Urban greenery's effects on Public Health and Wellbeing of Citizens and how to assess it – preliminary euPOLIS findings

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Keywords: urban greenery, urban biodiversity, public health, wellbeing, holistic monitoring

ABSTRACT

Introduction. Many studies report on the ability of natural environments and accessible green and blue spaces in the cities to diminish climate change impacts and lower the possibility of disasters. However, that is not the full extent of their effects. Among others, these urban spaces enhanced with nature-based solutions (NBS) can support active recreation and allow places for relaxation and consolidation from daily stress.

There is some evidence that NBS with their extensive greenery can give the positive impact on numerous psychological and physiological outcomes. Urban areas rich in greenery and biodiversity provide great opportunity for humans to come closer to nature and improve their health and well-being through interaction with a variety of flora and fauna species. Specifically, there is evidence that mental health (anxiety, stress levels) and psychological wellbeing may benefit from plant species richness (Fuller et al., 2007), animal species richness (Dallimer et al., 2012) and soil biodiversity (Wall et al., 2015). Furthermore, it has been shown that soil organisms, through their roles in controlling soil-borne pathogens and pests (soil vitality) lessen the prevalence of allergic diseases (Wall et al. 2015). Replacing or restoring the soil, regulation of water conditions, enabling plant species diversity - especially native ones, can substantially increase soil biodiversity leading to recovery of the natural soil food web, so the pathogen risk would be minimized with respect to communicable and non-communicable diseases (Crump et al., 2021). However, urban green spaces can also be linked to negative health outcomes, such as allergic reactions, or vector-borne diseases, as the result of increased exposure to allergenic pollen or increased amount of disease vectors in urban green environments (Calaza-Martinez and Iglesias-Díaz, 2016). These potential harmful effects may be addressed through the adequate design, maintenance and management of urban green spaces and selection of species.

Although different studies show some positive (or negative) effects of NBS on public health and wellbeing (PH&WB), still it is a challenge to actually quantify the extent of the effects, and also attribute the quantity to particular characteristics of an NBS. This is why EC has established a call topic SC5-14-2019 - Visionary and integrated solutions to improve well-being and health in cities, to fund projects that will implement different types of solutions that are capable of enhancing PH&WB in cities and assess their impacts. Once demonstration sites are developed and assessed, key findings and indicators will be included in the already available EC Handbook of indicators - Evaluating the impact of nature-based solutions: A handbook for practitioners.

This paper presents preliminary findings in the endeavour to quantify urban greenery's and biodiversity's effects on PH&WB, by integrating subjective, objective, physiological, and psychological monitoring approaches and producing a multifaceted understanding that is essential for policymakers, urban planners, and public health professionals to design sustainable and nature-inclusive cities that promote the well-being of their inhabitants.

Methods&Materials. Understanding the extent of urban greenery's (and biodiversity's) effects on PH&WB requires a comprehensive approach that covers different monitoring aspects. By combining subjective, objective, physiological, and psychological assessments (Figure 10), it is possible to gain a holistic understanding of these effects. **Subjective** assessments involve gathering information directly from

individuals through questionnaires or surveys. These tools can capture people's perceptions, attitudes, and experiences related to urban biodiversity and its impact on their PH&WB. Questions may focus on aspects such as stress levels, mood, overall satisfaction, and perceived benefits or drawbacks of biodiversity in urban areas. It should be noted that results of these assessments are correlated with the extent of participant's prior knowledge on greenery or biodiversity and relations between greenery & biodiversity and PH&WB. **Objective** assessments involve conducting field studies to observe and measure various aspects of urban greenery & biodiversity (e.g., species richness – birds, butterflies, plants, habitat quality and diversity, blue space availability, connectivity, and accessibility of urban green spaces, etc.) and their potential influence on public health. These studies typically involve trained researchers or experts who collect data on parameters such as species diversity, abundance, and ecological interactions. By analysing these objective measures, it is possible to understand the direct and indirect impacts of greenery & biodiversity on factors like air quality, noise reduction, temperature regulation, and natural spaces for physical activity. Monitoring **physiological** effects through smart wearables offers a more detailed understanding of how urban biodiversity affects individuals on a biological level. "euPOLIS by BioAssist" (Gallos et al., 2022) is an interactive health-centric platform developed in the euPOLIS project, that is compatible with multiple commercial smart bracelets that provides accurate recordings of physiological parameters (skin temperature, pulse, oxygenation and/or respiration), levels of physical activity (intensity and duration), sleep quality and user interactive feedback, and can provide inputs for physiological monitoring. This data can provide valuable insights into the immediate and long-term impacts of greenery & biodiversity on physical health. In addition to physiological effects, proprietary smart wearables can provide insights into **psychological** well-being. Feel Data Monitoring Device (along with Feel Data Monitoring platform by SentioLabs) for monitoring and assessment of the emotional status and stress/anxiety levels is another source of bio-signal data in the euPOLIS project, that provides inputs on psychological responses to implemented NBS interventions. The Feel Emotion Sensor is a wristband that has integrated bio-sensors which monitor a variety of end user physiological signals throughout the day, while in the background, proprietary advanced algorithms analyse these signals to recognize the wearer's emotions.

Figure 10 Subjective, Objective, Physiological, and Psychological assessments to gain a holistic understanding of the extent of greenery's and biodiversity's effects on PH&WB

All the different aspects of monitoring need to be performed before and after the implementation of NBS, and depending on the actual type of data can be of a sub-daily or daily timestep or be static. The data gathered from multiple types of smart health wearables is collected from a diverse group of volunteers, with a sub-daily timestep, and statistically analysed for peaks, trends, and inconsistencies to showcase the impact of NBS (by comparing the "before" and "after").

Case studies. euPOLIS case studies include 4 front-runner cities of different sizes in different biogeographical and climatic regions in which NBS are designed and tailored to each urban environment characteristics and challenges (Belgrade in Serbia, Piraeus in Greece, Łódź in Poland and Gladsaxe in Denmark). There are also five follower cities (Palermo in Italy, Limassol in Cyprus, Trebinje in Bosnia & Herzegovina, Bogota in Colombia, Fengxi in China), that are getting the knowledge and experience about planning of NBS from the front-runner cities, but also participate in mentoring sessions for replication of socio-cultural-urban hubs.

The clusters of NBS which are designed and implemented (under different scales) in the front-runner cities include: (1) NBS-based multifunctional pocket parks accessed by NBS locally conditioned pathways and shared spaces, (2) Waterways with mini biotope nodes, aquatic biodiversity – feed from groundwater aquifer or purified surface runoff, (3) NBS for surface runoff quality and pluvial flood management, (4) Groundwater abstraction for water, energy, greenery nexus, (5) MF NBS canopy for socializing, „recharging electronics", or „green bus stop" etc., (6) Multi-functional Live vegetation shaded waterfront promenade, (7) Air pollution abatement shrubs, trees and vertical green curtains, (8) Urban Metabolic hub with multi-functional ecotechnology demonstration/promotion, roof garden and art/cultural performance, (9) Multi-functional floating island, river water purification, (10) Coastal sea bottom marine aquatic biotope with euPOLIS-NBS, (11) Multi-functional euPOLIS Urban square/streetscape and other NBS (biotopes, sensory garden, waterfall, biodiversity & kitchen garden for socialising, recreation), and (12) Space for NBS business activation and promotion.

The most notable expected impacts of different NBS clusters on PH&WB include improvements of microclimatic conditions, air, water and soil quality, reduction of noise, increase of greenery and socializing spaces and changes in biodiversity, resulting in the reduction of the number of risk factors for non-communicable diseases (obesity, depression, stress, cardiovascular, etc.), increased duration and quality of physical activities, enhanced overall PH&WB stemming from the positive aesthetic experience and pleasure created in contact with visual attraction of dryland/marine aquatic interaction, stimulated relaxation and restoration, etc. A whole array of improvements can be attributed to augmentation of the use of NBS-enhanced public space on continuous basis, increasing the number of citizens of all ages in outdoor activities and interactions, create positive emotional attachment to the neighbourhood resulting in WB enhancement and improved socializing (improving space friendliness, safety, sense of ownership of the public space and sense of belonging to the community, community social cohesion, inclusivity, building trust in the decision-making process by being part of the process, etc.). The interplay of different effects of a particular NBS, and demonstration sites as a whole, together with their effects on the whole neighbourhood (and finding the extent of a "neighbourhood") is one the main tasks of euPOLIS and its assessment methods (see Baki et al., 2023 for more details on the setup of the euPOLIS assessment framework).

Future work. The project is currently in its implementation phase, with a focus on deploying a comprehensive monitoring system (network of sensors, smart wearables, remote sensing, digital and analog people and field surveys, workshops, interviews, etc.) and constructing NBS within the urban environment. This phase aims to collect valuable data and assess the effectiveness of NBS in enhancing public health and wellbeing. While progress is being made, it is important to acknowledge that determining the precise extent to which specific NBS characteristics contribute to these enhancements remains a task for further investigation. This attribution process will involve statistical analyses, modelling, and advanced data interpretation techniques. It requires a multidisciplinary approach involving environmental scientists, urban planners, public health experts, and social researchers, among others. Ultimately, the determination of the extent to which specific NBS characteristics contribute to enhancements in public health and wellbeing will provide valuable evidence for policymakers, urban planners, and stakeholders. This

knowledge will guide future decision-making processes regarding the design and implementation of NBS, ensuring that they are optimized to create sustainable, healthy, and resilient urban environments.

Acknowledgements

The work presented herein is part of the euPOLIS project. euPOLIS has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement number: 869448 – Integrated NBS-based Urban Planning Methodology for Enhancing the Health and Well-being of Citizens: the euPOLIS Approach. The authors would like to thank all partners within the euPOLIS project for their cooperation and valuable contribution.

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