Transforming Stormwater Infrastructure for Urban Resilience and Circular Water Solutions through the CURE-NbS Project

Transformer les infrastructures de gestion des eaux pluviales pour une resilience urbaine et des solutions circulaires en matière d'eau grâce au projet CURE-NbS

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RESUME

Le changement climatique et l'urbanisation contribuent aux problèmes liés à l'eau en milieu urbain, qui ont un impact sur la durabilité à long terme, la résilience climatique et la pollution. Le projet CURE-NbS explorera les défis liés aux solutions fondées sur la nature (NbS) dans le but de concevoir une approche innovante de gestion de l'eau qui intègre les systèmes de drainage de surface dans les stratégies existantes d'urbanisme et de réutilisation. Neuf NbS différentes réparties dans cinq laboratoires urbains internationaux (ULL) seront évaluées à l'aide d'un cadre combiné de modélisation et de surveillance. Chacune sera évaluée sur la base de ses performances hydrauliques afin d'évaluer l'efficacité des NbS pour atténuer les rejets urbains excessifs lors d'événements pluvieux, améliorer la qualité de l'eau et soutenir des stratégies efficaces de gestion de l'eau. Les résultats du projet fourniront également des informations sur les avantages connexes, les conséquences socio-économiques et les implications spatiales des NbS. Des activités structurées, telles que des ateliers interactifs ClimateCafé, soutiendront les initiatives de participation des parties prenantes et adapteront les solutions au contexte local. En outre, ClimateScan, un outil de cartographie numérique open source, tirera parti de la technologie pour faciliter la collecte de données géospatiales pertinentes pour les stratégies mondiales d'adaptation au changement climatique. Les résultats du projet devraient démontrer des améliorations mesurables dans la gestion de l'eau en milieu urbain et fournir des conseils pratiques pour accélérer le changement et intégrer les NbS dans la planification et les infrastructures existantes.

ABSTRACT

Climate change and urbanisation contributes to urban water issues that have an impact on long-term sustainability, climate resilience and pollution. The CURE-NbS project will explore Nature-based Solutions (NbS) related challenges with the purpose of designing a innovative water management approach that integrates surface drainage systems into existing urban planning and reuse strategies. Nine different NbS across five international urban living labs (ULL) will be assessed through a combined modelling and monitoring framework. Each will be evaluated based on hydraulic performance to assess the effectiveness of NbS in mitigating excessive urban discharge during storm events, improve water quality and support effective water management strategies. Project results will also provide insight into co-benefits, socio-economic consequences and spatial implications of NbS. Structured project activities, such as interactive ClimateCafé workshops, will support stakeholder participation initiatives and adapt solutions to the local context. In addition, an open-source digital mapping tool, ClimateScan will leverage technology to facilitate geospatial data collection relevant to global climate adaptation strategies. Project outcomes are expected to demonstrate measurable improvements in urban water management and provide practical guidance for accelerating change and integrating NbS into existing planning and infrastructure.

KEYWORDS

Blue-Green Infrastructure, Nature-based Solutions, Stakeholder engagement, Stormwater management, Water Circularity

1 INTRODUCTION

1.1 Background

Effective stormwater management requires a multidisciplinary approach that includes diverse research and consideration for the design and sizing of different measures, impacts, risks, and adaptive strategies to ensure resilient sustainable infrastructure under changing environmental and socio-economic conditions. NbS provide potential solutions as effective and cost-efficient adaptation strategies that transform existing infrastructure into resilient urban water management systems. A combination of innovative at-source NbS can alleviate water related issues, improve access to and reuse of non-conventional water, reduce dependence on less sustainable water supplies, enhance the water cycle and ecosystem health, and provide sustainable long-term solutions that integrate with existing infrastructure (Davies et al, 2021). This includes Blue-Green Systems (BGS) and Sustainable Urban Drainage Systems (SuDS) that consist of networks of strategically planned natural areas, which offer social and environmental services, mimic hydrological cycles, build system resilience and mitigate climate related pressures. Innovative NbS, BGS and SuDS included in this project transform problematic surface water into a resource that contributes to stormwater management, improves water quality and supports re-use potential. Research objectives include addressing knowledge gaps in how NbS can be used as an adaptation/mitigation strategy and identify barriers/challenges that hinder operation and/or implementation; analyse long-term functionality of NbS and monitor changes; analyse how NbS could be scaled up to sub-catchment level to increase urban resilience; develop structured guidelines and manuals of best practices; engage with local authorities and relevant stakeholders; and promote social/economic sustainability and knowledge transfer.

1.2 Project description

Five international partners, each with their own ULL, will contribute to project activities. Project data will serve as input into the most efficient design, dimensions, construction materials, performance and functionality of different NbS that support the development of urban resilience to extreme events. CURE-NbS will consider the interception of stormwater by NbS that facilitate storage and direct reuse for the purpose of irrigation, humidification, toilets or heating (Climate Road), as well as indirect reuse through aquifer recharge, irrigation, drinking water sources and flood/drought regulation. Water quality will be monitored in e.g wetlands that provide natural treatment systems for runoff and greywater. Measures such as bioswales and rain gardens also integrate multifunctional solutions in terms of vegetation selection, biodiversity conservation, enhancement of the water cycle, and flood protection. This closed loop-system (Figure 1) shows specific measures selected from each ULL, based on their capacity to manage stormwater, enhance water circularity and promote reuse.

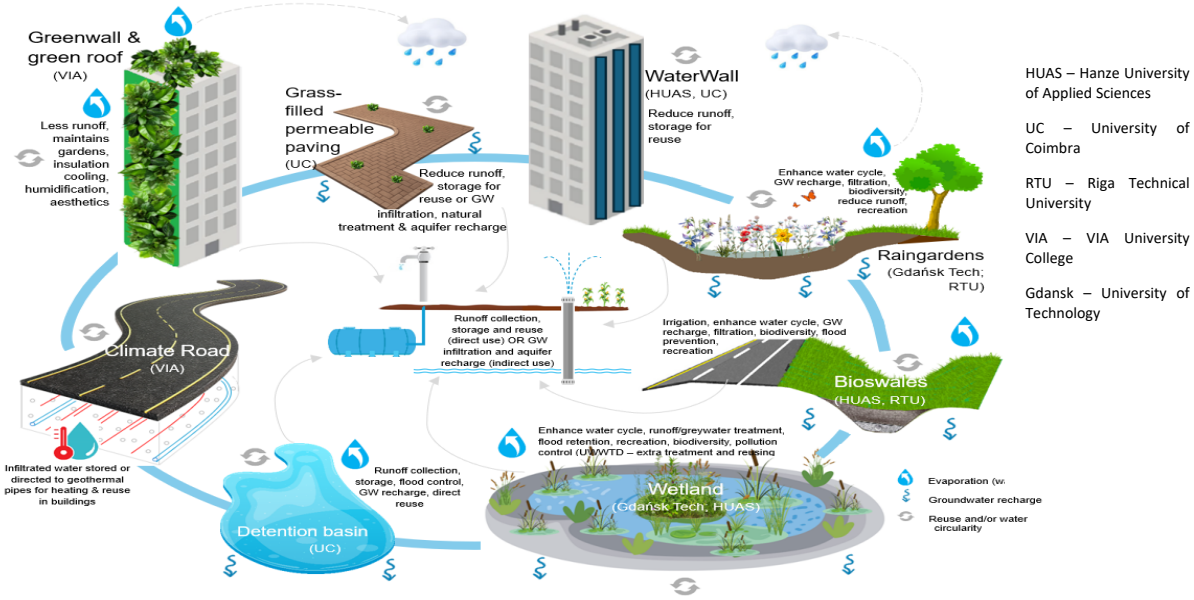

Figure 1 : Urban Living Lab measures per partner.

Further investigation will focus on how NbS can be implemented and upscaled to increase urban resilience. Due to the complexity of water challenges, solutions are not expected to come from one discipline or individual measure. For this reason, this project's innovation also lies in determining the most efficient location and combination of NbS, from each of the partner's ULLs, which has not yet been implemented internationally. This hybrid NbS and technology approach will consider the contribution of measures that support efficient stormwater management. In addition, various barriers hamper the efficient uptake and implementation of NbS. This includes the challenge of limited urban space, which this study aims to address by integrating existing stormwater infrastructure with NbS. Another challenge is that decision-makers often prefer traditional infrastructure, largely because of a limited understanding of the value of NbS, concerns over operational performance (Boogaard and Lucke, 2019; Boogaard, 2022), the lack in continuous maintenance/monitoring and limited scientific evidence of the hydrological impacts. CURE-NbS will address these barriers. Since NbS deliver targeted and non-targeted ecosystem services that contribute to urban resilience, water management, sustainable hydrological functioning of the natural environment and reuse potential, the value of these services will be assessed through a socio-economic and ecological Cost Benefit Analysis (CBA). Co-benefits will be characterised as the environmental, social, and economic advantages provided by NbS, in addition to their primary function, that enhance urban resilience and support community wellbeing. Assessments will be carried out on ULL and sub-catchment level. By attaching economic and non-economic value to NbS, CURE-NbS aims to advance Technology Readiness Levels (TRL), build confidence and accelerate the change in practices, adoption of measures and cutting-edge technologies.

2 METHODOLOGY

2.1 Applied urban research

The project will develop an extensive data inventory and NbS characterization strategy that quantify and documents the long-term hydraulic performance, water treatment capacity, and co-benefits of NbS. Data, including ULL construction, configuration, and operational parameters will be collected, standardized and analysed. All ULLs will remain operational throughout the project, with site surveys measuring water levels, flow rates, runoff, infiltration rates and soil moisture. To fill knowledge gaps and gather relevant data, we apply the concept of practical, interdisciplinary and solution-orientated applied urban research within ULLs. Real-time monitoring and historical long-term hydrological data, and physical, chemical and biological information will be compiled and unified. It also includes data on vegetation, soil types and characteristics such as permeability in different ULL location that facilitate infiltration and reduce runoff. A total of 5 ULLs will include 9 NbS, facilitating stormwater management, water retention, storage and reuse. This includes measures consisting of constructed wetlands for greywater purification and reuse, rainwater harvesting and bioswales; rain gardens, located in flood-prone European historic areas, that are equipped for detailed hydrological and quality monitoring; a 50 m long multifunctional permeable road (Climate Road) with an underlining water retention unit and a coupled sewage system for water/energy circularity (capable of run-off storage and energy harvesting), a green roof and green wall system that intercepts/stores stormwater and treats light grey water; a waterwall, and other innovative SuDS. Data will be accessible through ClimateScan (open access), comprising weather data for all ULLs, groundwater levels, substrate humidity in rain gardens, green walls and roofs, long-term infiltration rates in soil-based solutions and permeable pavements, as well as measurements of water quantity and quality from each system's influent and effluent. Soil and water pollution will also be monitored in measures that enhance infiltration and groundwater recharge.

2.2 Knowledge transfer and training

The project will build on unique communication and stakeholder engagement strategies (e.g. ClimateCafés and ClimateScan) for knowledge exchange, multidisciplinary collaboration and capacity building in climate adaptation. Participatory workshops, known as ClimateCafés, provide a 'learning-by-doing' approach through field-based education. They are aimed at connecting actors to improve coordination of activities, build capacity, generate socio-economic data and co-create knowledge with multidisciplinary stakeholders including representatives from water agencies/authorities, NGOs, ministries, academia, policy advisors, ministries, decision-makers, urban planners, industries, the financial sector, designers, business sector, engineers and the wider community (including end-users and citizens). ClimateCafé workshops create platforms for collaboration, stakeholder participation, and co-creation, highlighting the importance of multidisciplinary collaboration in assessing and implementing sustainable climate adaptation solutions, and integrating them into the urban

environment. Since each ClimateCafé is developed around specific local urban challenges and relevant stakeholders, they also support decision-makers and designers to adapt solutions to the local context. ClimateCafés make use of a variety of tools to facilitate stakeholder engagement and knowledge exchange. This includes a digital interactive web-based mapping tool for international knowledge transfer on 'blue-green' projects. This tool, ClimateScan, is the world's largest open-source database for innovative and sustainable climate solutions of water management projects such as adaptive green and flood measures. Another workshop tool consists of 'Augmented Reality' (AR) solutions (supported by AI) used as immersive technologies that bridge the gap between abstract concepts and practical applications. This visualisation tool will help build environmental awareness, motivating behaviour change and encouraging people to take part in decision-making and implementation efforts. By incorporating AR solutions during engagement with the local community and other stakeholders, we enhance public understanding and participation, promote TRLs and develop social and economic sustainability. Questionnaires will provide information from stakeholders to establish a baseline for social awareness of climate change, adaptation strategies, technologies and acceptance levels, and a follow-up questionnaire, integrated into ClimateCafés. These interactive knowledge transfer and training tools facilitate the mobilisation of data, transferability of information, stakeholder involvement, urban resilience, and innovative climate adaptation measures.

2.3 Modeling

Hydrodynamic models will provide a simulation of how water moves through different systems, thereby optimising the design and operation of sustainable climate-resilient stormwater strategies that support re-use approaches. By modelling the hydrological behaviour of NbS, planners can predict performance and ensure compliance with directive targets. Hydrodynamic models will also help demonstrate to stakeholders how to select, design, and implement specific NbS solutions and assess their potential contribution to climate resilience, using different levels of model complexity appropriate to each planning stage. Partners will employ different modelling tools using long-term performance data from the ULLs, encompassing a range of scenarios: without and with NbS, present situation and climate change impacts, at different complexity levels.

2.4 Socio-economic impact assessment

Given limited urban land space, private property owners play a critical role in urban water management as NbS increasingly shift responsibilities from the public to the private sector. In support of sustainable implementation, the project will undertake a comprehensive socio-economic assessment that includes a CBA at both ULL and sub-catchment levels. Suitable incentive instruments and decision-support tools for upscaling will be analysed, including the social and decision-making impacts of measures. These activities will produce a socio-economic impact assessment for each NbS, and economic impact pathway report identifying incentive gaps, and fact sheets/decision trees with recommendations for governance instruments, incentives and funding models.

3 DISCUSSION AND CONCLUSION

The planned research in CURE-NbS introduces several innovative approaches that address current knowledge gaps in long-term performance and monitoring activities, as well as providing insight into its active/direct and passive/indirect role in stormwater management, water circularity, re-use and the hydrological cycle. By gathering historical and real-time data analytics across ULLs, this project will deepen understanding of NbS processes, effectiveness and overall performance of different measures, both independently and in synergy with other measures. Since hydrodynamic modelling will be used to scale up solutions and demonstrate potential for implementation in other contexts, this project will also contribute to wider acceptance and implementation. This project includes the quantification of economic/social benefits and provide actionable insights for stakeholders that include recommendations on policy/governance instruments, incentives and funding models. To foster citizen engagement and strong political, economic, and social support towards NbS, CURE-NbS will leverage tools such as AR, ClimateCafés, ClimateScan and residential/urban development modelling that provide context to local impacts, solutions and facilitate interactive communication. The development of this novel framework is designed to build urban resilience, provide sustainable integrated water management practices, develop practical solutions and accelerate the adoption of measures and cutting-edge technologies.

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