TOWARDS HUMAN HEALTH, WELL-BEING AND SUSTAINABILITY: ESTABLISHING AND TESTING A KEY INDICATORS FRAMEWORK TAILORED FOR DIFFERENT TYPES OF GREEN SPACES

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ABSTRACT

The NATURELAB project aims to enhance green and blue spaces, strengthening climate resilience, biodiversity, and water management while promoting environmental, health, and societal benefits for a sustainable future. The type and quality of green spaces strongly influence health and well-being of the users, which is significant for the case of nature-based interventions (NBI). NATURELAB developed a *Framework of Key Indicators* to address this therapeutic potential and assess different nature spaces, namely i) forests and protected areas, ii) urban parks and healing gardens, and iii) horticultural or gardening spaces. The framework integrates cultural ecosystem services (CES) and resilience dimensions. It distinguishes indicators by complexity (Levels 1–3), and suitability for each of the nature contexts typologies. This work presents the framework as well as the results of its application to 14 project experimental sites (ES). This methodology can support city planners to implement nature-based solutions with high impact in the population's health and well-being.

Keywords: Forest; Urban Park; Health Status; Well-Being; Sustainability.

1. Introduction

Green spaces are increasingly recognised as essential for both public health and climate resilience (Hunter *et al.*, 2023; van den Bosch & Ode Sang, 2017; WHO, 2016). They provide ecosystem services, such as cooling, air purification, and noise reduction (Bratman *et al.*, 2019), and reduce risks of mental and physical illness while promoting human health (Hartig *et al.*, 2014). These benefits are associated with characteristics such as biodiversity, accessibility, and aesthetics (Barnes *et al.*, 2019; Felappi *et al.*, 2020; Nguyen *et al.*, 2021). Expanding health-specific outcomes, nature spaces enrich everyday life through cultural ecosystem services (CES), e.g., fostering education, social connection, and personal identity (Yang & Cao, 2022). Nature-based interventions (NBI; e.g., forest therapy, horticultural therapy) draw on the "nature–health link," though their effectiveness for promoting health and well-being varies by context and site characteristics (Shrestha *et al.*, 2025), as well as by the type of activity undertaken in green spaces (e.g., active vs. passive) (e.g. Ihle *et al.*, 2024).

2. Objective

The NATURELAB project addresses these challenges by developing a comprehensive Framework of Key Indicators to assess i) forests and protected areas, ii) urban parks and healing gardens, and iii) horticultural or gardening spaces. As a comprehensive approach linking environmental conditions, human health, and social impact, the framework also integrates sustainability and resilience, distinguishes between simple and complex measurements, and adopts a CES perspective. One of the project's objectives is to design, test and validate this indicator framework, based on comparative insights across 14 sites.

3. Methods

3.1. Framework development

An extensive literature review (Web of Science, PubMed, Google Scholar) informed the framework (Figure 1). Domains and dimensions were synthesised from systematic reviews, with indicators defined and linked to metrics and assessment methods. Expert validation was conducted by initialising several rounds of feedback on the framework at different stages of its development, conducting internal reviews along the process and external reviews after its completion.

The preliminary *Framework of Key Indicators* contains three overarching domains with multiple dimensions (Fernandes *et al.*, 2024). The first domain covers green space characteristics, including spatial, natural, and infrastructural properties, while the second addresses cultural ecosystem services. The third domain emphasizes sustainability and resilience, incorporating indicators such as water management, daylight exposure, thermal comfort, air quality, and soundscapes.

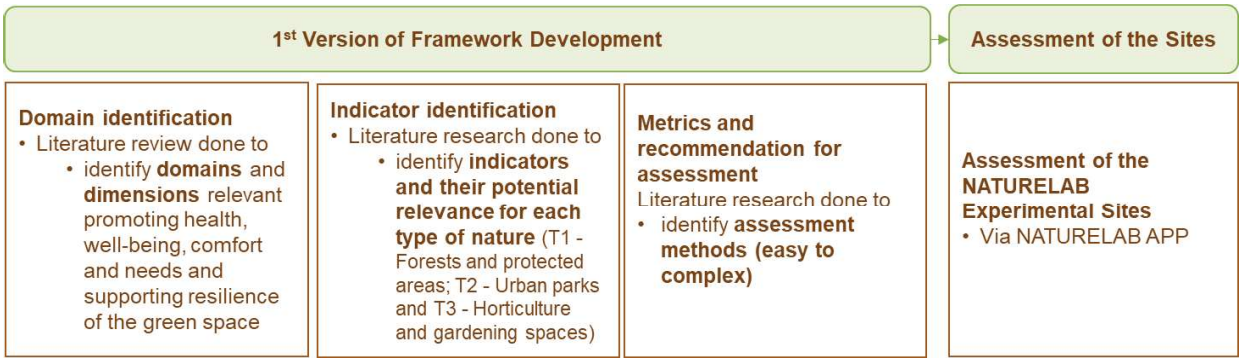


Figure 1. Flow-chart on the progress of the Framework of Key Indicators

3.2. Implementation

Fourteen experimental sites (ES) were selected. Data collection was supported by the NATURELAB App (ArcGIS Survey123). Each site was assessed in summer 2024 using the first framework version. The data collection ended in November 2024. Data was assessed across all sites. We grouped the ES (n = 14) by type (Type 1: n = 3; Type 2: n = 9; Type 3: n = 2). The cross-site data analysis provides insight into the relationships between sub-dimensions across types.

4. Results

This section presents key findings that highlight the framework's strengths and weaknesses.

4.1. Size

Heterogeneity across ES is evident, with ES1 being considerably larger than the other sites. Size of forests and protected areas (Type 1) ranged from 6.46 to 23,280.00 ha, urban parks (Type 2) from 0.04 to 45.00 ha, and horticultural/gardening spaces (Type 3) from 0.25 to 0.52 ha.

4.2. Green space characteristics

This part of the framework allows for a structured overview of site characteristics accompanied by quality ratings. Therefore, we used several sub-dimensions (e.g. facilities, accessibility, safety, maintenance, amenities, and attractiveness) of the RECITAL Assessment Tool (Knobel *et al.*, 2021). Notably, the framework allows to compare ES by their basic facilities as shown in Figure 2. Half of the ES provide grass pitches, Type 1 ES provide water-related features and most ES provide open multi-use spaces in good quality. Notably, disability adaptations score low overall (except for ES05 and ES07). Space entrances are generally adequate (except ES05, ES07), and walking paths meet standards in most locations (except ES12 and ES14). Safety features show the greatest dispersion: street lighting is consistently present at the Greek sites ES10–ES12); protection from car and bikes are uncommon (except ES07 and ES09). Cleanliness is high overall, though moderate litter is reported at ES07 and ES13. Problematic behaviors (e.g., vandalism) are rare, whereas noise and odors vary more, particularly in Peru (ES13, ES14), Portugal (ES02, ES03, ES04, ES06), and the Netherlands (ES07). Because RECITAL

(Knobel *et al.*, 2021) was designed for urban parks, results for Type 1 and Type 3 sites should be interpreted with some caution.

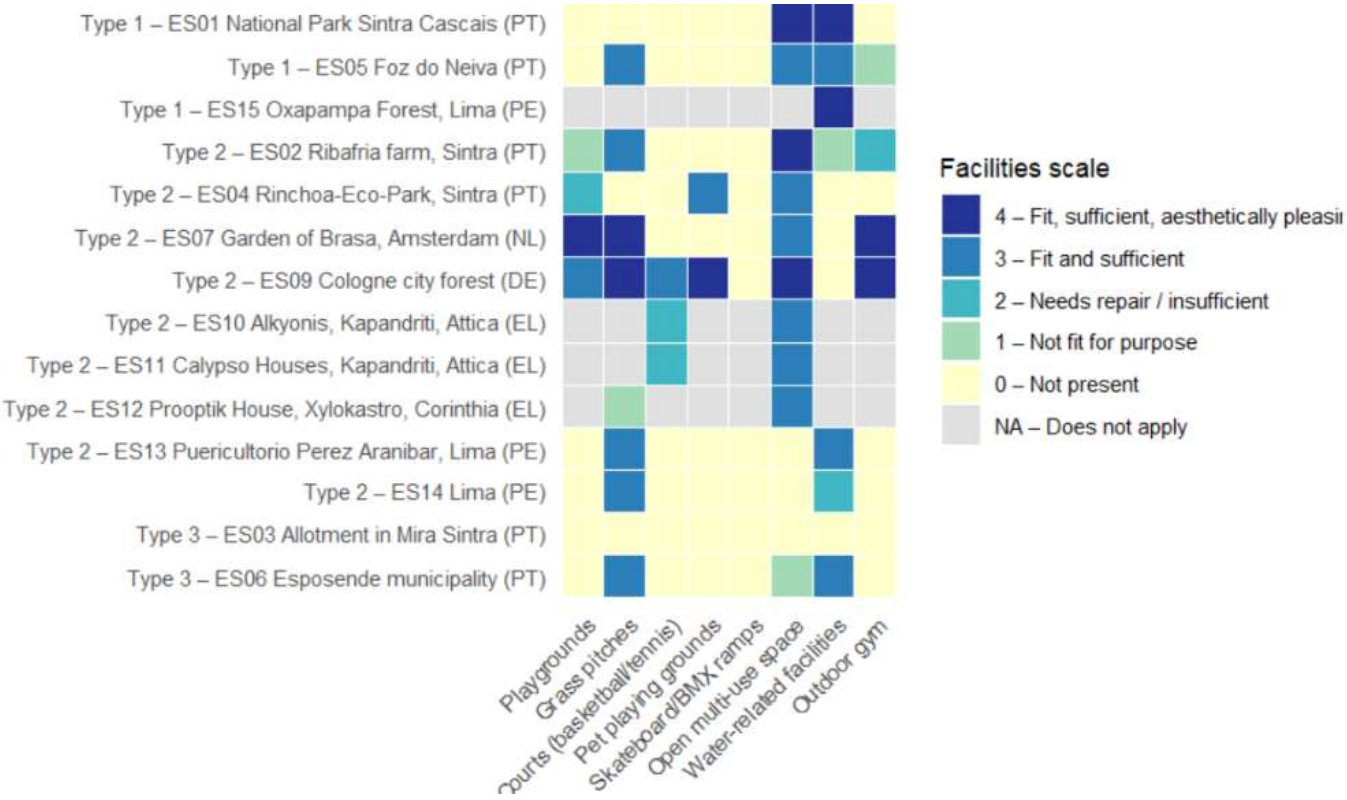


Figure 2. Presence and Quality of Facilities across all Sites

4.3 Cultural Ecosystem Services

The potential of sites to provide a range of cultural ecosystem services was assessed using the TESSA method "free listing tool" (based on TESSA method Cultural M1.C; Peh *et al.*, 2022). For Type 1 sites, benefits were more evenly distributed across categories, whereas for Type 2 sites, the most frequently reported benefits included mental and physical health, as well as a sense of place (feeling connected). The CES assessment also captured the main reasons for visiting the site, number of educational visitors, therapeutic use and social interaction for all sites.

4.4. Geophysical indicator

This section of the framework contained water management, daylight and solar radiation, climate context, air quality and sound measurements. The assessment required specialized equipment and technical expertise. This part of the framework also allowed for monitoring the sites and compare the data with common quality standards. Details on the approach, measurements and preliminary data related to the six ES Portuguese can be found in Barbosa *et al.* (2025).

5. Discussion

The preliminary evaluation of the framework demonstrates the value of integrating human health, climate resilience, and sustainability perspectives into the assessment of diverse types of green spaces. Its application across different ES highlighted both strengths and challenges. On the one hand, the framework proved effective in capturing multidimensional benefits of nature, from ecological resilience to cultural ecosystem services. On the other hand, initial testing revealed the need to distinguish indicators according to their relevance, measurability, and sensitivity to specific conditions of local contexts. Ultimately, developing a flexible and adaptive framework is critical for advancing evidence-based nature-based interventions and for supporting policies that link human health, well-being, and sustainability.

6. Conclusion

The NATURELAB project developed and tested a Framework *of Key Indicators* to evaluate forests, parks, and gardens in terms of health, well-being, and resilience. Ongoing refinement will ensure that it becomes a practical and scientifically sound tool to guide sustainable NBIs that can be used beyond the scope of the project.

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References

Barbosa, A. E., Fernandes, J. N., Cardoso, M. A., Santos, A., & Antunes, S. (2025). *NATURELAB study of indicators to assess nature spaces' potential to support communities' resilience and sustainability* (Report No. 97/2025; DHA/NRE). LNEC.

Barnes, M. R., Donahue, M. L., Keeler, B. L., Shorb, C. M., Mohtadi, T. Z., & Shelby, L. J. (2019). Characterizing nature and participant experience in studies of nature exposure for positive mental health: An integrative review. *Frontiers in Psychology, 9*, Article 2617. https://doi.org/10.3389/fpsyg.2018.02617

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., De Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., … Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances, 5*(7), Article eaa x0903. https://doi.org/10.1126/sciadv.aax0903

Felappi, J. F., Sommer, J. H., Falkenberg, T., Terlau, W., & Kötter, T. (2020). Green infrastructure through the lens of One Health: A systematic review and integrative framework uncovering synergies and trade-offs between mental health and wildlife support in cities. *Science of the Total Environment, 748*, 141589. https://doi.org/10.1016/j.scitotenv.2020.141589

Fernandes, J. N., Barbosa, A. E., Finkhäuser, M., Cardoso, A., Santos, A., Antunes, S., Schultner, J., Mühlan-Rehmer, H., & Schmidt-Schuchert, S. (2025). *Framework of key indicators to assess and categorize different types of nature spaces and their impact for therapeutic indications* (Deliverable D1.1). NATURELAB Project.

Hartig, T., Mitchell, R., De Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health, 35*(1), 207–228. https://doi.org/10.1146/annurev-publhealth-032013-182443

Hunter, R. F., Nieuwenhuijsen, M., Fabian, C., Murphy, N., O'Hara, K., Rappe, E., Sallis, J. F., Lambert, E. V., Dueñas, O. L. S., Sugiyama, T., & Kahlmeier, S. (2023). Advancing urban green and blue space contributions to public health. *The Lancet Public Health, 8*(9), e695–e706. https://doi.org/10.1016/S2468-2667(23)00156-1

Ihle, T., Jahr, E., Martens, D., Mühlan, H., & Schmidt, S. (2024). Health effects of participation in creating urban green spaces: A systematic review. *Sustainability, 16*(12), 5000. https://doi.org/10.3390/su16125000

Knobel, P., Dadvand, P., Alonso, L., Costa, L., Español, M., & Maneja, R. (2021). Development of the urban green space quality assessment tool (RECITAL). *Urban Forestry & Urban Greening, 57*, 126895. https://doi.org/10.1016/j.ufug.2020.126895

Nguyen, P.-Y., Astell-Burt, T., Rahimi-Ardabili, H., & Feng, X. (2021). Green space quality and health: A systematic review. *International Journal of Environmental Research and Public Health, 18*(21), Article 11028. https://doi.org/10.3390/ijerph182111028

Peh, K. S.-H., Balmford, A. P., Bradbury, R. B., Brown, C., Butchart, S. H. M., Hughes, F. M. R., Ingwall-King, L., MacDonald, M. A., Pellier, A.-S., Stattersfield, A. J., Thomas, D. H. L., Trevelyan, R. J., Walpole, M., & Merriman, J. C. (2022). *Toolkit for ecosystem service site-based assessment (TESSA)* (Version 3.0). http://tessa.tools

van den Bosch, M., & Ode Sang, Å. (2017). Urban natural environments as nature-based solutions for improved public health: A systematic review of reviews. *Environmental Research, 158*, 373–384. https://doi.org/10.1016/j.envres.2017.05.040

World Health Organization. (2016). *Urban green spaces and health*. WHO Regional Office for Europe.