphy in a dedicated test plot where artificial rain events of selected magnitude are simulated.
Participatory planning and governance	Active involvement of citizens	Overall evaluation considering: 1) activities implemented by the Urban Living Lab; 2) data collection (survey) to evaluate the willing of citizens to participate in the management of NbS in the Gavoglio Park. [number of people]

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
New economic opportunities and green jobs	Real estate value increase of Buildings	Overall evaluation of the real estate value increase due to the construction of Gavoglio Park and NbS, in terms of rent and selling prices of the surrounding buildings.

vii.	**Maintenance strategy**

The maintenance of a sand play area is very cheap and easy to carry out and can also be done in collaboration with volunteer associations in the area. It basically consists in keeping sand into the area (bi-weekly), remove leaves and other vegetation materials as well as little waste (bi-weekly), plough the surface layer paying attention not to damage the bottom membrane (yearly), refill sand (every 5 years).

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Rain garden

i. NBS description

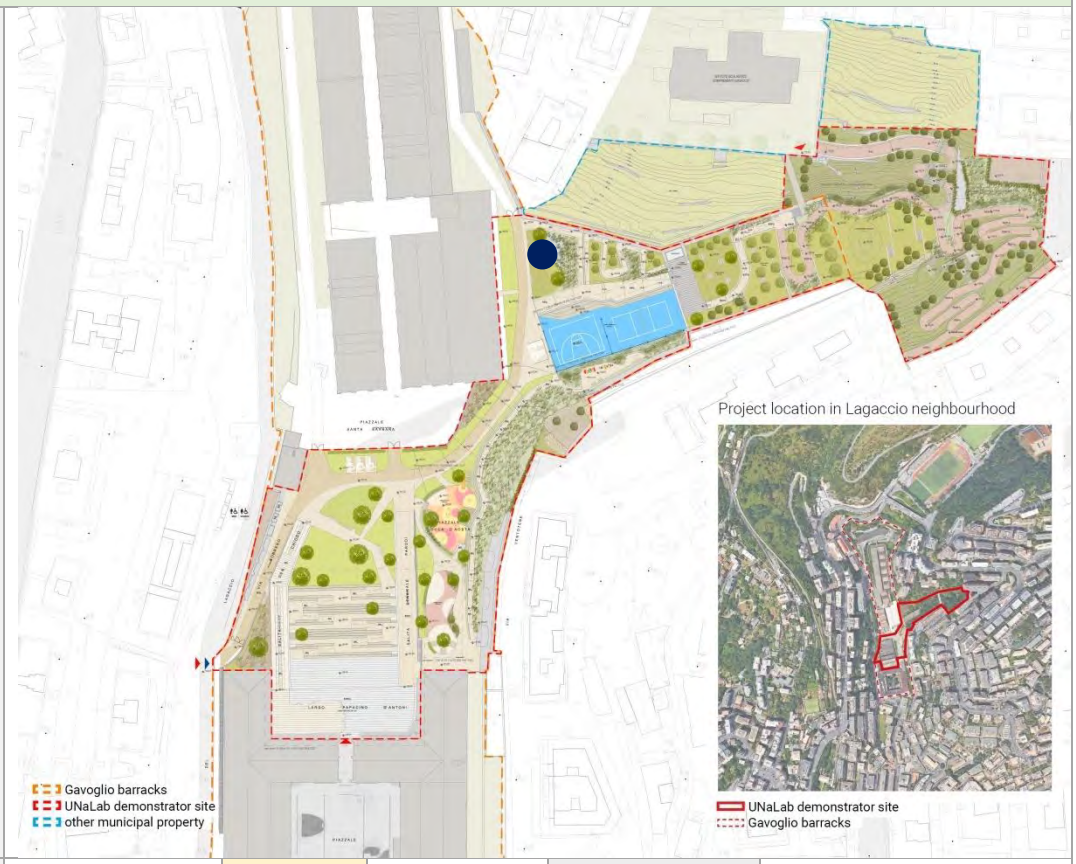
A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. Stormwater is drained into rain gardens, where is stored for a short period; here hence it either infiltrates into the ground or flows into the sewage system through a dedicated underground drainage pipe. To optimise its functions, it must include a porous soil mixture, native wetland vegetation and some hyperaccumulator plants, capable of phytoremediation. A grass/herbaceous mix of *Filipendula ulmaria*, *Lythrum salicaria, Echinacea purpurea* 25%, *Juncus effusus* 15%, *Iris japonica* 15% and *Iris pseudacorus* 15% are used in the rain garden,

Via Keplero park, Pero (LAND)

Parco via Keplero, Pero (LAND)

ii. Basic information

Location



Type[1]	1	2	3	Size	117 m^2	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality

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	X	X	X	X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X				X	X

iii. Specific challenges targeted

Due to the heavy rainfall in the area, and the high degree of impermeability of the surface, especially downstream of the park, a raingarden is useful to mitigate flooding.

Benefits:

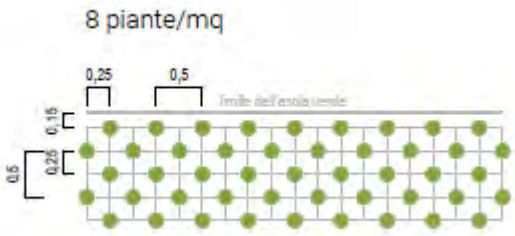
- Flood risk reduction
- stormwater detention
- infiltration, lamination and qualitative treatment of rainfall by vegetation
- Increase biodiversity

Co-benefit:

- Social relations

iv. Technical and design parameters

The design provides a wetland area in which the water level changes as a function of weather events. Hygrophilous plants are used in the floodable area. The population density is 4/6/8 plants each square meter.



v. Potential for replication and upscaling

One of the main problems of the city of Genova is the high waterproofing of the soil which, combined with the geology, characterized by often very steep slopes, causes many problems in the disposal of rainwater. The Rain Gardens, in addition to filtering and purifying the collected water in a completely natural way, allow the slowing of the flow of surface flowing water so as to reduce the possibility of alluvial phenomena downstream.
A Rain Garden is a system in transition, mainly linked to atmospheric events: an intense rain, even of short duration, leads to the submersion of the garden and the species it contains. Situation which quickly returns to normal, ensuring an integral view of the green area. On the contrary, dry seasons or with reduced rains, will not lead to aesthetic changes of the garden. This transition induces a greater interest on the part of citizens in the factors climatic and environmental conditions that surround them.

A Rain Garden conserves and filters rainwater delivering it to the sewer system in a less polluted way, less fast and with a constant flow, so as not to alter the regular operation of the system itself. This particular type of garden, if used on a large scale, significantly helps to limit the phenomenon of road flooding and even manages to reduce the concentration of pollutants in the receiving water system by 30%.

Positives
- high flexibility.
- excellent environmental integration;
- discrete purification yields mainly due to filtration and adsorption mechanisms;
- poor maintenance;

Downsides:
- requires quite high surfaces.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Increased carbon sequestration	For tree only. Methods are also available for herbaceous species and consist in cuttings and weighing of dried plant biomass and the related carbon sequestration.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the

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		NBS area. Comparison with the mean values of the town.
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation for the area and NBS evaluation of species richness (plants and birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and pollinator species richness compared with the starting point (before plantings).
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Total amount and percentage of water (per unit surface area) retained in laboratory testing of the design stratigraphy in a dedicated test plot where artificial rain events of selected magnitude are simulated.
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Green space management	Increased access to green space	Accessible urban green spaces. Data from project in [m^2]
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the costruction of Gavoglio Park and NbS, in terms of rent and selling prices of the surrounding buildings.

vii.	**Maintenance strategy**
It is necessary to provide for the cleaning and cutting of the herbaceous species present in the filter channel and on the shores of the vegetated area at least once a year and for cleaning of the draining channels.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Infiltration basin

i. NBS description

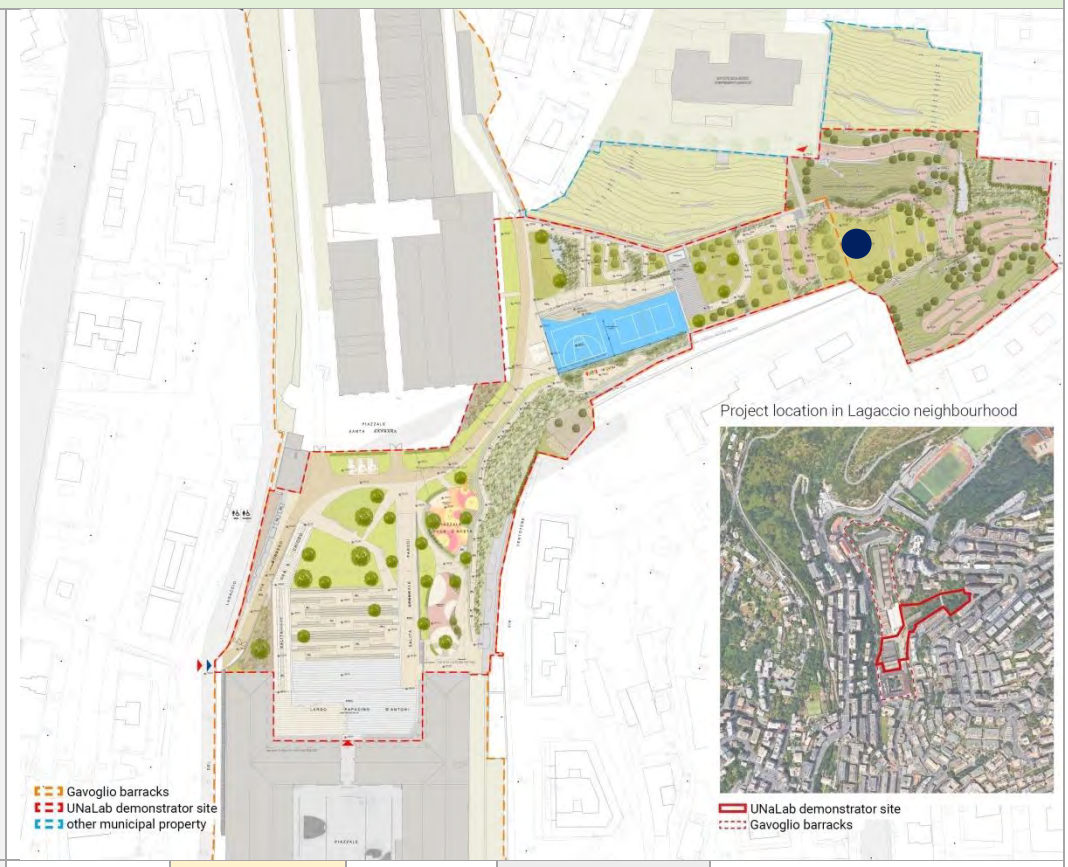
Infiltration basin is a vegetated depression designed to hold runoff from impervious surfaces, allow the settling of sediments and associated pollutants. Infiltration systems allow water runoff to infiltrate into the ground over a period of time, in order to reduce the volume of runoff during a rainfall event. The detention time is approximately 48/72 hours and the 50% of their storage volume must be disposed of within 24 hours. Infiltration basins is dry except in periods of heavy rainfall. Mix of *Festuca arudinacea* and *Cynodon dactilon* is used.

Construction works in Gavoglio Park, Genova

Construction works in Gavoglio Park, Genova

ii. Basic information

Location



Type[1]	1	2	3	Size	109 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality

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	X	X	X	X		
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
			X		X	X

iii. Specific challenges targeted

Genova is known as a high-risk area for flooding due to the amount of rain that falls on the city. The infiltration basin can help improve the infiltration of water into the ground and also reduce water runoff in the lower part of the city, since the park is located upstream.

Benefits:

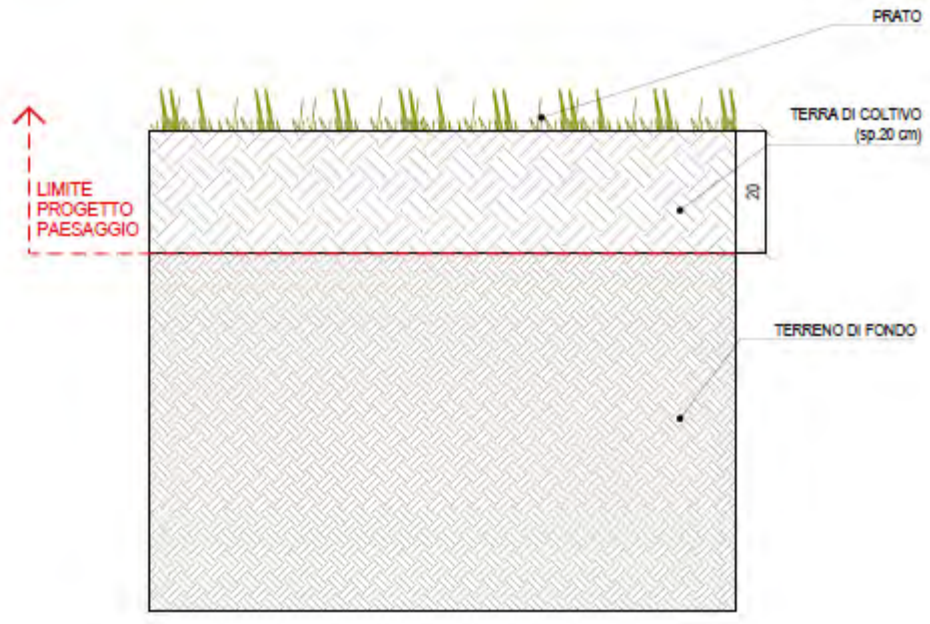
- stormwater management and control water retention and storage water infiltration water evapotranspiration water filtering
- reduced flood risk
- improvement of water quality
- improvement of amenity value
- water conveyance

Co Benefits

- soil management and quality
- biodiversity habitat provision for wildlife
- urban space development and regeneration
- urban space management

iv. Technical and design parameters

Above the rocky substrate there is the cultivation soil of average thickness of 20 cm. The seeds supplied must be of excellent quality, in original sealed packages and provided with a certificate of identity, indicating the level of purity and germinability and expiry date, and must be certified in accordance with the law. The mix of seeds can be modified according to the indications of the works management who will verify the results achieved during he works. If the seed mixture is not commercially available, it must be made by mixing the seeds divided by quality, and the percentages must be maintained as indicated.



v. Potential for replication and upscaling

The infiltration basin has the purpose of releasing the rainwater slowly into the ground.
It is an easily used solution to de-waterproof urban areas that are to be dedicated to public green spaces. A minimum surface is not necessary, even a small surface can constitute an intervention area.

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Increased access to urban public outdoor recreation space	Ratio of open spaces to build form / reclamation of contaminated land (brownfields) available for recreation purposes. Data from project in [m^2]
Green space management	Increased access to green space	Accessible urban green spaces. Data from project in [m^2]
Green space management	Increased area for pedestrians	Proportion of area devoted to roads and paths for pedestrian. Data from project in [%]
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Climate resilience	Increased carbon sequestration	Evaluation of carbon stored in the dry biomass of vegetation.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM10, PM2.5, NO2 and O3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O3, NO2, and PM2.5 capture/removal by vegetation	Analysis and comparison of the time series of PM10, PM2.5, NO2 and O3 concentration values recorded by low-cost sensor placed inside and

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

		nearby the NBS area. Comparison with the mean values of the town.
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation of the NBS within the area considering species richness (plants and birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and pollinator species richness compared with the starting point (before plantings).
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the costruction of Gavoglio Park and NbS, in terms of rent and selling prices of the surrounding buildings.

vii. Maintenance strategy

Regular mowing near infiltration basins is only necessary for a long time at the access routes for maintenance and the attractive areas (for example paths), between the embankments and in the main storage area.

The remaining areas can be managed as "lawn" or other appropriate vegetation, unless there are no other requests for aesthetic purposes. Grass cutting may be necessary to accommodate special grass rinds or special mixes according to the recommendations of the seed suppliers.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Bioswales

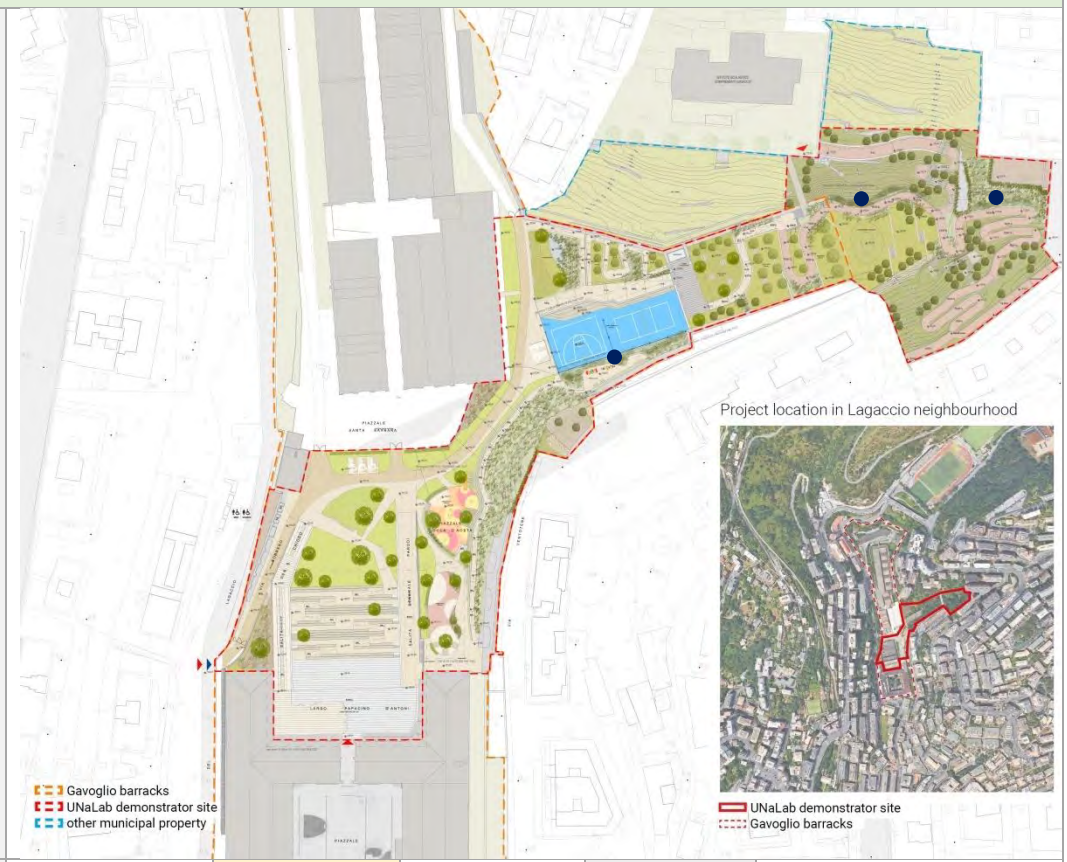
i. NBS description

Bioswale is a long-channelled depression, often established near the sport area and the east side of the park with the objective to reduce flood risk during or after heavy rain events. The intention of bioswales is comparable to rain gardens. Bioswales absorb, store and convey surface water runoff (mainly draining from roadways) and also remove pollutants and sediments, when the water trickles through the vegetation and soil layer. The bioswale has got a mix of *Carex appressa* 20%, *Echinacea purpurea* 30%, *Festuca mairei* 20%, *Iris laevigata* 30%, they will be planted with a density of 4/6/8 plants each square meter.

Thyssen Krupp Kindergarden, Essen (LAND)

ii. Basic information

Location



Type[1]	1	2	3	Size	123 m²

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X	X			X	X
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X		X		X	X

iii. Specific challenges targeted

A bioswale is one way to protect the land by flooding by decreasing stormwater runoff. It is a gently sloping vegetative swale designed to slow and reduce stormwater runoff while filtering out pollutants. Located near path can prevent them from becoming unusable during heavy rain events.

Benefits:

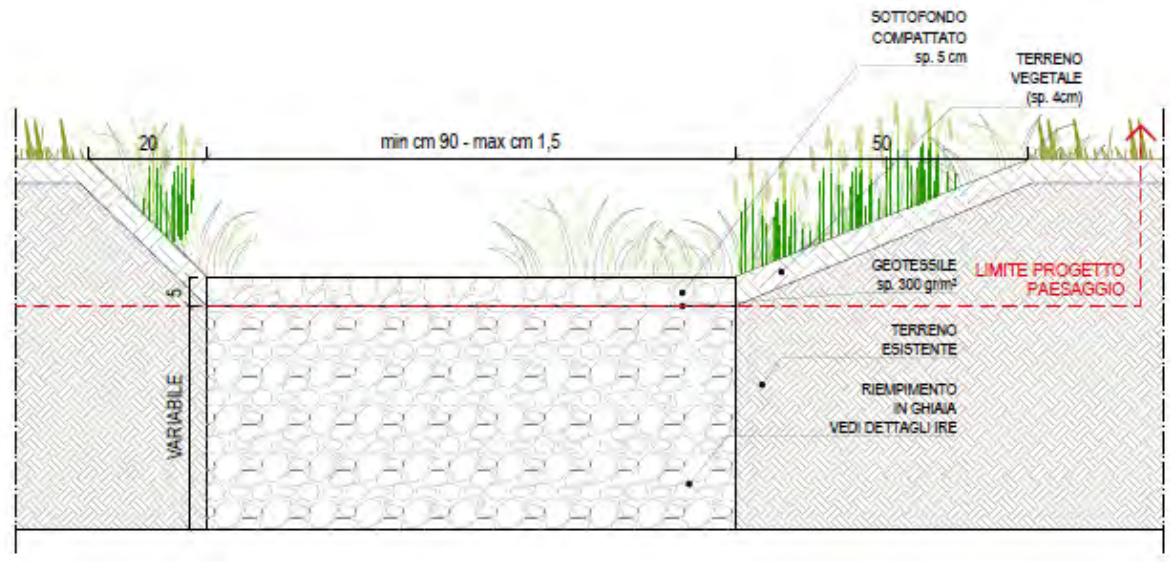
- Urban Water Management
- Flood Management
- Water conveyance
- Water infiltration

Co-benefits:

- Increase biodiversity
- Urban space development and regeneration
- Urban space management
- Soil management and quality

iv. Technical and design parameters

The bioswale has a variable width and a shallow depth, and hygrophilous vegetation in order to resist to temporary flooding. The bottom of the bioswale is covered with a 5 cm thick layer of marble pebbles, which facilitates the temporary flow of rainwater. A geotextile is laid between the pebble layer and the underlying soil.



v. Potential for replication and upscaling

The bioswales are particularly suitable for solving the drainage problems of sloping land typical of the Genoese and Ligurian territory. They are simple to make and relatively inexpensive, using natural materials and easily available on site. They also enhance the natural landscape and provide aesthetic benefits and biodiversity.

Positives
- discrete purification yields mainly due to mechanisms of filtration and absorption;
- groundwater recharge;
- poor maintenance.

Downsides
- low rolling capacity.

vi. Monitoring strategy

Challenge	Indicator	Details
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Climate resilience	Increased carbon sequestration	Evaluation of carbon stored in the dry biomass of vegetation.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation for the area and NBS evaluation of species richness (plants and birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and

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		pollinator species richness compared with the starting point (before plantings).
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the costruction of Gavoglio Park and NbS, in terms of rent and selling prices of the surrounding buildings.

vii.	Maintenance strategy
Swales require regular maintenance to ensure continued operation and maintain the standard of performance. The main intervention is mowing, which should ideally maintain a length of the grass a 75-150 mm to help filter pollutants and conserve sediments and to reduce the risk of flattening during runoff events.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Tree groups and green areas

i. NBS description

The group of trees creates an environment in summer which is similar to a small patch of forest in order to perform an adequate microclimate. Trees can form a closed canopy, and, in this way, they can cover the surface beneath them. The effect of tree groups and green areas are arranged depends on several factors such as the species that we use; The choice must follow criteria relating to climate resilience, functional compatibility, allergenic and toxic properties, high aesthetic and ecological value, favouring native species and ease of maintenance. *Cinnamomum camphora*, *Jacaranda mimosifolia*, *Schinus molle*, *Cercis siliquastrum* are ornamental trees used in these specific areas. A mix of *Ballota pseudodictamnus*, *Cistus x purpureo*, *Lavandula x intermedia 'Grosso'*, *Myrtus communis*, *Teucrium fruticans* and *Santolina* is used as herbaceous.

Parco Nord, Milano (LAND)

Adda Mallero Park, Sondrio (LAND)

ii. Basic information

Location

Type[1]	1	2	3	Size	2740 m^2

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X		X	X	X	X
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X			X	X	

iii. Specific challenges targeted

A large amount of green areas complemented by tall trees and shrubs helps regulate the local microclimate and increase the amount of permeable soil that can reduce runoff.
Benefits:

- Climate mitigation
- Climate adaptation
- Urban water management
- Improve air quality
- Increase biodiversity
- Urban space development and regeneration
- Soil management and quality

Co-benefit

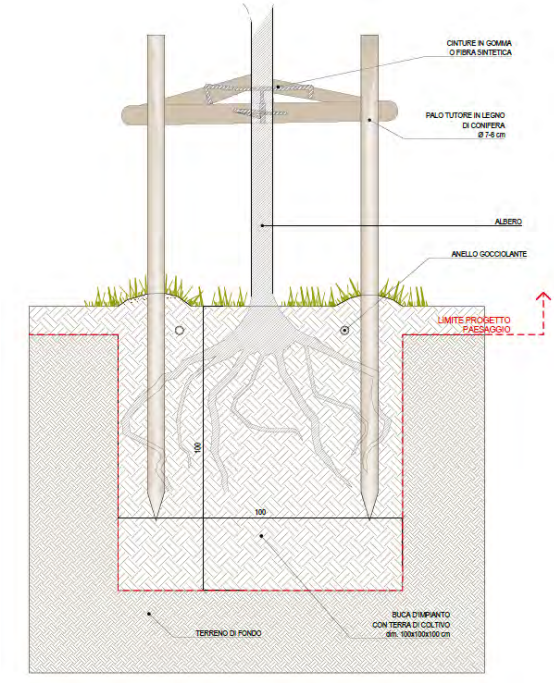
- Social cohesion

iv. Technical and design parameters

Plants should be brought to the site at the time of planting, andbe planted by species and size. Each plant should be placed in a prepared hole, with the root surrounded by soft ground. Deciduous plants can be planted only in the period of vegetative rest (from early autumn to spring, excluding frost periods).
If they are in containers, they can be transplanted in any period of the year, except during the summer (June-July-August).

After planting, each plant should be watered with:
- tree plants up to 200 cm in height: from 5 to 15 liters / day;
- trees over 200 cm tall: from 20 to 50 liters / day.

During winter periods, cold-sensitive plants will have to be covered with straw or branches. Furthermore, the large plants will have to be oriented with the same sun exposure they had in the origin site.



v. Potential for replication and upscaling

Urban forestry is the new environmental objective of many municipalities, to fight the climate crisis and create healthier places. Trees can mitigate the effects of water and air pollution, are able to contribute to the reduction of climate-altering gases, contain hydrogeological instability, produce material for industry and benefit health and the psyche of the inhabitants.

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Increased area for pedestrians	Proportion of area devoted to roads and paths for pedestrian. Data from project in [%]
Green space management	Increased access to urban public outdoor recreation space	Ratio of open spaces to build form / reclamation of contaminated land (brownfields) available for recreation purposes. Data from project in [m^2]
Green space management	Increased access to green space	Accessible urban green spaces. Data from project in [m^2]
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Climate resilience	Increased carbon sequestration	For tree only. Methods are also available for herbaceous species and consist in cuttings and weighing of dried plant biomass and the related carbon sequestration.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration

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		values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation for the area and NBS evaluation of species richness (plants and birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and pollinator species richness compared with the starting point (before plantings).
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the construction of Gavoglio Park and NBS, in terms of rent and selling prices of the surrounding buildings.

vii.	**Maintenance strategy**
Maintenance will be greater during the first years, when the tree is consolidating, they should involve regular inspections, removal of invasive vegetation and possibly irrigation during long periods of drought, especially in soils with high percentages of voids, because the roots some trees must make good contact between the root and the soil before they can efficiently mine water from the ground.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Drought-resilient orchard and meadows

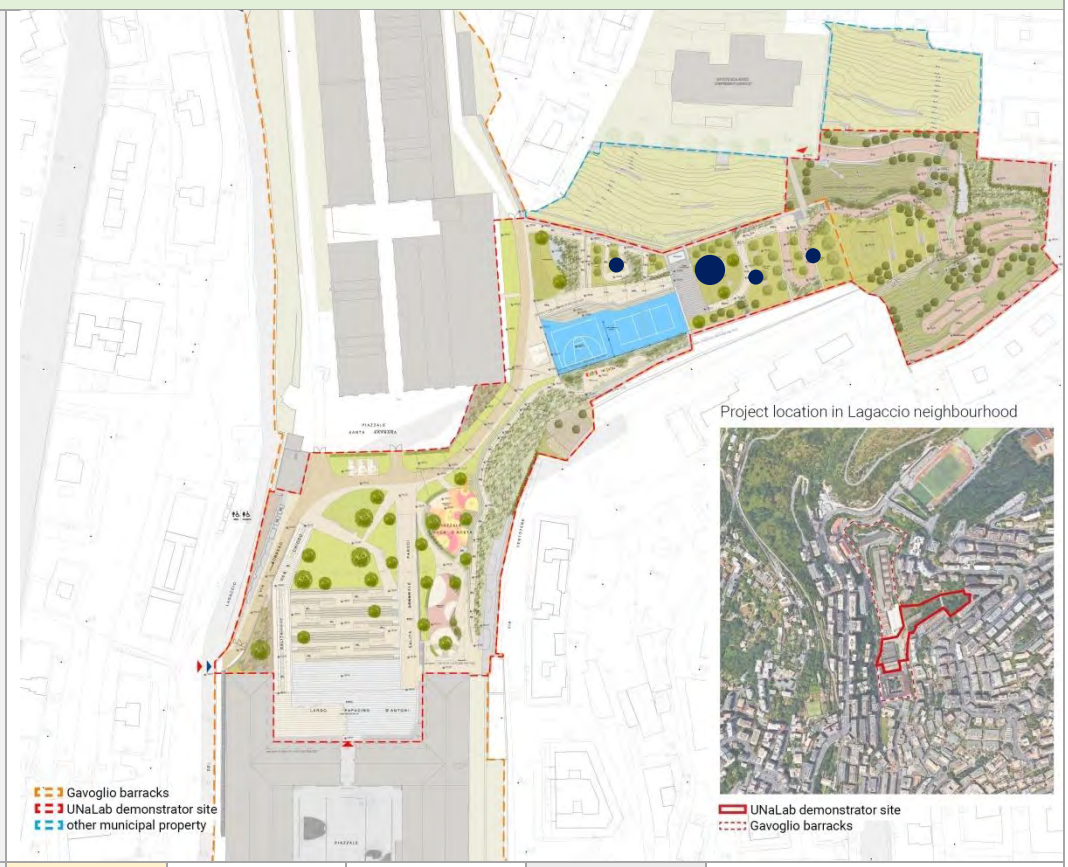
i. NBS description

Small plots will be used as cultivation area, making the management easier and using drip irrigation systems. Different fruit trees grow in these plots. It is considered a social/community space where people can stay with the nature and obtain its benefits. As a sort of preverdissment technique it could be used for temporary purposes. Grown trees were chosen for the orchard: *Arbutus unedo, Olea eurpaea, Punica granatum and Morus sp.*

Thyssen Krupp Kindergarden, Essen (LAND)

ii. Basic information

Location



Type[1]	1	2	3	Size	1568 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
				X	X	X

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X	X		X	X	X

iii. Specific challenges targeted

Orchards which have importance in terms of the sustainability of urban ecosystems are essential for the planning of the Mediterranean cities. Since the area where the park is located, the orchard helps to create an area of cohesion and social sharing.

Benefits:

- urban space development and regeneration
- urban space management
- soil management and quality
- quality of life health
- environmental justice
- social cohesion

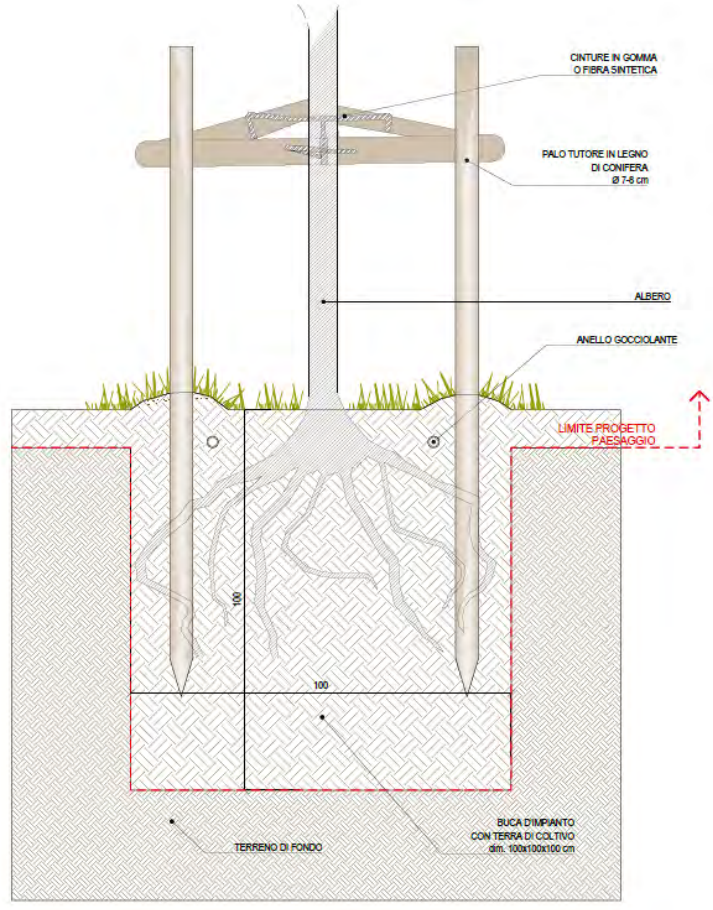
Co-benefit

- Climate Adaptation
- Flood management
- Increase biodiversity

iv. Technical and design parameters

An orchard with low irrigation and maintenance needs has been designed. In order to allow the usability of these areas, a system of ramps and terraces has been planned built by a system of gabions. The fruit trees are placed in a 100x100x100 cm hole filled with topsoil. The trees are structurally maintained by wooden supports that help to stabilize them: the stakes should be driven into the plant hole before planting to a depth of 50-80 cm, one stake if the plant is a shrub or tree less than 1.8 m and 2-3 stakes in other cases.

Since the orchard can be assimilated to an agricultural crop, denser planting distance (5x5 m) has been chosen.



v. Potential for replication and upscaling

The goal of urban orchards is the one called "tree to table", that is, the direct passage from tree to table, for a healthier diet and with economic repercussions in support of some of the most disadvantaged categories. But the intentions go much further, it is first of all to begin to give the green not only an aesthetic value but also a productive one, an aspect that had never been considered until now.

It can also be considered a social experiment, given that the urban public orchard was born as a shared space where citizens, usually from the neighbourhood, take care of the trees and / or shrubs directly from plantation to harvest, sometimes even going further with the management of cooking workshops. It is now common knowledge that working in a context of this type has therapeutic effects on the person, especially on those suffering from mental illness.

vi. Monitoring strategy

Challenge	Indicator	Details
Green space management	Increased area for pedestrians	Proportion of area devoted to roads and paths for pedestrian. Data from project in [%]
Green space management	Increased access to urban public outdoor recreation space	Ratio of open spaces to build form / reclamation of contaminated land (brownfields) available for recreation purposes. Data from project in [m^2]
Green space management	Increase in green and blue space	Availability and equitable distribution of blue-green space [m^2]
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Climate resilience	Increased carbon sequestration	For tree only. Methods are also available for herbaceous species and consist in cuttings and weighing of dried plant biomass and the related carbon sequestration.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation for the area and NBS evaluation of species richness (plants and birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and pollinator species richness compared with the starting point (before plantings).
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the construction of Gavoglio Park and NbS, in terms of rent and selling prices of the surrounding buildings.

vii. Maintenance strategy

Maintenance will be greater during the first years, when the tree is consolidating, they should involve regular inspections, removal of invasive vegetation and possibly irrigation during long periods of drought, especially in soils with high percentages of voids, because the roots some trees must make good contact between the root and the soil before they can efficiently mine water from the ground.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Slope afforestation

i. NBS description

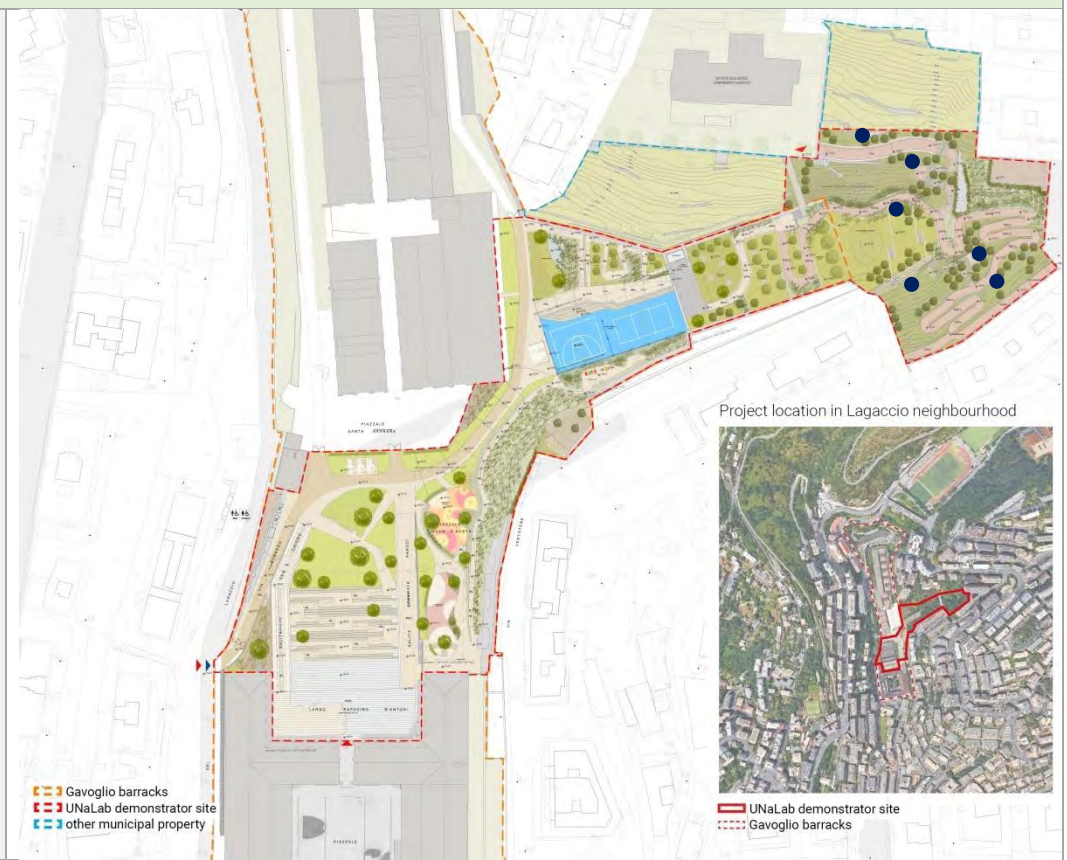
These are forestation actions on steep slopes devoid of vegetation. There will be an experimental use in some flat areas of biodegradable devices for irrigation efficiency. The structure ensures a quick consolidation effect of the gradings in instability. In fact, the wood can rot in a relatively short time, the rooting and the growth of cuttings and seedlings ensure, in the next phase, the slope stability. *Quercus crenata, Quercus ilex, Quercus pubescens, Quercus suber, Quercus cerris, Acer opifolium* are the species of forest trees, used for this purpose.

Parco delle Colline ex Burgo, Corsico

Bicocca district, Milano (LAND)

ii. Basic information

Location



Type[1]	1	2	3	Size	2013 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
			X	X	X	X

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X			X	X	

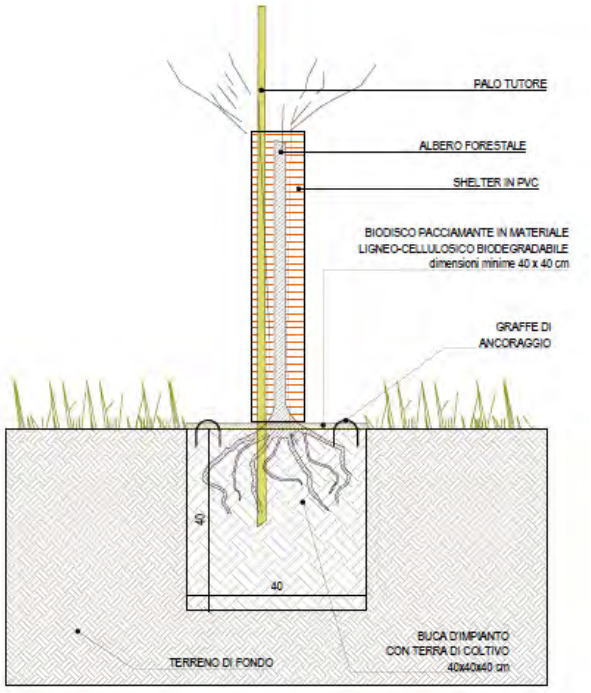
iii. Specific challenges targeted

Considering that the area in some spots has very steep slopes, the afforestation in those areas can help to stabilize them. The benefits of this action are:

- Increased resistance to prolonged periods of drought,
- slope stabilization,
- increase biodiversity

iv. Technical and design parameters

Species in the reforestation areas along the slopes will be provided as developed forest plants 120-150 cm high and trunk diameter 10-12 cm. A stem protection element called shelter will be introduced. This element will be made of polycarbonate. It will be placed around the stem of the forest plants, to protect them from small rodents, and will ensure protection to the plants in the first two years. It should also allow, with its colour, an easy identification of forest plants during mowing operations or any other work. Anchorage to the ground is provided using a bamboo pole or stick, while a mulching disc attached with metal clips ensures rooting. Finally, a collar is inserted at the base to protect the tree from damage during turf maintenance.



v. Potential for replication and upscaling

One of the typical aspects of the Ligurian landscape is the treatment of the hilly slopes to solve the problems due to the poor stability of the steep slopes. The solution adopted based on independent biodegradable devices for the efficient irrigation of seedlings is particularly suitable for solving similar problems typical of the area.
The anti-erosion coatings represent an ideal solution both from the point of view technical-functional and from the point of view of aesthetic-landscape integration and ecological intervention.
The realization of surface consolidation works using materials live plants in timber or other material (plantations, wickerwork or trellis, steps, piling, palisade, grates) have an environmental impact very small. In fact, their construction does not require earth movement significant capable of causing damage to vegetation or the ecosystem.

vi. Monitoring strategy

Challenge	Indicator	Details
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate,	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys,

	psychological wellbeing, social cohesion)	one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Climate resilience	Increased carbon sequestration	For tree only. Methods are also available for herbaceous species and consist in cuttings and weighing of dried plant biomass and the related carbon sequestration.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation for the area and NBS evaluation of species richness (plants and birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and pollinator species richness compared with the starting point (before plantings).
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the construction of Gavoglio Park and NBS, in terms of rent and selling prices of the surrounding buildings.

vii. Maintenance strategy

To ensure the effectiveness of this nature solution, it is essential to safeguard the health of forest trees by pruning annually, fertilising developed specimens in the spring before the start of growth again, suckering, and replacing deadwood.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Green wall

i. NBS description

A green wall consists of a vine that can climb a structure on its own. The plants should be planted on the bottom of the wall and grow versus the top of the structure. The main purpose is landscape mitigation, air quality improvement, and local noise reduction, intervening along existing and new wall faces. A mix of *Hedera hibernica* and *Hedera helix* 50% is used on the green wall of the park.

HQ Diesel, Breganze (LAND)

ii. Basic information

Location

Type[1]	1	2	3	Size	154 m^2

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
				X	X	X
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X				X	

iii. Specific challenges targeted

The green wall is used especially as a visual impact mitigation, in order to visually hide the existing wall.
Benefits:

- Climate mitigation
- Climate adaptation
- Quality of life

Co-benefits:

- Air quality
- Biodiversity
- Urban space regeneration

iv. Technical and design parameters

The creepers are attached to walls and walls and fastened to these surfaces by means of metal rings and wire (or jute if available) combined with each other. An exception is the support system of the green wall under via Ventotene, which consists of a metal structure made ad hoc to cover the consolidation of the landslide.
The young branches (1-2 years old) are wrapped with elastic, which is itself knotted to the ring inserted into the wall face, to guide their growth during the first few years.

v. Potential for replication and upscaling

Given the scarcity of territory, using vertical walls to establish plants and climbing greenery can be a valid alternative. The green walls can also be used to cover the retaining walls made of reinforced concrete that characterize many urban and suburban areas.

vi. Monitoring strategy

Challenge	Indicator	Details
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Total amount and percentage of water (per unit surface area) retained in laboratory testing of the design stratigraphy in a dedicated test plot where artificial rain events of selected magnitude are simulated.
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings)
Biodiversity enhancement	Biodiversity increase (Shannon Diversity Index)	Overall evaluation for the area and NBS evaluation of species richness (plants and

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		birds) respect to the starting point (before plantings).
Biodiversity enhancement	Increase of pollinator insects	Overall evaluation for the area on the number of pollinators sampled and pollinator species richness compared with insects respect to the starting point (before plantings).
Climate resilience	Increased carbon sequestration	For tree only. Methods are also available for herbaceous species and consist in cuttings and weighing of dried plant biomass and the related carbon sequestration.
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the construction of Gavoglio Park and NBS, in terms of rent and selling prices of the surrounding buildings.
vii. Maintenance strategy		
Climbing plants are to be pruned if the vegetation surface becomes too large and fallers are to be replaced if they dry out; the plants are indeed to be fertilised twice a year, and sanitary treatments are to be carried out only if necessary, where physical and/or biological treatments cannot be used.		

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Natural engineering for slope securing

i. NBS description

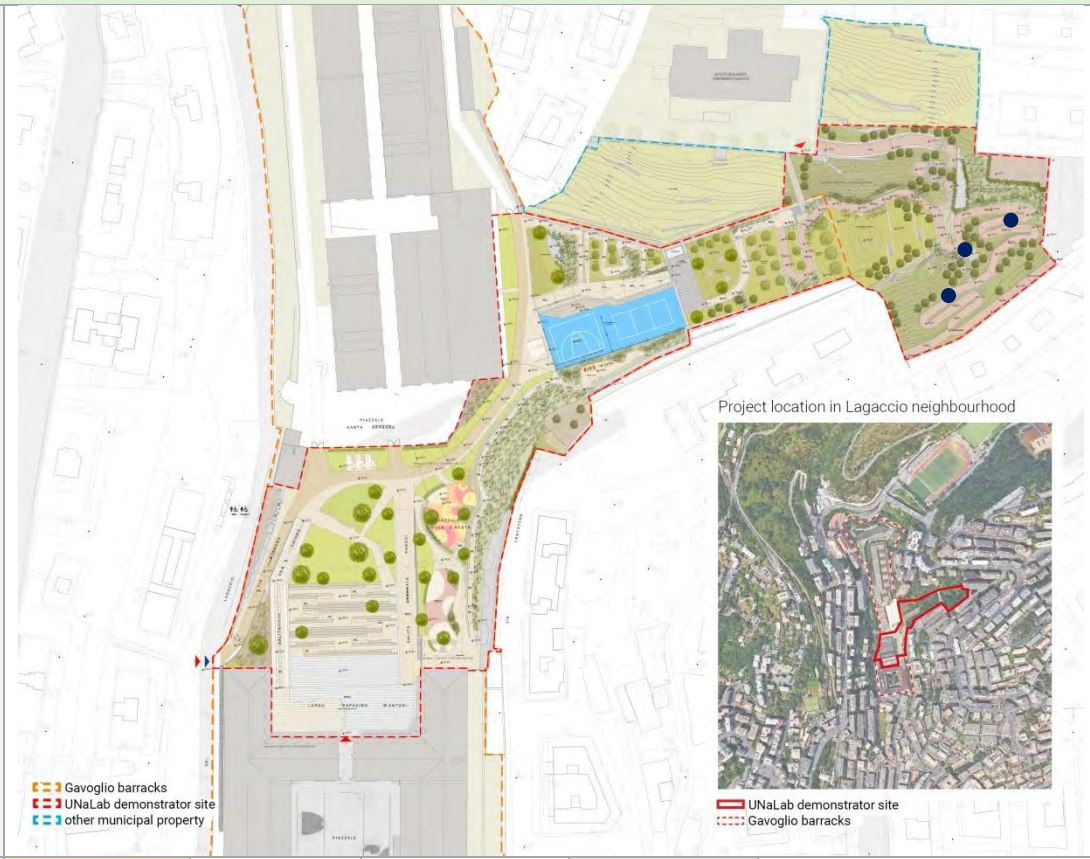
Log crib walls are retaining walls constructed with wooden logs to secure slopes against sliding and to hold up paths. The main structure is made by using chestnut timber forming a like-wall framework, then willow live cuttings are planted into the structure to have an additional reinforcement when roots gradually take over.

Parco del Lura, Milano (LAND)

Parco dell'acqua, Arcore (LAND)

ii. Basic information

Location



Type[1]	1	2	3	Size	1.255 m^3	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
			X		X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X					

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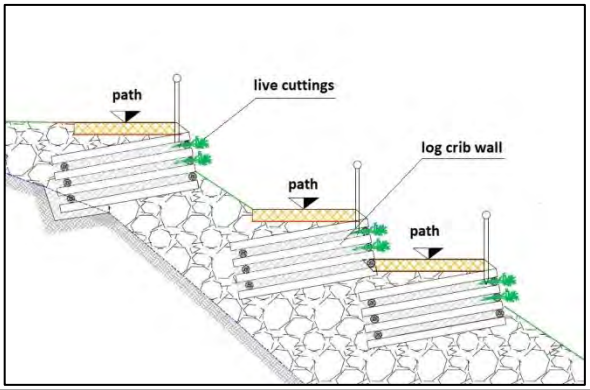
iii. Specific challenges targeted

In the upper part of the demo area there are very steep slopes and we need to create a path to reconnect the park to the district. Vegetative log crib wall is a natural based solution to sustain the path along the slope.

iv. Technical and design parameters

Logs are placed horizontally to form an angle of 10° towards the slope to increase stability. Once timbers are laid horizontally at the base of the slope in longitudinal direction, these are fixed in position by nailing sharpened interlocking elements running back into the slope. Parallel and transversal elements are 20 cm chestnut logs.



v. Potential for replication and upscaling

Natural engineering for slope securing is used to replace the use of concrete walls in applications such as underground walls, bridge abutments, noise barriers and masking works, and is particularly suitable for the Ligurian territory. A stabilization system of the embankments is used through the use of metal meshes.

Aesthetic and natural, it's also an economic solution by using on-site fill material and timber. Not adapted when big soil volumes need to be stabilized and not intended to resist large, lateral earth stresses.

vi. Monitoring strategy

Challenge	Indicator	Details
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Health and wellbeing	Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	Overall evaluation of the effects of NBS on citizen wellbeing. The assessment will rely on the collection of data by means of two surveys, one regarding NBS perception and ecosystem services and one specific on the Gavoglio park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Water management	Increased evapotranspiration	Amount of water evaporated from soils of transpired by plants respect to the starting condition (before plantings).
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration

		values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O_3, NO_2, and $PM_{2.5}$ capture/removal by vegetation	Analysis and comparison of the time series of PM_{10}, $PM_{2.5}$, NO_2 and O_3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
New economic opportunities and green jobs	Real estate value increase of buildings	Overall evaluation of the real estate value increase due to the construction of Gavoglio Park and NbS, in terms of rent and selling prices of the surrounding buildings.

vii.	**Maintenance strategy**

Maintenance does not involve much effort:

- Every year thin out weeds and cut the planted essences to allow the roots to branch at the base.
- Twice a year verify log crib alignment and nails between logs.

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

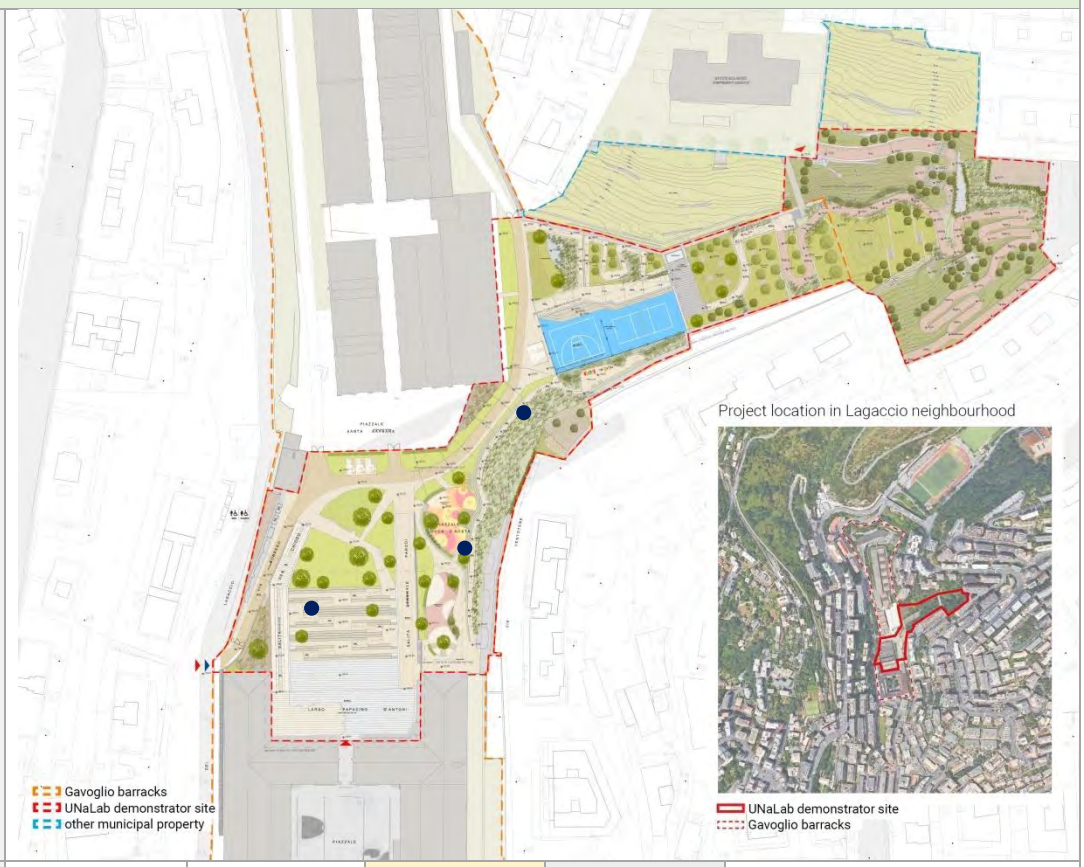
Gabions

i. NBS description

Gabions are steel cages filled with debris and rocks that allow to create retaining walls by reusing construction site debris and sustainable materials. Some gabions are completed with a vegetative task, to increase biodiversity and reduce heat stress, others are completed with stone top to create benches for public spaces.

ii. Basic information

Location



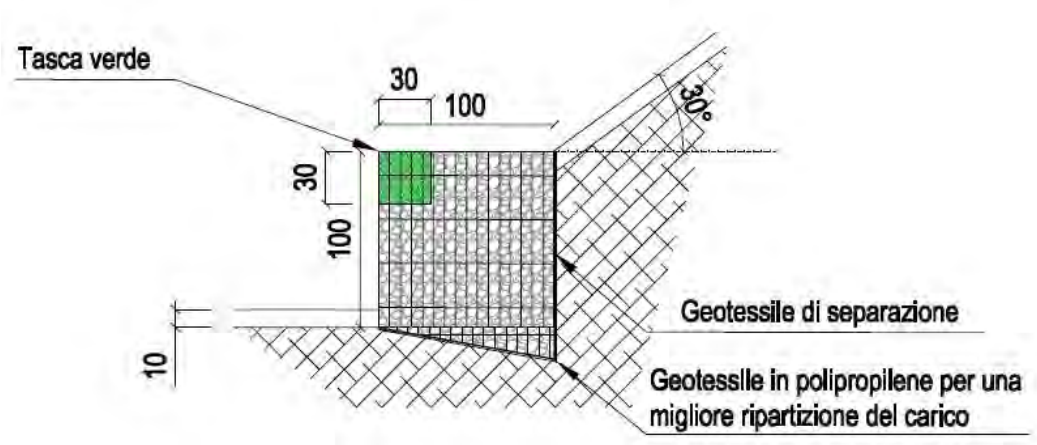
Type[1]	1	2	3	Size	1226 m^3	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X		X			
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
	X	X				X

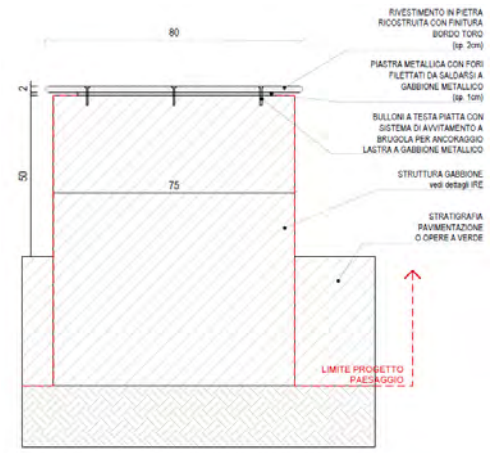
iii. Specific challenges targeted

Green gabions minimize the visual impact of the landslide under via Ventotene and reduce the heat stress of the concrete big wall. A lot of debris from the building demolitions can be reused in the gabions and the central stepped square becomes a recreational public space for the neighbourhood.

iv. Technical and design parameters

Gabions can be assembled, filled and vibrated in site with debris from building demolitions, adequately shattered and sifted. The filling must be done gradually, by 25-30 cm layers. Geotextile must be placed under the gabions for a better loadings distribution and behind them for draining and soil retaining. The finest sifted part is used to make a base filling. Adjacent units are joined to one another by lacing wires.





v. Potential for replication and upscaling

Liguria is characterized by the use of dry-stone walls for the construction of the typical hill terraces. These dry-stone walls have a very high construction cost. The "gabion" technique solves this problem in many cases, allowing the construction of structures similar to those of dry-stone walls but with much lower times and costs. Metal gabions are cubic and modular structures and are typically made of electro-welded or double-twisted mesh with zinc, zinc / aluminum or zinc and PVC cover. The meshes can be square or rectangular, while the metal wires have a diameter that usually varies between 4 and 5 mm. During the installation phase these gabions are filled with suitable stones.

Among the fundamental characteristics of gabions we find:

- Flexibility and drainage capacity such as to minimize the risk of landslides in silt-clayey and water-rich soils, allowing the flow of water itself and at the same time containing the soil.
- Solidity and resistance. The electro-welded mesh makes them suitable for forming high-height and self-supporting structures. Furthermore, they do not undergo deformations, thus reducing the problems due to the unevenness of the ground and natural walls.
- They have a high capacity to absorb mechanical stresses.

European Commission

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Gabions form flexible, permeable, monolithic structures that can be filled with buildings debris or on-site rocks and stones. They can be easily vegetated to blend into the natural environment. Gabions work as a gravity wall, they have bigger dimensions than concrete wall.

vi. Monitoring strategy

Challenge	Indicator	Details
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Infiltration	Infiltration capacity in [m/s]. Estimation from project
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Ability to retain a specific volume of rainwater. Estimation from project [m3]
Water management	Irrigation demand	Water exploitation [l/day]
Climate resilience	Reduction in Urban Heat Island effect	Analysis and comparison of the time series of T and R.H. values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Concentration of PM10, PM2.5, NO2 and O3 in ambient air	Analysis and comparison of the time series of PM10, PM2.5, NO2 and O3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Air quality	Annual O3, NO2, and PM2.5 capture/removal by vegetation	Analysis and comparison of the time series of PM10, PM2.5, NO2 and O3 concentration values recorded by low-cost sensor placed inside and nearby the NBS area. Comparison with the mean values of the town.
Material reuse	Demolition materials reused on site	Volume of material reused on site [m^3]

vii. Maintenance strategy

Gabions are structures that do not require special maintenance:

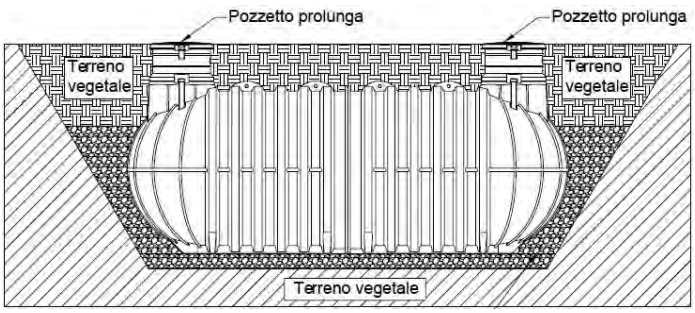
- Every year verify retaining wall stability
- Twice a year thin out weeds from vegetative tasks
- Twice a year look for damaged component of gabions and their topping

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Underground water retention basin

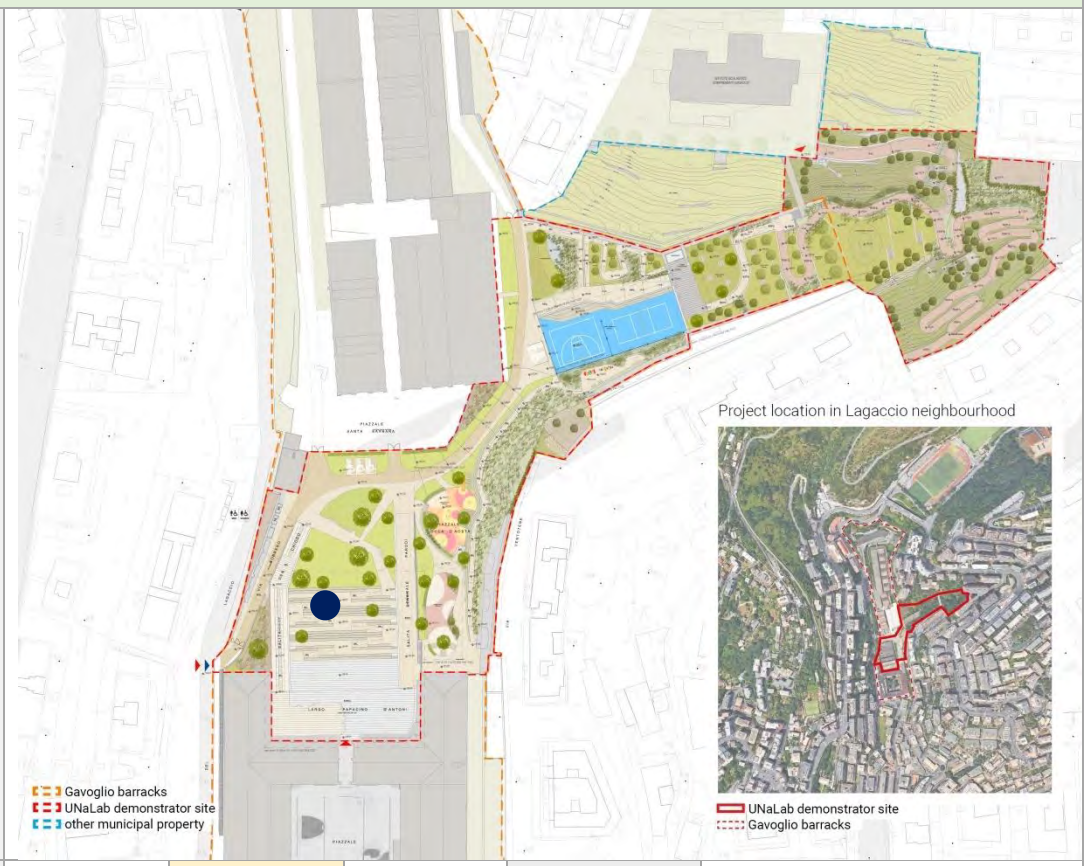
i. NBS description

An underground water retention basin can manage excess stormwater runoff in an urban setting where there is insufficient space on the site to infiltrate it.



ii. Basic information

Location



Type[1]	1	2	3	Size	30 m^3	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X				
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

iii. Specific challenges targeted

The underground water retention basin improves the water management of the park for the green area irrigation. It receives water from an existent spring and from some drainage pipes or from the public aqueduct if necessary.

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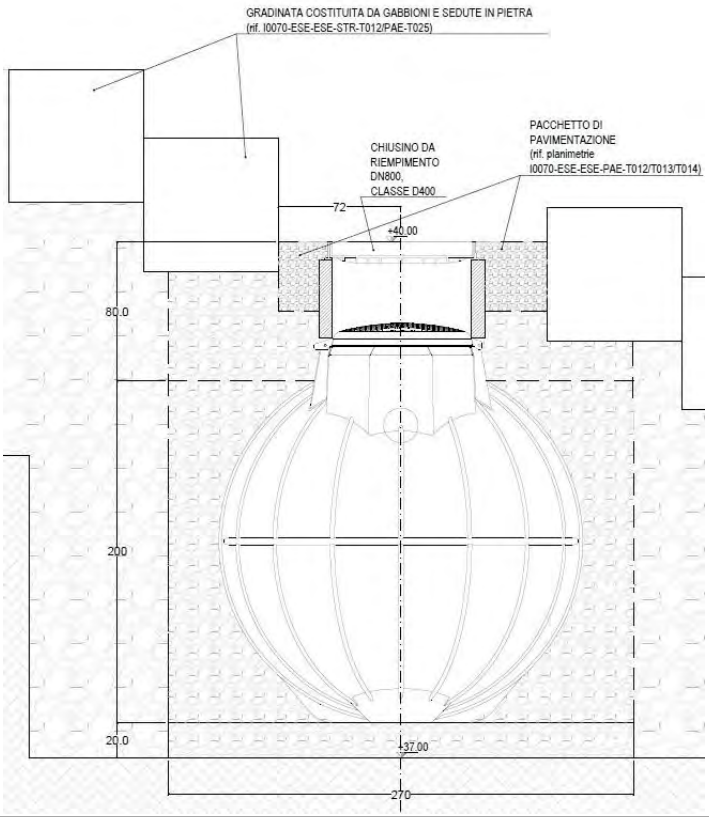
iv. Technical and design parameters

The tank must be positioned on a flat stable surface, with a 15-20 cm gravel bed. The tank and the dig must be filled together, step by step. Upon it there are two manholes, properly embedded in the draining pavement to sustain the load, for inspection, maintenance and cleanings. A pump station in the tank inlet and outlet pipes provide water to the irrigation system.



v. Potential for replication and upscaling

The increasingly frequent occurrence of very intense meteoric events that alternate with periods of drought makes it useful to collect and recycle rainwater systems to reduce, on the one hand, the run-off phenomenon and on the other the use of drinking water for non-human uses.

There are many underground water retention basins available, different for type, destination and dimensions. The tank needs a pump station to work.

vi. Monitoring strategy

Challenge	Indicator	Details
Water management	Reduced stormwater runoff	Run-off reduction in relation to surface material and slope.
Water management	Increased stormwater retention	Total amount and percentage of water (per unit surface area) retained in laboratory testing of the design stratigraphy in a dedicated test plot where artificial rain events of selected magnitude are simulated.
Participatory planning and governance	Active involvement of citizens	Overall evaluation of the effects of NBS on citizen wellbeing, by means of qualitative and quantitative data on NBS perception and ecosystem services and on the Gavoglio Park.
Water management	Daily water volume collected	Volume of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.
Water management	Water used for irrigation	Total volume and annual percentage of rainwater that can be collected from the installed NBSs and made available for irrigation purposes in the area.

vii.	Maintenance strategy

The water retention basin is the only engineering construction in the area, and therefore requires more specific maintenance:

- Twice a year inspect the tank, if there are sediments in it, remove them and clean it
- Twice a year check that all the pipes connected to the tank are watertight and not obstructed.
- Twice a year check the pump functioning

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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11.3 NBS and supporting measures in Tampere

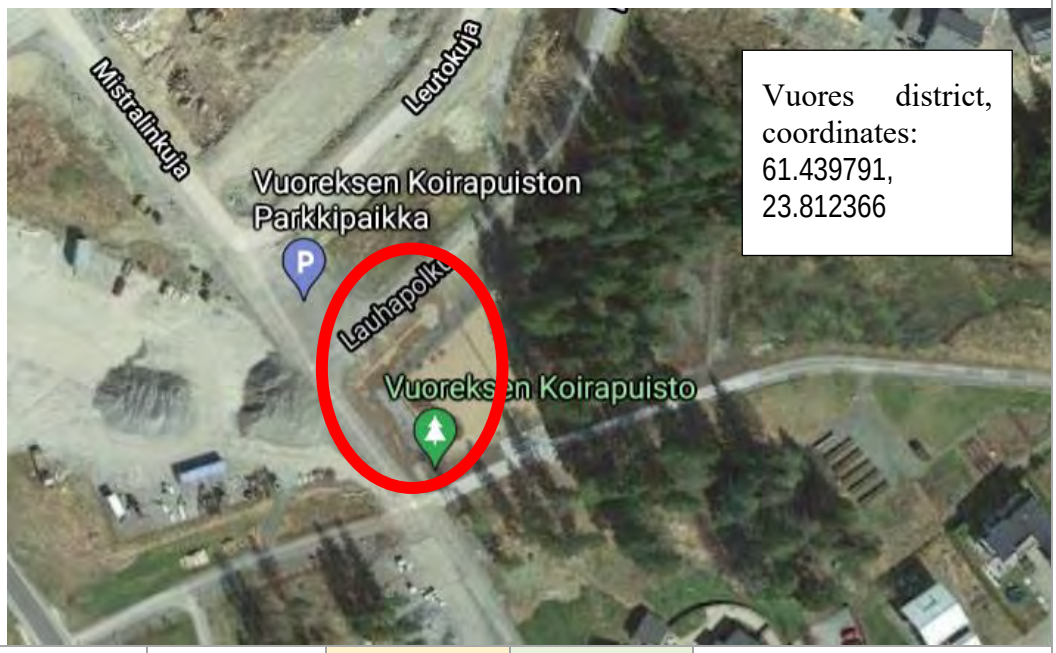
Biofilter in Vuores

i. NBS description

Biofilter (with sand as a filtering media) is implemented to treat urban run-off and run-off from a dog park. Vegetation planted on top of the filter includes plants that tolerate changing moisture conditions (Finnish "alluvial meadow" seed mix and bushes: *Salix repens, Physocarpus opulifolius*). NBS is equipped with the sign explaining the NBS and its functions.

ii. Basic information

Location



Type	1	2	3	Size	ca. 200 m^2	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		X			X	

iii. Specific challenges targeted

Water quality (urban run-off & dog park impact), green space management

iv. Technical and design parameters

Biofilter's catchment area is ca. 3,5 ha. Catchment is new development area consisting mostly of small detached apartment houses and streets. Catchment's TIA is roughly 1,4 ha. Biofilter receives some surface runoff from the small dog park next to it too.

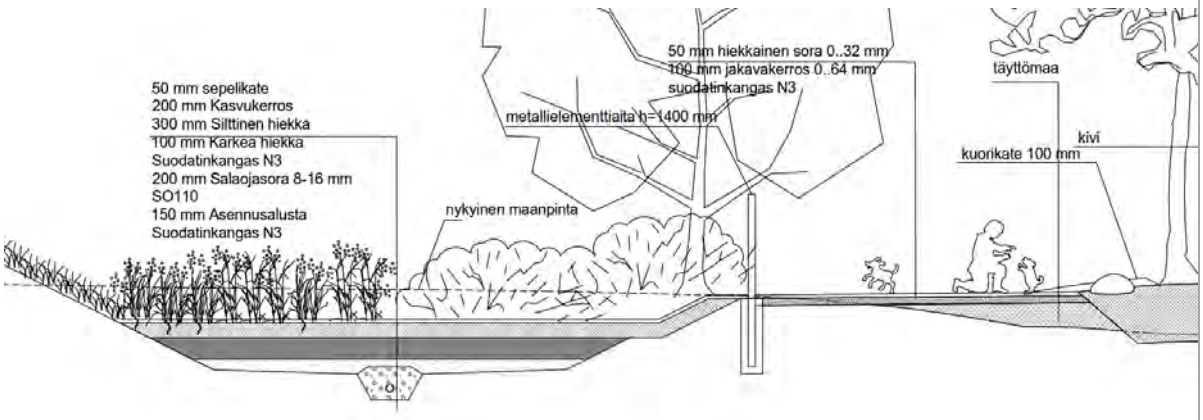
Catchment's streets are drained with conventional separated system pipe drainage. Houses are equipped with stormwater retention systems for rooftop and yard drainage.

Biofilter area is just under 300 m^2, about 2 % of its catchment's TIA. Filter's vegetation consists of a sown mixture of domestic wild alluvial meadow plants.

Biofilter has a total of 600 mm of filtrating layers, consisting of

- 200 mm layer of growth medium
- 300 mm layer of loamy sand
- 100 mm layer of coarse sand

Underneath the filtration layers is a perforated underdrain pipe. The biofilter has an overflow through an elevated manhole attached to a stormwater pipe. Underdrain is also connected to this system.



v. Potential for replication and upscaling

Results from Tampere and other studies show that, in many cases, sand-based biofiltration is a cost-efficient solution for storm water purification. Since the performance is not only based on vegetation, filters also function in Nordic climate. Sand-based biofilter is effective in phosphorus, suspended solids and pathogen removal but does not retain nitrogen. If the removal of nitrogen is important for watercourses downstream of the runoff site, biochar or expanded clay aggregate can be used as filtering material. Also, with the suitable selection of vegetation, it should be possible to enhance the removal of nitrogen. There is an uncertainty related to biofilter's life cycle. It is dependent on at least the quality and quantity of water channeled into the filtration area and the filtering materials used. If runoff contains plenty of suspended solids, it is recommended to build a retention pond for pre-treatment. This can prolong the life cycle of the biofilter. However, the phosphorus removal seem to decline after five years of use and needs to be enhanced in sand-based filters. With a large drainage basin and therefore large amounts of water, the capacity of the biofilter needs to be sufficient or, alternatively, multiple solutions need to be used. Biofiltration solutions can be replicated in areas where problems with the quality of storm water runoff have been identified. Tampere is planning biofilter to Nekala, which will treat runoff from the industrial area, railway yard and Lempääläntie road. Storm water from these areas burden the Vihioja stream as it occasionally contains hydrocarbons and glycol.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project

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Climate resilience	Total amount of carbon stored in vegetation	Calculations by the end of the project
Climate resilience	Mean or peak daytime local temperatures	Weather station of Vuores district Data collection every 10 min
Water management	Flood peak height	Automated continuous data collection at the end of the Vuores NBS for storm water management using a data logger Data collection frequency once/15 mins
Water management	Time to flood peak/Peak discharge	Automated continuous data collection at the end of the Vuores NBS for storm water management using a data logger Data collection frequency once/15 mins
Water management	Runoff in relation to precipitation quantity	Precipitation monitoring in Vuores district Data collection every 1 min
Water management	Nitrogen and phosphorus	P determined based automatic turbidity measurement N determined based on continuous nitrate monitoring Data collection every 15 min.
Water management	Basic water quality: flow, pH, temperature, EC, turbidity	Automated continuous data collection using a data logger Data collection frequency once/15 mins
Water management	Total suspended solids	Manual sampling in Vuores Virolaistenoja monitoring station monthly/based on need/changes in NBS performance
Biodiversity enhancement	Increase in suitable habitat for selected pollinator and plant species + Shannon Diversity Index	Field surveys Data collection frequency 1-2 time/year
Green space management	Distribution of public green space	Modelling
Green space management	Accessibility of urban green spaces	Modelling/one time survey in Vuores in Spring 2020
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	One time survey in Vuores in Spring 2020
Health and well-being	Encouraging a healthy lifestyle	One time survey in Vuores in Spring 2020

vii. Maintenance strategy

- Comprehensive maintenance is done to ensure optimal performance of the NBS
- Maintenance card/plan is done
- Cutting the vegetation will be done once a year in late summer
- Inspections of underdrains/manholes (grey infra related to the NBS) once a year
- Flushing of underdrains every 5 years
- Inspection of sedimentation on top of the filter once a year. When sediment thickness is more than 10 cm, it is removed purification performance is monitored (when there is enough water coming in) twice a year

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

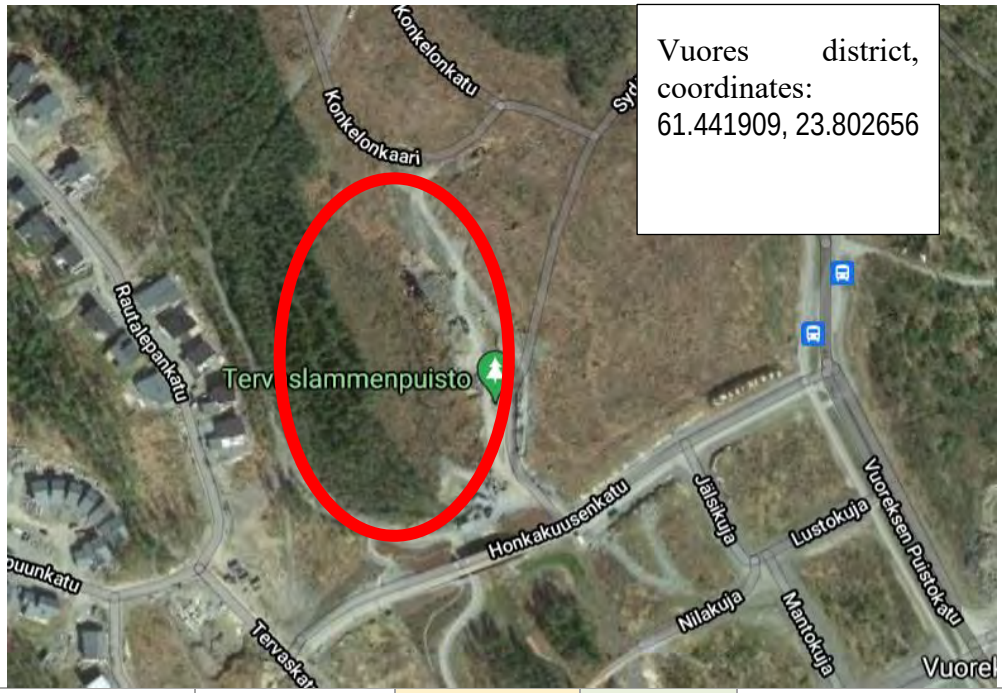
Retention pond

i. NBS description

Treatment (retention and sedimentation) of urban run-off from new housing around Tervaslampi park. To complement the Vuores area measures for enhanced stormwater quality and quantity management. NBS is equipped with the sign explaining the NBS and its functions.

ii. Basic information

Location



Type	1	2	3	Size	ca. 250 m^2	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

		X			X	

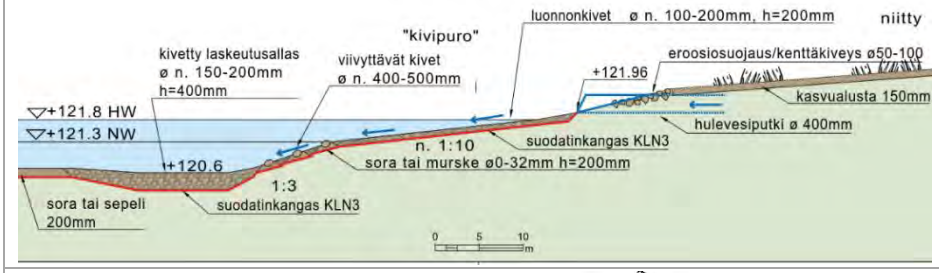
iii. Specific challenges targeted

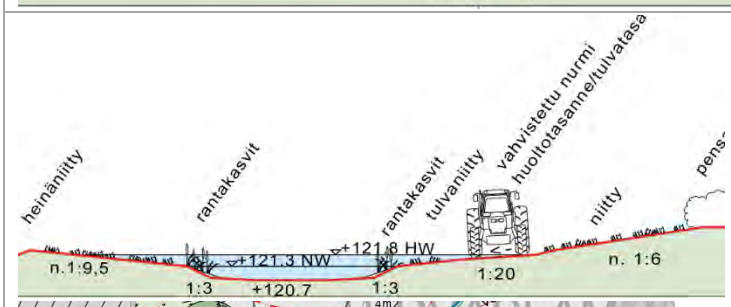
Water quality, flooding, climate resilience

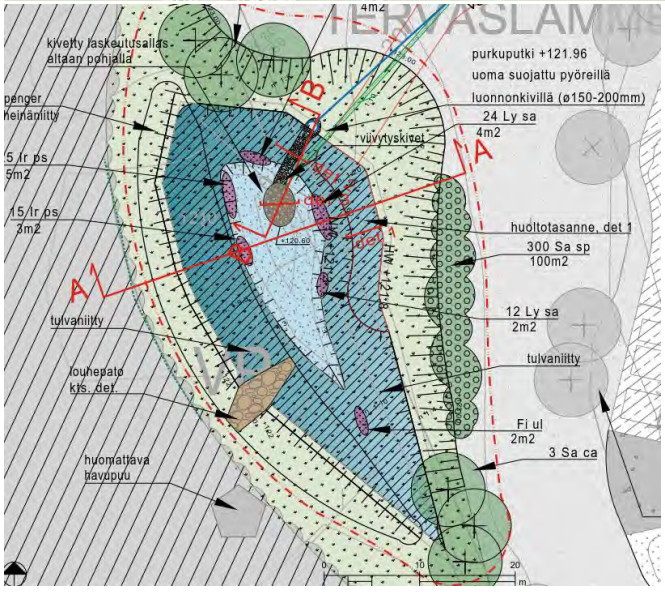
iv. Technical and design parameters

Retention pond's water area varies from ca. 150 m² to ca. 690 m² depending on the water level. It receives stormwater from a newly built housing estate through a stormwater pipeline. The pond has been formed on a formerly marshy area, that has been partially filled with crushed rock, by building an embankment out of moraine. Water exits the pond by infiltration and filtration through the moraine embankment. There is a stone covered overflow route over the embankment for heavy storm events.

Normal water elevation in the pond is +121,3 and maximum flood elevation is +121,8. Normal water level is maintained by high ground water levels in the remaining marshy area. The retention pond is surrounded by alluvial meadows, which get covered under flood during rain events.







v. Potential for replication and upscaling

Retention ponds can be replicated in urban areas for improvement water quality and prevention of floods. Retention ponds enable reuse of stormwater for irrigation. When complemented with sand filter ponds function effectively for treatment of runoff from construction sites. This is a typical solution used in construction sites in Tampere but in some cases sizing has been too small for effective sedimentation. Retention ponds need space for effective sedimentation. In Vuores some residents have been worried of possible drowning risk for children since retention ponds retain stormwater continuously. Also there have been worries related to mosquitos and flooding of stormwater to cellars when located close to housing. In Tampere retention ponds are replicated to new residential areas like Ojala but are designed with lower permanent water level.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
Climate resilience	Total amount of carbon stored in vegetation	Calculations by the end of the project
Climate resilience	Mean or peak daytime local temperatures	Weather station of Vuores district Data collection every 10 min
Water management	Flood peak height	Automated continuous data collection at the end of the Vuores NBS for storm water management using a data logger Data collection frequency once/15 mins
Water management	Time to flood peak/Peak discharge	Automated continuous data collection at the end of the Vuores NBS for storm water management using a data logger Data collection frequency once/15 mins
Water management	Runoff in relation to precipitation quantity	Precipitation monitoring in Vuores district Data collection every 1 min
Water management	Nitrogen and phosphorus	P determined based automatic turbidity measurement N determined based on continuous nitrate monitoring Data collection every 15 min.
Water management	Basic water quality: flow, pH, temperature, EC, turbidity	Automated continuous data collection using a data logger Data collection frequency once/15 mins
Water management	Total suspended solids	Manual sampling in Vuores Virolaistenoja monitoring station monthly/based on need/changes in NBS performance
Biodiversity enhancement	Increase in suitable habitat for selected pollinator and plant species + Shannon Diversity Index	Field surveys Data collection frequency 1-2 time/year
Green space management	Distribution of public green space	Modelling
Green space management	Accessibility of urban green spaces	Modelling/one time survey in Vuores in Spring 2020
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	One time survey in Vuores in Spring 2020
Health and well-being	Encouraging a healthy lifestyle	One time survey in Vuores in Spring 2020

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

vii.	Maintenance strategy
	• comprehensive maintenance is done to ensure optimal performance of the NBS • no maintenance card yet, but we are going to make one based on the maintenance plans/cards in central park Vuores • Inspection of sedimentation once a year. When sediment thickness is more than 10 cm, it is removed in dry season • Inspection of pipes once a year in spring

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

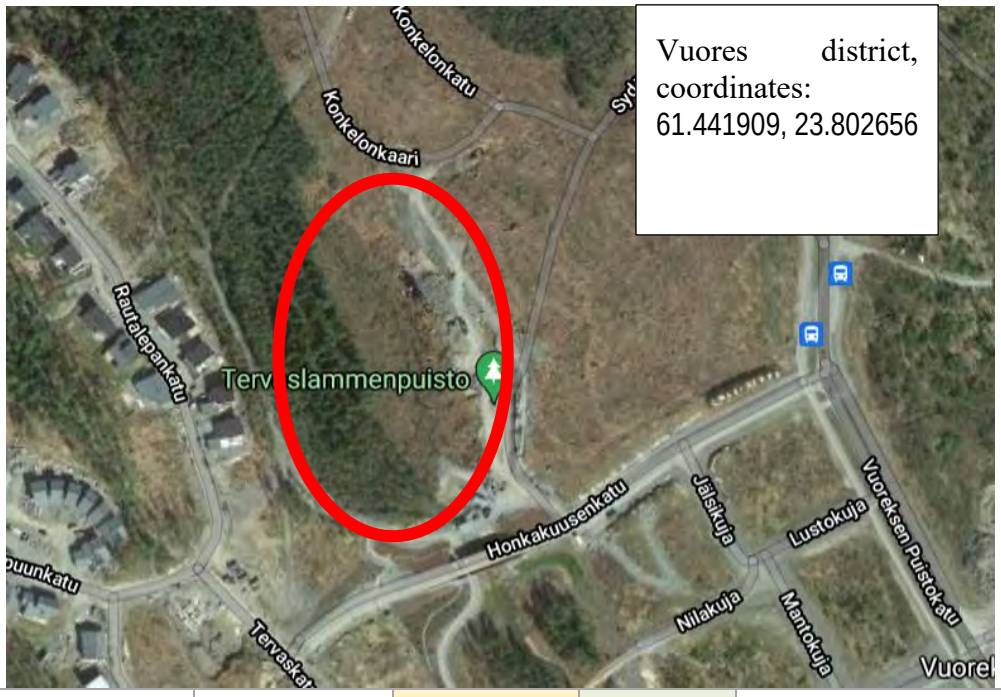
Alluvial meadows

i. NBS description

Space for retention of the urban run-off in the times of heavy rain. Most of the times meadows are without water. Biodiversity is taken into account in selection of vegetation (Finnish "alluvial meadow" seed mix and "meadow hay" mix; perennials suitable for wet area *Filipendula ulmaria, Iris pseudacorus, Lythrum salicaria, Myositis scorpioides*). Around the alluvial meadow trees (*Alnus clutinosa, Salic caprea*) and bushes (*Salix purpurea*) are planted. To complement the Vuores area measures for enhanced stormwater quality and quantity management. NBS is equipped with the sign explaining the NBS and its functions.

ii. Basic information

Location



Vuores district, coordinates: 61.441909, 23.802656

Type	1	2	3	Size	ca. 500 m^2	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

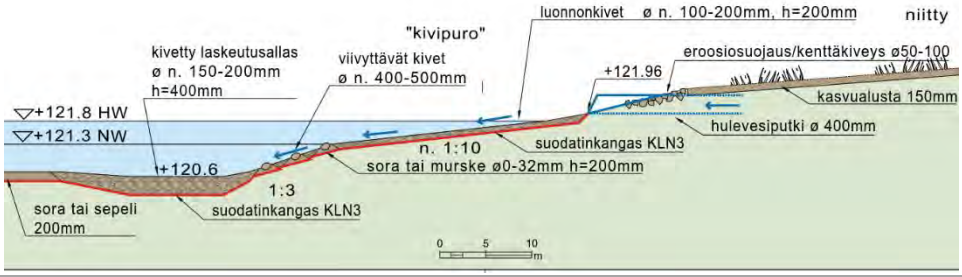
		X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		X			X	

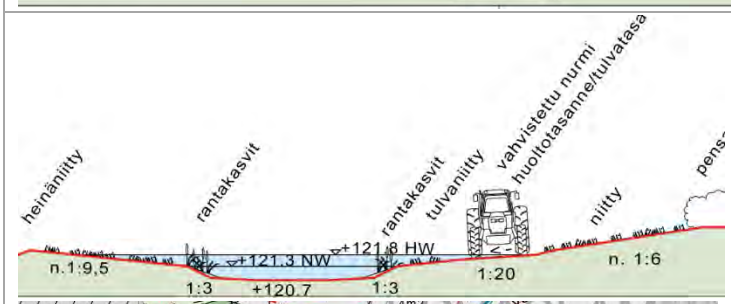
iii. Specific challenges targeted

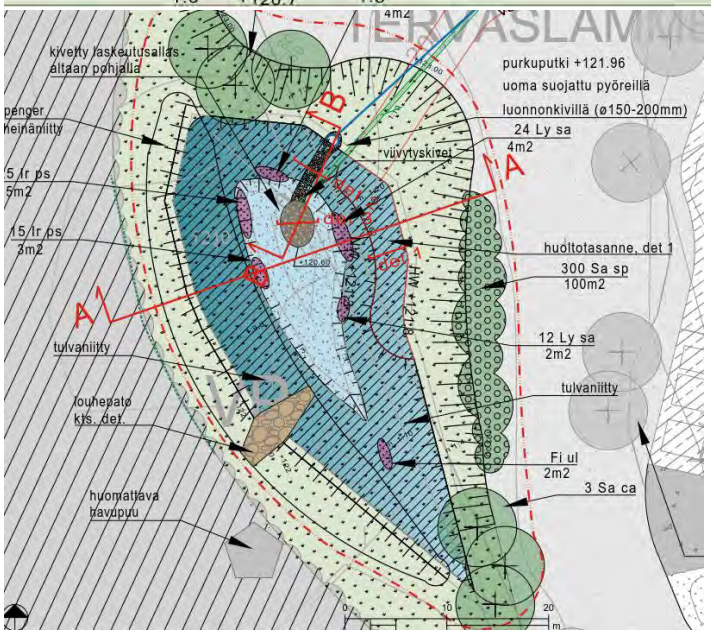
Flooding, biodiversity, climate resilience, green space management, recreation

iv. Technical and design parameters

Alluvial meadow's area is ca. 500 m^2. Normal water elevation is +121,3 and maximum flood elevation is +121,8. Meadow slope varies from 1:10 to 1:20 and the meadows are occasionally flooded depending on the severity of the storm. Alluvial meadow was grown from a commercially available seed mixture of domestic alluvial meadow plants sown on a 150 mm thick growth medium layer.







v. Potential for replication and upscaling

Alluvial meadows not only retain urban run-off in the times of heavy rain but also improve biodiversity. Flowering plants have important role in providing habitat for pollinators. In Tampere alluvial meadows are

replicated in new residential areas around retention ponds and stream restoration projects in Härmälänoja stream and Vuohenoja stream.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
Climate resilience	Total amount of carbon stored in vegetation	Calculations by the end of the project
Climate resilience	Mean or peak daytime local temperatures	Weather station of Vuores district Data collection every 10 min
Water management	Flood peak height	Automated continuous data collection at the end of the Vuores NBS for storm water management using a data logger Data collection frequency once/15 mins
Water management	Time to flood peak/Peak discharge	Automated continuous data collection at the end of the Vuores NBS for storm water management using a data logger Data collection frequency once/15 mins
Water management	Runoff in relation to precipitation quantity	Precipitation monitoring in Vuores district Data collection every 1 min
Water management	Nitrogen and phosphorus	P determined based automatic turbidity measurement N determined based on continuous nitrate monitoring Data collection every 15 min.
Water management	Basic water quality: flow, pH, temperature, EC, turbidity	Automated continuous data collection using a data logger Data collection frequency once/15 mins
Water management	Total suspended solids	Manual sampling in Vuores Virolaistenoja monitoring station monthly/based on need/changes in NBS performance
Biodiversity enhancement	Increase in suitable habitat for selected pollinator and plant species + Shannon Diversity Index	Field surveys Data collection frequency 1-2 time/year
Green space management	Distribution of public green space	Modelling
Green space management	Accessibility of urban green spaces	Modelling/one time survey in Vuores in Spring 2020
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	One time survey in Vuores in Spring 2020
Health and well-being	Encouraging a healthy lifestyle	One time survey in Vuores in Spring 2020

vii. Maintenance strategy

- comprehensive maintenance is done to ensure optimal performance of the NBS
- no maintenance card yet, but we are going to make one based on the maintenance plans/cards in central park Vuores
- cutting the vegetation will be done once a year in late summer (September when flower seeds are ready)

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Small-scale NBS in Vuores: Urban garden 1

i. NBS description

Community garden of 2 housing co-operatives. Small-scale NBS funded via innovation vouchers (6500 € for materials) and planned & built as voluntary work of residents.

ii. Basic information

Location

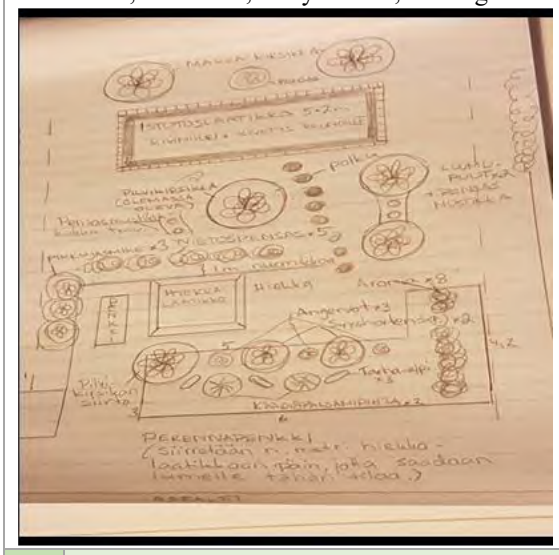
Type[1]	1	2	**3**	Size	ca. 250 m^2	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		X		X	X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		X	X	X	X	

iii. Specific challenges targeted

Green space accessibility, social cohesion, biodiversity, awareness, sense of empowerment, water management

iv. Technical and design parameters

Perennials, fruit trees, berry bushes, urban gardening boxes, composts and rainwater harvesting systems.



v. Potential for replication and upscaling

Innovation vouchers encourage residents and other city actors than municipality ideate and implement novel nature based solutions to city. Nature based solutions created were feasible: DIY-type rather than professional/engineered solutions. Housing cooperatives were very happy with the end results and agree that these collective projects have further enhanced the relations between the residents. Our living lab is in a new area and we did not receive many applications. In the future, targeting such funding to older and more dense areas with less nature and resources, is recommended. The inclusion of innovation vouchers in Tampere's NBS business model proved to be a successful approach and solution to engage citizens to a greater extent in the city's NBS efforts. This solution can easily be replicated in other cities or contexts, when small- or medium-scale NBS are implemented. Tampere is also shortly providing citizens a raingarden guide for supporting NBS implementation in small scale.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
	Total amount of carbon stored in vegetation	Calculations by the end of the project
	Mean or peak daytime local temperatures	Weather station of Vuores district; data collection every 10 min.
Green space management	Distribution of public green space	via modelling
	Accessibility of urban green spaces	via modelling/interview of users in Spring 20
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	interview of users in Spring 20

vii. Maintenance strategy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

- maintenance of composts - maintenance of fruit trees and berry bushes - growing vegetables in urban gardening boxes - irrigation with harvested rainwater - fertilizing with compost - uprooting the weeds all voluntary work of residents

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Small-scale NBS in Vuores: Urban garden 2

i. NBS description

Community garden of a housing co-operative. Small-scale NBS funded via innovation vouchers (1000 € for materials) and planned & built as voluntary work of residents.

Before

After

ii. Basic information

Location

Type[1]	1	2	**3**	Size	ca. 200 m^2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 730052
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
				x	x	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		x	x	x	x	

iii. Specific challenges targeted

Green space accessibility, social cohesion, biodiversity, awareness, sense of empowerment

iv. Technical and design parameters

Fruit trees, berry bushes and urban gardening boxes.

v. Potential for replication and upscaling

Innovation vouchers encourage residents and other city actors than municipality ideate and implement novel nature-based solutions to city. Nature based solutions created were feasible: DIY-type rather than professional/engineered solutions. Housing cooperative was very happy with the end results and agree that these collective projects have further enhanced the relations between the residents. Our living lab is in a new area and we did not receive many applications. In the future, targeting such funding to older/more dense areas with less nature and resources, is recommended. The inclusion of innovation vouchers in Tampere's NBS business model proved to be a successful approach and solution to engage citizens to a greater extent in the city's NBS efforts. This solution can easily be replicated in other cities or contexts, when small- or medium-scale NBS are implemented. Tampere is also shortly providing citizens a raingarden guide for supporting NBS implementation in small scale.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
	Total amount of carbon stored in vegetation	Calculations by the end of the project
	Mean or peak daytime local temperatures	Weather station of Vuores district; data collection every 10 min.
Green space management	Distribution of public green space	via modelling
	Accessibility of urban green spaces	via modelling/interview of users in Spring 20
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	interview of users in Spring 20

vii. Maintenance strategy

- maintenance of fruit trees and berry bushes
- uprooting the weeds
- growing vegetables in urban gardening boxes

all voluntary work of residents

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Small-scale NBS in Vuores: Community Horse Park

i. NBS description

A community horse park in the Vuores Central Park managed by the local stable, funded via innovation vouchers (16 364 €). In this multi-use green space residents can observe and interact with the horses guided by the stable staff. Management effects on biodiversity are studied. NBS is equipped with the sign explaining the NBS and its functions.

ii. Basic information

Location

Type[1]	1	2	**3**	Size	ca. 2500 m^2 (50 m x 50 m)	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
				x	x	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

		x	x	x	x	

iii. Specific challenges targeted

Green space accessibility, social cohesion, biodiversity, health and wellbeing, sense of empowerment, place identity

iv. Technical and design parameters

Horse paddock in the Vuores Central Park, next to Vuores School.

v. Potential for replication and upscaling

Innovation vouchers encourage other city actors than municipality ideate and implement novel nature-based solutions to city. Nature based solutions created were feasible: DIY-type rather than professional/engineered solutions. Participants enjoyed working with neighbours and social aspect was highlighted. Our living lab is in a new area and we did not receive many applications. In the future, targeting such funding to older/more dense areas with less nature and resources, is recommended. The horse park represents an example of how a green space can be managed for multipurpose use. The aim of the horse park is to promote citizen engagement in a natural setting, while also enabling residents to take part of and learn about the cultural heritage of the Vuores area. The horse park also aims to increase residents' accessibility to outdoor activities, which otherwise may not be within their reach due to financial or social reasons. Interaction with horses has also been shown to enhance peoples' well-being and general health, which is one of the objectives of the horse park. UNaLab partners will examine management effects on biodiversity in this multi-use green space. Animals are also brought to other urban areas in Tampere, e.g. cattle to Iidesjärvi conservation area and sheep to Tohloppi meadow.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
	Total amount of carbon stored in vegetation	Calculations by the end of the project
	Mean or peak daytime local temperatures	Weather station of Vuores district; data collection every 10 min.
Green space management	Distribution of public green space	via modelling
	Accessibility of urban green spaces	via modelling/interview of users in Spring 20
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	interview of users in Spring 20
Biodiversity enhancement	Increase in suitable habitat for selected pollinator and plant species + Shannon Diversity Index	Field surveys; data collection frequency 1-2 time/year
Health and Wellbeing	Encouraging a healthy lifestyle	one time survey in Vuores in Spring 20

vii. Maintenance strategy

- inspecting and fixing the fences in spring
- collecting and composting horse manure
- cutting the vegetation if needed (City of Tampere)
- horses do maintenance by grazing
- most of the work done by local horse stable

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

Lake Koukkujärvi nature trail (Supportive Action)

viii. NBS description

Nature trail around the Lake Koukkujärvi with information signs regarding nature values (biodiversity) of the area. Paths around the small lake in Vuores district were improved with duckboards, simple benches and wood chips. Improvements were partly done as voluntary work of the local residents.

ix. Basic information

Location

Type[1]	1	2	3	Size	1,5 km	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
				x		
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		x	x	x	x	

x. Specific challenges targeted

Green space accessibility, social cohesion, recreation, awareness, health and wellbeing

xi. Technical and design parameters

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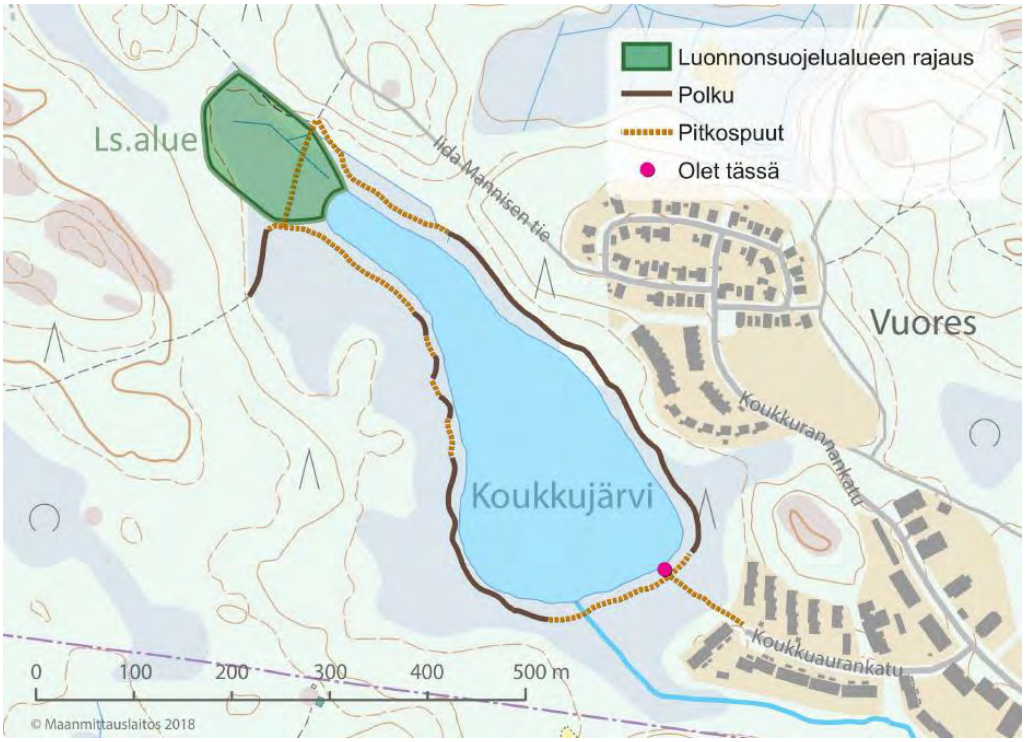
Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Length of the nature trail is 1,5 km. Existing path was improved with duckboards, simple benches and wood chips. Duckboards are marked on a map below with dashed line. Total length of the duckboards is ~600 m and they are made of thick larch. Normal paths are marked with black line and moist parts were improved with wood chips. Nature trail is partly located at conservation area (green area on the map). Building was done by Ecofellows Ltd. with the help of voluntary work of the residents' association, the Finnish Association for Nature Conservation and employment service.



xii. Potential for replication and upscaling

According to the results of a survey sent to the residents of Vuores, the Koukkujärvi nature trail has increased the quality of living in the Vuores area. Residents are pleased to recreate by the lake and receive information of area's nature values. It has been delighting to see residents actively participating in improvements of paths. Similar trails can easily be replicated in other areas and other cities. In Tampere similar trails and signs are replicated at stream restoration sites in Vihioja, Vuohenoja and Härmälänoja streams.

xiii. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Mean or peak daytime local temperatures	Weather station of Vuores district; data collection every 10 min.
Green space management	Distribution of public green space	via modelling
	Accessibility of urban green spaces	via modelling/interview of users in Spring 20
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Awareness of citizens regarding urban nature and ecosystem services	interview of users in Spring 20
Health and Wellbeing	Encouraging a healthy lifestyle	one-time survey in Vuores in Spring 20

xiv. Maintenance strategy

- condition is inspected once a year and needed maintenance measures are done if needed - adding woodchips to wet parts if needed - duckboard removal in ca. 15 years - possibly cutting the vegetation that grows on top of the path if needed - this is a suitable site for residents to participate on maintenance

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

Biofilter for seepage waters

i. NBS description

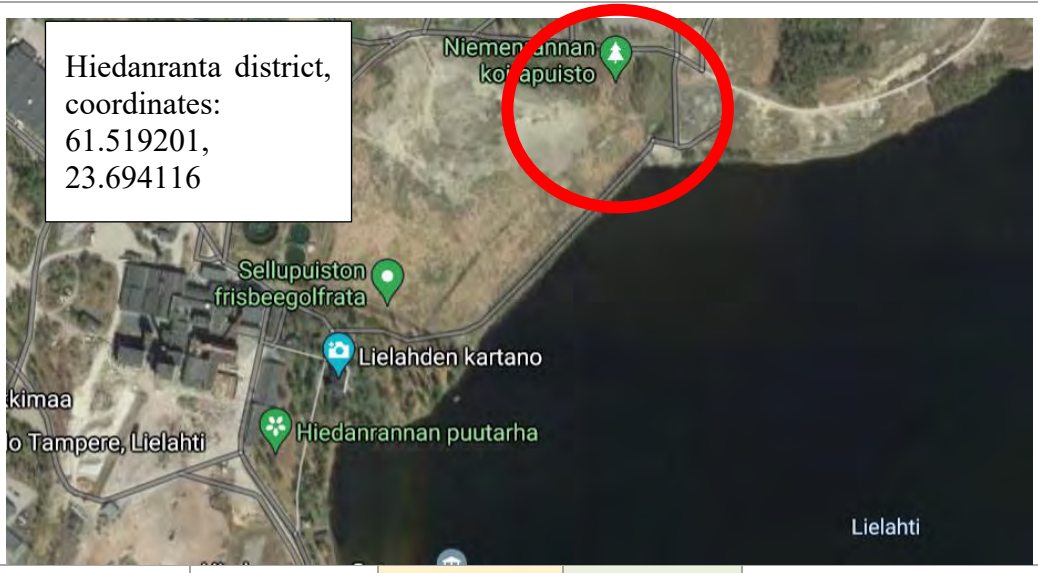
Biofilter (with biochar, peat and expanded clay media) is implemented to treat leachate from the old industrial (pulp mill) landfill. Deep-rooted bushes and perennials native to the area were planted on top of the filter to retain water and nutrients.

- The biofilter has several types of nature-based water treatment techniques including biological, chemical and mechanical treatment processes. These are induced by the soil layer materials, vegetation and soil organisms.
- The biofilter enables natural water cycling within the catchment, hence less water is expected to be conveyed outside the biofilter that was conveyed in.
- Vegetation consists of bushes and perennials that tolerate changing moisture conditions and have deep growing roots. The plant species include flowering plants that offer a good living environment for pollinators.
- Bushes: Phylocarpus opulifolius, Salix lanata, Salix purpurea, Salix viminalis
- Perennials: Carex muskingumensis (Palm sedge), Calamagrostis x acutiflora Dracocephalum sibiricum, Geranium macrorrhizum 'Bevan´s Variety' (rock cranesbill), Geranium sanguineum (bloody cranesbill), Geum coccineum (red avens), Iris pseudocarus (yellow flag), Iris sibirica (siberian iris), Lysimachia punctata (dotted loosestrife), Lythrum salicaria (purple loosestrife), Sanguisorba officinalis (great burnet), Stachys macrantha,Telekia speciosa (large yellow ox-eye) and Veronica longifolia (long-leaved speedwell)
- The demonstration seeks to further integrate urban blue-green-grey infrastructure and develop nutrient recovery.

NBS is equipped with the sign explaining the NBS and its functions and water measurement stations before and after the NBS.

Taking calibration samples from automatic water measurement stations during winter.

ii. Basic information

Location						
Type[1]	1	2	3	Size	ca. 100m^2	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
		x		x	x	x
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		x	x		x	x

iii. Specific challenges targeted

Water quality, biodiversity, green space management, recreation

iv. Technical and design parameters

Biofilter's catchment area is ca. 2 ha.
Polluted seepage water (particularly high concentrations of nitrogen and phosphorus compounds) from the demonstration area (2 ha) is conveyed into the biofilter with an underdrain in 1 m depth.
The soil layer below the underdrain is peat-based growth medium that contains spruce biochar that is produced in Hiedanranta. Biochar accelerates the retention of pollutants and water that can be further uptaken by the topsoil vegetation.
In the bottom drainage layer of the system, light gravel aggregates are used to improve pollutant and odor removal. The drainage layer includes an underdrain pipelines that finally conveys treated water to nearby lake.
The purification ability of the biofilter is monitored through automatic water quality measurement for inflow and outflow. Conductivity, turbidity, pH, temperature and flow are monitored online. Nutrients and pollutants are measured manually.

Layers of the biofilter:
1500mm layer of filtratig growth medium 1: mineral soil 80% and 20% peat
400mm layer of filtrating growth medium 2: including +30% biochar and 70% mineral soil and peat
150mm transition layer of macadam (#4-8mm)
200mm drainage layer of light gravel aggregates (#8-10mm)
150mm installation base

v. Potential for replication and upscaling

Biofilter with special filtering materials (biochar, peat and light gravel aggregate Leca) is a possible solution for treating nutrient rich leachate from old landfills etc. It can remove nutrients, including nitrogen. It should be noted, that biochar used for water treatment should not include fine particles because it can cause blocking or particles can be leached to receiving waterbody. Biofilters can only handle relatively small amounts of water and, in the case of overflow, nutrients and other contaminants may be leached out of the structure. In case of

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Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions

large catchment area and high flow rate, plenty of space is needed or/and a solution for overflow situations. There is an uncertainty related to biofilter's life cycle. It is dependent on at least the quality and quantity of water channeled into the filtration area and the filtering materials used. Hence, more studies are needed of the long-term performance. In Tampere biofiltration solutions are replicated in areas where problems with the quality of storm water runoff have been identified. A leca-based biofilter has been built to Rusko industrial area where the poor quality of urban runoff is causing problems. The bad hygienic quality of the runoff from Hervanta is problematic with regard to the use of Houkanoja stream water for irrigation. The filter seems to function well in the summertime but during cold winters it can freeze.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
Climate resilience	Total amount of carbon stored in vegetation	Calculations by the end of the project
Water management	Basic water quality: flow, pH, turbidity, EC, temperature	Automated continuous data collection using a data logger; data collection frequency once/15 mins
Water management	Nitrogen and phosphorus	Manual sampling before and after the filter monthly/based on need/changes in NBS performance.
Water management	Total suspended solids	Manual sampling before and after the filter monthly/based on need/changes in NBS performance.
Water management	Metals in surface water	Manual sampling at the filter inlet and outlet four times/year. Measured Fe, Mn, Pb, Cr, Cd and Zn (total and dissolved concentrations)
Biodiversity enhancement	Increase in suitable habitat for selected pollinator and plant species + Shannon Diversity Index	Field surveys; data collection frequency 1-2 time/year
Green space management	Distribution of public green space	via modelling
Green space management	Accessibility of urban green spaces	via modelling

vii. Maintenance strategy

The functionality of the Hiedanranta biofilter will be monitored through continuous measurements for at least two years. Data on the functionality of the filter and possible saturation of contaminants in landfill leachate will be gathered.

Biofilter's wells and underdrains should be maintained in accordance with normal stormwater system maintenance procedures. At each inspection visit the wells and ventilation ducts should be examined visually and functioning of overflow pipe flaps should be checked. sediment nests are emptied as needed.

If the sediment nests are completely full or there is otherwise a lot of sand accumulating, whole line should be rinsed. Any erosion damage at the overflow point will be repaired as well as the front of the discharge opening in those respects. Visually inspect the condition of the drains through the ventilation / inspection pipes. Flushing of underdrains every 5 years.

The sampling wells are flushed, and the precipitate accumulated in front of the measuring dam is removed if necessary.

Caution must be taken in the maintenance of sampling wells because of the measuring equipment in the wells. The locking of the sampling wells is checked.

Vegetation maintenance

The plantation gets its nutrients from stormwater. The condition of the crop and the intake of fertilizers are monitored visually. If signs of nutrient deficiencies appear, the necessary measures are taken by soil analysis.

The bark cover around the planting is considered weed-free mechanically or chemically

combating. Weeds are mechanically uprooted or chemically controlled whenever necessary and with special care during the first two years of planting to get the shrubs and perennials to cover the ground as quickly as possible.

Basket willow and wool are subjected to improvement cut annually to remove shoots that are in poor condition or out of shape. If necessary, they are rejuvenated by thinning, although the wicker will last also downsizing. The purple lobster and dwarf red willow are cut down as the crop deteriorates. The branches are chipped for mulch. Perennials are planted dynamically so the different plant species are interacting whit each other. Perennials are cut down with a line cutter in the spring winter when the ground is in the frost. Evergreen leaves are left uncut. Plant mass may be left as fertilizer, as long as the large parts of the plant are shredded, the appearance of the planting is neat and the plant mass does not suppress the growth of perennials. Activated carbon filter of the odor removal unit is changed once a year

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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Pilot-scale micro algae system

viii. NBS description

Pilot-scale wastewater treatment system, where micro algae (*Scenedesmus acuminatus*) is grown in source separated and diluted human urine. The focus is on nutrient removal and recovery, energy recovery potential, as well as on the performance in sub-arctic conditions.

ix. Basic information

Location

Type	1	2	3	Size	2 raceway ponds (400 L and 2000 L) in a green house

Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X	X				
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
		X				

x. Specific challenges targeted

Water quality, climate resilience, resource recovery in integrated urban water management

xi. Technical and design parameters

The study consisted of two pilot raceway ponds (RWP) with working volumes of 400 L and 2000 L. The human urine for the experiments was collected with source separating toilets in Hiedanranta, Tampere, and the urine was stored in containers for at least 6 months before use in the RWPs. In the 400 L raceway pond, the algae were cultured in batch mode with diluted (1:20 water) human urine and the harvested algae was used to inoculate the 2000 L pilot raceway pond. After growth of inoculum for the larger pond, the smaller raceway pond was used to determine the maximum growth of *S. acuminatus*. In 2000 L raceway pond, diluted human urine (with 1:20 and 1:15 dilutions) was used as the culture media for growing *S. acuminatus* at a hydraulic retention time (HRT) of 14 d. Algal biomass was harvested from the pond twice a week and replaced with diluted human urine. The growth of the microalgae in the pilot ponds was monitored by measuring optical density (OD), total (TSS) and volatile suspended solid (VSS). In addition, the soluble ammonium nitrogen and total phosphorous were analysed from the ponds upon feeding.

xii. Potential for replication and upscaling

Cultivation of algal species in source separated urine is a promising approach for recovering nutrients from real waste streams and for producing biomass with cheap nutrient supply (e.g. for biogas and bioethanol production or as aquaculture feed). Enhanced biomass concentrations are required to improve the nutrient recovery from source separated human urine. In this demonstration, the source separated human urine was diluted with tap water for practical reasons but in the future, the dilution could be done with local storm waters, which would broaden the storm water utilisation options However, if future studies on semi-continuous or continuous cultivation systems show that less urine dilutions is needed, then the need for storm water will be lower.

xiii. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	Calculations by the end of the project
Climate resilience	Total amount of carbon stored in vegetation	Calculations by the end of the project
Climate resilience	Mean or peak daytime local temperatures	Temperature measured every working day
Water management	Nitrogen and phosphorus	Culture suspension samples were collected from the raceway ponds every working day and the effluent after harvesting was collected twice a week. The culture suspension samples were analyzed for total soluble phosphorus (Ptot), total soluble nitrogen (Ntot) and ammonia nitrogen (NH4+-N).
Water management	Basic water quality: flow, pH, temperature, EC, turbidity	Culture suspension samples were collected from the raceway ponds every working day and the effluent after harvesting was collected twice a week. The culture suspension samples were analyzed for OD, pH, dissolved oxygen (DO), volatile suspended solids (VSS), total chemical oxygen demand (TCOD), soluble COD (SCOD), and other cations namely potassium, magnesium, calcium and sodium.
Water management	Total suspended solids	Culture suspension samples were collected from the raceway ponds every working day and the effluent after harvesting was collected twice a week. The culture suspension samples were analyzed for total suspended solids (TSS).

xiv. Maintenance strategy

- process inspection every workday during the microalgae growing season
- emptying the waste containers when needed
- emptying the system in late autumn
- starting the system in early spring

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Green wall

i. NBS description

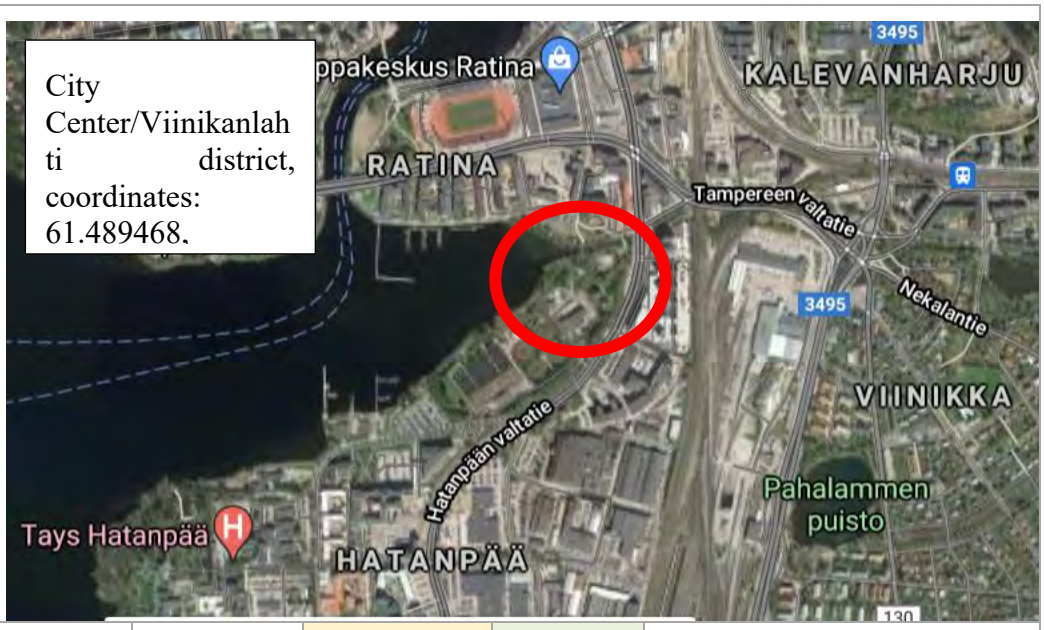
The green wall is built on the wall of the wastewater pumping station to be built in Viinikanlahti district.
The vegetation of plant boxes is implemented as multispecies mixed planting. Vegetation is selected from local species to support biodiversity and ensure growth in harsh climate.
Plants used in the green wall:

1. *Calluna vulgaris, Heather*
2. *Clechoma hederacea, ground ivy*
3. *Fragaria moschata, musk strawberry*
4. *Luzula pilosa, hairy woodrush*
5. *Lychimachia nummularia, moneywort*
6. *Lychnis alpina, alpine catchfly*
7. *Lychnis viscaria, sticky catchfly*
8. *Polypodium vulgare,common polypody*
9. *Prunella vulgaris, self-heal*
11. *Thymus serpyllum, wild thyme*
12. *Thymus serpyllym Magic Carpet*

+ forest plants (mor) taken from a new city district (Ojala-Lamminrahka) building site

Testing green wall element

ii. Basic information

Location	

Type[1]	1	2	3	Size	ca. 64 m²	
Addressed challenges	Climate resilience	Water management	Natural and climate hazards	Green space management	Biodiversity enhancement	Air quality
	X	X			X	
	Place regeneration	Knowledge and social capacity building	Participatory planning and governance	Social justice and cohesion	Health and well-being	New economic opportunities and green jobs
					X	

iii. Specific challenges targeted

Challenges targeted were climate resilience, biodiversity enhancement, water management and Health and well-being.

The carbon storage capacity of the green wall

The storm water on the roof is used to water the green wall

The green wall also provides attractive green areas for citizens in a densifying city and therefore provides health and well-being.

iv. Technical and design parameters

The green wall designed is size of 8m x 8m. It consists of four vertical pillars with 1m x1m plant boxes in between. There are total of 64 plant boxes and structures are steel.

Plant boxes are 15 cm deep. The vegetation of the boxes are implemented in two different ways: 1) plants (mor) from forest which is becoming a new residential area (Ojala-Lamminrahka) and 2) planted boxes. In plant boxes, the first layer is rock wool (8 cm), then soil+linen fiber+water retention granulas and plants or mor. Mor is ca. 7 cm deep, so soil mixture is not needed in mor boxes. On top of the box, there is steel net. The vegetation is grown ready during the summer in horizontal position, and then the pre-grown boxes are installed to the wall vertically.

Rainwater harvested from the roof is used for wall irrigation. The watering of the wall in is carried out using gutter and channels in the between area of the pillars. Each channel waters two rows of plant boxes. If necessary, additional irrigation is used.

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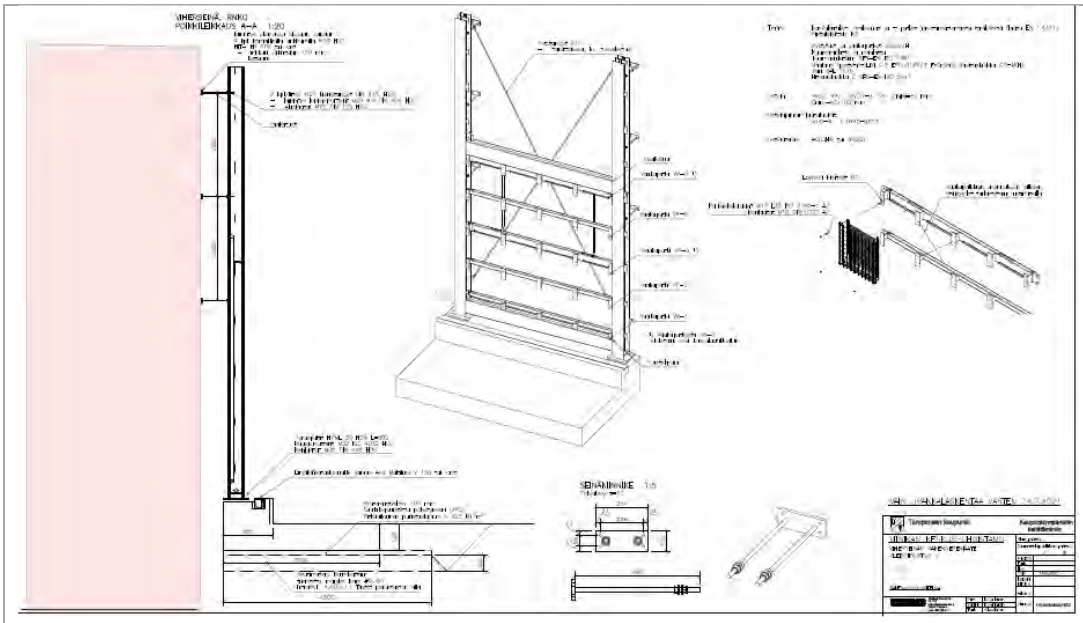
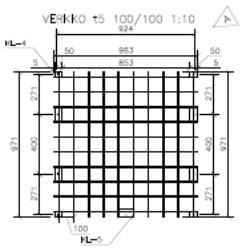


Green wall structure



Plant box

v. Potential for replication and upscaling

Vegetation has been selected from local species to support biodiversity and to ensure growth in harsh climate. Aim is to monitor the performance of the structure and noting the lessons learned of this demonstration, replicate such solutions in public and private buildings.

vi. Monitoring strategy

Challenge	Indicator	Details
Climate resilience	Carbon removed or stored per unit area per unit time	calculations by the end of the project
Climate resilience	Total amount of carbon stored in vegetation	calculations by the end of the project
Climate resilience	Mean or peak daytime local temperatures	Measurement at the wall
Water management	Flood peak height, time to flood peak/peak discharge	Will be measured, method determined later
Water management	Runoff in relation to precipitation quantity	Precipitation monitoring at wall, data collection every 1 min
Water management	Nitrogen and phosphorus	Manual sampling monthly/based on need/changes in NBS performance
Water management	Basic water quality: flow, pH, temperature, EC, turbidity	Manual/automatic sampling based on need
Water management	Total suspended solids	Manual/automatic sampling based on need
Biodiversity enhancement	Increase in suitable habitat for selected pollinator and plant species + Shannon Diversity Index	Field surveys; data collection frequency 1-2 time/year
Green space management	Distribution of public green space and Accessibility of urban green spaces	via modelling

vii.	Maintenance strategy
Maintenance plan is not done yet, but basically green wall maintenance is similar to other green areas maintenance. Plant selection has (among other targets) aimed to minimize maintenance (costs). In the beginning resources are used for monitoring (soil moisture conditions, plant condition) and supporting first seasons of the plants and fixing the problems.	

[1]*Type 1: protection/conservation; Type 2: restoration + managing; Type 3: retrofitting + creation*

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