Evaluating Nature-Based Solutions Impacts: A Preliminary Framing of Assessment Methods

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Abstract. Nature-based Solutions (NBS) are increasingly promoted to support resilient urban planning. However, integrating NBS into traditional urban planning requires knowledge about the NBS impacts within the environmental, economic, and social spheres. The objective of this paper is to contribute to this knowledge, by systematically identifying assessment methods 'both qualitative and quantitative' for NBS impacts evaluation. This literature review is not fully comprehensive, whereas this study represents a first attempt and aims at guiding future research in this field. The literature review is developed according to a threefold approach that represents the sustainability paradigm, i.e., environmental compatibility, economic development, and social equality. From the literature review imbalances are detected between the environmental, economic, and social spheres.

This contribution is addressed to public and private bodies dealing with NBS, regarding urban practitioners addressing a comprehensive NBS impacts assessment within urban and territorial transformations.

The results of this literature review underline criticalities in dealing with NBS issues comprehensively.

Keywords: Nature-Based Solutions (NBS) · Multiple impact evaluation · Monetary and non-monetary evaluation · Quanti-Qualitative assessment

1 Introduction

As cities are rapidly growing and densifying, urban green spaces play an increasingly vital role in the sustainability challenges associated with urbanization [1]. In Europe, over the latest years, funds such as the Next Generation Europe to the European Regional Development Fund are soliciting country members' governments at all levels with huge amounts of economic financing to invest in nature and secure the future for generations. Planning and evaluation of urban and territorial transformations are given great consideration to reach high and ambitious targets like climate neutrality and net zero

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emissions by 2050. In this exceptional time, it must be recognized that several of these efforts are remaining on charter. This becomes evident in some realities when these economic financings reach a local level (i.e. municipal, neighbourhood, or building). Good intentions clash with political, technical, and financial barriers. For example, the reporting of well-known and emerging best practices on budgeting the nature neutrality (e.g. Colombian, English, French, or Italian experiences [2–4]) seems to be still observed by local bodies through a "lanternosophy" approach; or it can happen that when public and private sectors are willing to cooperate, there is a high probability to unbalancing the project dimensions, sometimes due to policy agendas ticking and economic revenues. With an exception for strategic and pilot experiences, a foresight vision capable to orient the implementation of the project for a "Good Anthropocene" is still missing operatively (Bennet et al., 2016). On the one hand, new constructions look mainly at costs and revenues and risk investments to support and secure finance, even if private subjects often must agree on (environmental) mitigation and compensation actions with public bodies. Environmental quality, community safety, and well-being took a backseat too frequently and then excluded from the process cause of the lack of economic resources. The effects of these choices are quite evident showing their implication today. On the other hand, reconstruction and regeneration processes deal with (and should make that here and after) externalities to produce socio-economic benefits. Particularly, the need for a reform of public expenditure with regard to green finance should be evident to all the parties more than ever. The concept of Nature-based solutions (NBS) comes as an alternative that can act at several levels, being more than just an aesthetical improvement.

NBS appears as an attempt to face this issue. NBS is a term introduced by the European Commission (EC) in 2015. EU defines NBS as "*Solutions that aim to help societies address a variety of environmental, social, and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature, both using and enhancing existing solutions to challenges as well as exploring more novel solutions. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, in order to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth*" [5].

NBS are transversal to hot research topics such as ecosystem adaptation, green, blue, and grey infrastructures, Natural Climate Solutions (NCS), ecological engineering, Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM) [6].

In light of this evidence, the authors identified the following research questions: i) "*What are the tools that can support an integrated assessment and design of an NBS project?*", and ii) "*How to support a NBS implementation across the environmental quality, the social inclusion and safety, and the economic feasibility*?".

NBS is considered the new planning tool to overcome the boundaries of traditional approaches 'predict and prevent', while playing a crucial role in addressing societal challenges and providing benefits through the supply of Ecosystem Services (ES). By connecting people with nature, NBS have a proven positive impact on citizens' well-being such as on public health, physical and social resilience, equity, inclusiveness, and social equity [7]. At the same time, they can reduce the carbon footprint of cities, if wisely designed, constructed, and managed [8]. Their effects referred to ES depend on

the way the NBS are aligned with the physical, social, economic, and environmental driving forces in an urban district [9] or more in general in a territory.

The increasing attention to NBS impacts by proving their effectiveness influence positively the willingness to include these solutions in spatial transformations. Determining NBS costs distributed over time (within climate scenarios) helps to better integrate such solutions into urban and territorial planning and project design as well [10]. However, designing and evaluating long-term adaptation strategies is still a challenge [11]. They depend on complex and uncertain factors that cannot be all foresighted, but it is possible to envision impacting strategies, thanks to the support of scenario-based tools [12, 13]. The various methodologies that can assess a wide range of NBS impacts within the environmental, economic, and social challenges, demonstrate the NBS impacts assessment framework as complex and interdisciplinary. Therefore, the current demand is providing a comprehensive evaluation framework that embraces all the NBS implementation aspects [14].

The objective of this study is to review the NBS impacts assessment methods by collecting and analyzing the existing quanti-qualitative methodologies within the environmental, economic, and social spheres. These spheres were selected because they represent the pillars of sustainable development, which NBS implementation strives to implement and achieve in its multidimensionality. Hence, this contribution represents a first attempt to collect such methodologies in an integrated way to support climate change adaptation planning.

This study is addressed to both public and private bodies, with attention on urban practitioners in addressing a more comprehensive NBS impacts assessment while helping to integrate such solutions in spatial planning strategies and project interventions.

2 Methodology

This study proposes a preliminary insight to collect qualitative, quantitative, monetary, and non-monetary evaluation frameworks to address NBS impacts in urban and territorial transformations, according to the social, economic, and environmental dimensions. Three different preliminary literature reviews are developed according to the threefold force of the sustainability paradigm (Fig. 1).

The first review concerns the identification of the most applied evaluation methods in the environmental field. The second review is of economic type, that collects the main valuation techniques to estimate NBS feasibility in both the economic-financial and the socio-economic terms, along the project cycle and alternative solutions. The third review is a preliminary insight to collect several assessment frameworks applied in the social sphere to address the social impacts of NBS implementation.

This methodological research aims to deliver an overview of the most applied evaluation methods of the environmental, economic, and social spheres, that are retained and suitable for NBS design, construction, and implementation while examining both shortcomings and challenges. The three literature reviews go beyond the single-based risk approach to focus on the multiple risks assessment (e.g., floods, landslides, heatwaves, or climate change, among others).

The three reviews have been developed parallelly and have been carried out using the same methodological framework (Fig. 1). The expected output is to integrate the results

of each review into an overall discussion to support the final users actively involved in the NBS project and assessment phases.

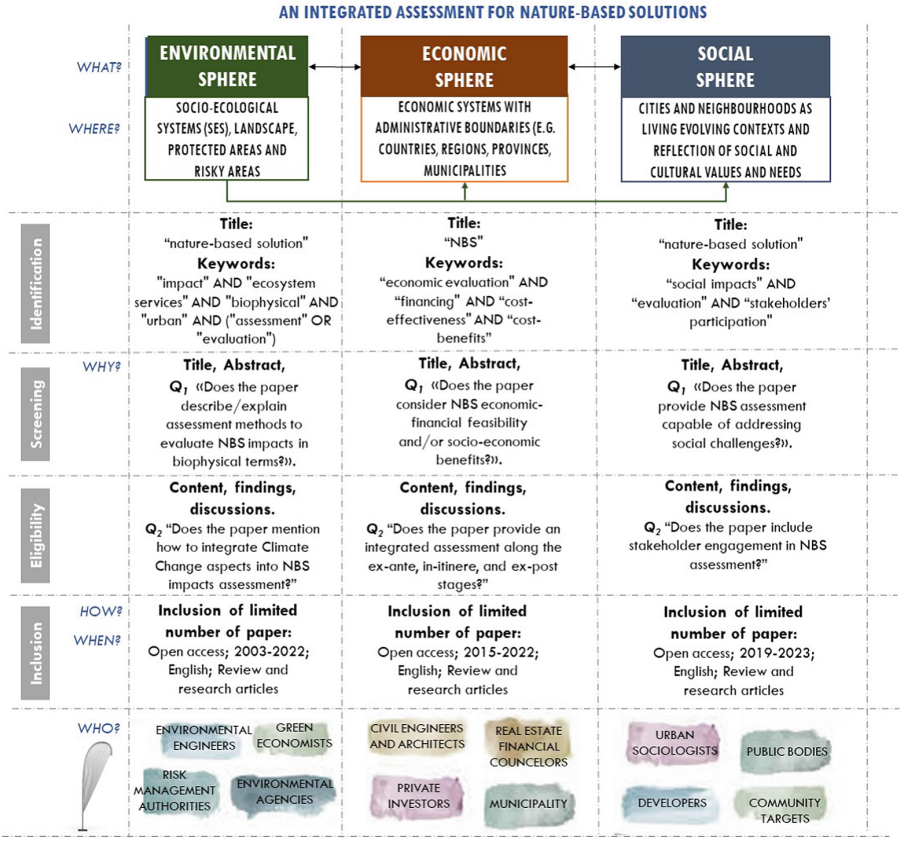

Fig. 1. Threefold review of NBS environmental, economic, and social spheres.

3 Analysis of the Evaluation Methodologies

In this paper, the attention is devoted only to publications of relevant literature, with the purpose to deepen this analysis and including policy documents and reports in a next study of the authors. The research was performed using the Scopus platform, according to the environmental, economic, and social lens.

3.1 Environmental Sphere

For the systematic literature review, the search of peer-reviewed articles was limited to the last 20 years, from 2003 to 2022. The concept of NBS is very recent, thus making it

unnecessary to account for a longer time span. The articles were retrieved from Scopus in April 2023 using a search string by including various terms (see Fig. 1).

The screening phase (see criteria in Fig. 1) was performed to analyse papers describing quantitative or qualitative environmental assessment methods in urban contexts. As results of the search phase, 36 articles (review and research peer reviewed papers) of which only 19 are open access. Results from the abstract screening gave a number of three articles (see Table 1). Those papers excluded are focused on the concept of urban resilience, or ecosystem services mapping as well as the stakeholders risk perception to promote NBS, or specific on agricultural field (for example [15–17]).

Raymond et al. (2017) presented a set of principles to ensure holistic co-benefit assessments. The need to consider how to monitor and evaluate the effectiveness of NBS interventions into any NBS policy is crucial as well as considering how such assessments are embedded within a holistic process of option selection.

Table 1. Contributions found on NBS environmental sphere.

Authors and year	Description	Risk typology	Spatial dimension	Climate change aspect
Raymond et al. (2017) [20]	Holistic assessment framework for NBS co-benefits (and costs): socio-cultural and socio-economic systems, biodiversity, ecosystems, and climate	Multi-risk	Not mentioned	Not mentioned
Kumar et al. (2021) [19]	Review on methods, including ground-based measurements (e.g., gauging stations, wireless sensor network) and remote sensing observations used to monitor the performance of NBS	Hydro-meteorological risk (floods, droughts, heatwaves, landslides, storm surges and coastal erosion)	Not mentioned	Not mentioned
Ommer et al. (2022) [18]	Development of a comprehensive guidance on quantitative pre-assessment of potential co-benefits and disbenefits of NBS tackling Disaster Risk Reduction (DRR)	Multi-risk	Not mentioned	General overview

Later, another attempt to review existing NBS co-benefit assessment frameworks and quantification methods has been done [1]. Ommer et al. (2022) reviews methodologies that can be adopted for the pre-assessment of NBS co-benefits and disbenefits. This analysis summarizes frameworks and tools introduced into NBS assessment by presenting their focus, assessment type, and approached indicators [18].

More in detail, Kumar et al. (2021) presents various NBS performance indicators for the ecological/environmental sphere focused on the hydro-meteorological risk [19].

3.2 Economic Sphere

Before providing a literature review on the economic sphere, some preliminary remarks are needed. In the latest years, NBS have been (re)discovered by investors as capable of expressing a "good value for money"[21]. This is a high opportunity to get in this historical time. On the one hand, the global economy uncertainty and carrying at the same time secure and predictable revenues. On the other hand, the attention on losses, damages, and effects unequally distributed at spatial and social levels [22]. This can facilitate to rethink the design and planning of territory under Climate Change, thus looking for a zeroing of land and biodiversity degradation. The United Nations Environmental Programme (UNEP) published a financial gap equal to about USD 403 billion/year, where USD 133 billion/year are invested in NBS, whereas USD 536 billion/year are financing that need of NBS [23]. Yet finance flows to NBS are currently only USD 154 billion/year, which is less than half of the USD 384 billion/year investment in NBS needed by 2025 and only one-third of the investment needed by 2030 (USD 484 billion/year) [24]. Public-private partnerships play a crucial role to enable the environment's quality as capitalization of private capital. Even if this scenario is very appealing, its implementation in the next future will depend on governance, such as green public reforms in countries with different systems of governments, new forms of investment, or the estimation of NBS benefits as loan from the future.

The support of both traditional and novel economic tools can make the change happen. The location area, the project intentionality, and the *desiderata* by economic subjects (i.e. public bodies, developers, banks, real estate and financial advisors) can lead to the building of an economic framework by choosing specific evaluation tools and not others. Additional factors are the NBS level (e.g. building blocks, transformation areas, or water bodies) and the expected transformation. For example, a NBS project should strategically be supported by localisation studies to identify the most suitable site in terms of environmental compatibility, social well-being, and economic income [25].

NBS financial sustainability and intentionality are crucial requirements for feasibility investment, thus making even more central the common saying "no budget, no party". The project feasibility must satisfy both costs and revenues by considering profitability indicators to well support socio-economic benefits estimation. The NBS catalogue for urban resilience by World Bank provides costs grouped in costs of land, construction and implementation, and maintenance [26]. They can vary according to country, location, projects factors, and to general market rules that may influence on land, labor, and material prices.

In the light of this context, a set of queries have been submitted in the Scopus database by considering the combination of the following keywords:

- Q1 "NBS" AND "economic evaluation" = 18 results They are all ranged between 2015 and 2022. Most of the results belong to subject areas out of the topic of this paper (e.g. "Medicine", or "Immunology and Microbiology"). They are filtered and only three studies are considered ("Environment Science", "Agricultural and Biological Science", and "Social Science");
- Q2: "NBS" AND "economic evaluation" AND "financing" = One result. The addition of "financing" keyword has drastically reduced the results [6];
- Q3: "NBS" AND "monetary" AND "decision making"= One result. The study [27] surveys both contextual and attitudinal domains of NBS to identify barriers and drivers related to flood risk;
- Q4: "NBS" AND "cost-effectiveness" AND "co-benefits"= Six results. To complete the literature review with the investigation of NBS and socio-economic, a last query was submitted to Scopus, by changing the query. They are centered on subject areas "Environmental science" and "Social Science", "Earth and Planetary Science", and "Energy".

Despite the high interest in the field, the literature search has highlighted that economic part is not sufficiently explored yet than the environmental and social spheres. In fact, despite the changing and/or addition of keywords of the queries, few meaningful results are found and retained suitable for the aim of the paper (Table 2):

Table 2. Contributions found on NBS economic sphere.

Author and Year	Description	Project phases		
		Project idea	Definition project	Executive project
Wild et al. (2017) [28]	Comparison of benefits of urban greening development scenarios	√	√	
Hagedoon et al. (2021) [6]	NBS economic evaluation through stated preference methods, focusing on time than monetary contributions	√		
Quagliolo et al. (2022) [10]	Cost and benefits for NBS implementation and costs of operation and maintenance	√	√	√
Raymond et al. (2017) [20]	Seven-stage process for co-benefit assessment within policy and project implementation	√	√	

(*continued*)

Table 2. (*continued*)

Author and Year	Description	Project phases		
		Project idea	Definition project	Executive project
Debele et al. (2019) [29]	NBS costs, benefits, and effectiveness for hard engineering structures for the management of HMR impact	√	√	
Kumar et al. (2021) [19]	Assessments of NBS performance in different risky contexts, according to a co-construction approach in the experimentation and modelling	√	√	√
Menon (2021) [30]	NBS cost-effectiveness as a remedy and generation of co-benefits for health and biodiversity	√	√	
Vail Castro (2022) [31]	Optimization tools to support NBS in hydrological, environmental, and social co-benefits (SWMM, Gini index)	√	√	√

Even if these keywords stressed a hole in this NBS arena, it is possible to detect a slight increase in publications. The selected studies look for monetization of NBS benefits and the produced ES as a revenue stream. Most of the contributions concentrate on the estimation of NBS benefits, damage cost, avoided costs, and the difficulty of standardizing procedures to monetize the value (i.e. use and non-use).

There is also a certain short-sightedness on the financing issue in terms of lack of suitable financial instruments, high transaction costs for small project sizes, and the lack of tracked financial performance increase thus the perception of risk to invest in NBS. In addition, governments priorities agendas and the financial coping capacity of the world countries could influence the budget availability, amplifying in some cases the scissors between developed and developing countries [6].

Hence, the authors make a parallelism to state that economic techniques traditionally employed in the fields of building engineering, architecture, and spatial planning, can be adapted to estimate the NBS economic value. Indeed, awareness has only recently been raised to include construction and implementation costs in an integrated vision (and thus together environmental and social features). Moreover, technical project and economic evaluations are strictly related for their parallel and simultaneous development.

The following techniques can support the several phases of an NBS project, from the idea, passing from the design, until to the project as-built (Table 3). These are listed according to the approach, the project phases, and the contribution that each one can provide to NBS. Some of them can be replicated in more phases for a refinement of the

project evaluation, such as the Life Cycle Costing Analysis (LCCA) or the Multi-Criteria Analysis (MCA).

Table 3. Overview of economic techniques according to the NBS project cycle phases

Project phases	Economic approach	Techniques	Contribution
Phase 1 – Project idea	Synthetic	Parametric estimating	Span evaluation of the project based on parameter(s) to identify the scale of project costs
Phase 2 – Definitive Project	Mixed	Multi-Criteria Analysis (MCA)	Identification of the most suitable project between alternatives. Project actions ranking
		Single and Multiple Regression Analysis (MRA)	Estimation of benefit or damage to obtain a variation in well-being. Willingness to Pay (WTP) / Willingness to Accept (WTA) for an NBS and/or damages that can be prevented/mitigated by the project
		Discount-Cash Flow Analysis (DFCA)	Provision of the future cash-flows, including timing, entity and investment risk
		Cost-Benefit Analysis (CBA)	It complements feasibility study of the project through the estimation of the effects of a public investment and including alternative locations of resources
		Life Cycle Cost Analysis (LCCA)	Obtaining of the lowest whole project cost, in terms of construction, implementation, management and dismission. Possible refinement for a lowering of costs

(*continued*)

Table 3. (*continued*)

Project phases	Economic approach	Techniques	Contribution
		Life Cycle Cost-Effectiveness (LCCE)	Estimation of project costs and selection of the best investment program
		Sales Comparison Approach (SCA) or General Appraisal System (GAS)	Estimation of the NBS value market through a comparison with similar comparable
Phase 3 – Executive Project	Analytic	Estimate Metric Calculation (EMC)	Measurement of project elements and cost estimation on related prices
Phase 4 – Project as Built	Mixed	Direct costing or Full costing or Activity Based Costing (ABC)	Management control of the costs based on the project activities
		Monitoring indicators	Key Performance Indicators (KPI) indicators for the achievement of objectives, the project performance during the construction and after the implementation

3.3 Social Sphere

As for the other analysed spheres, before discussing the specific literature review, it is useful to underline some preliminary remarks. The NBS is actually proposed in urban systems to address and face the current challenge and support cities in the transition to sustainable development. Moreover, the interest in this type of intervention is increasing according to their ability to address social challenges [32] and mitigate the exposure of the population to environmental hazards and other risks related to climate change [14].

According to this statement declared by the literature, a preliminary literature review about the evaluation of NBS impacts in the social sphere was made using the Scopus database. A set of research questions have been asked in the Scopus platform considering the combination of the following keywords, to select only papers in journals:

- "Nature-based solutions" AND "social impacts" = 13 results. These papers are inserted in the time between 2021 and 2023. This fact strongly underlines the novelty of this research topic. They are mainly related to the topic of environmental science and policy and one of the listed papers discusses the problem of green gentrification. However, no none of the listed papers proposes an evaluation framework to be used to evaluate social impacts, or they are not strictly focused on the NBS.

- "Nature-based solutions" AND "social impacts" = 0 result.
- "Nature-based solutions" AND "social impacts" = 0 result.
- "Nature-based solutions" AND "evaluation" AND "social impacts" = Two results. These two papers belong to 2022 and they do not provide a method to assess social impacts, but they address the topic of social impacts evaluation through a methodological framework.

According to these results, other questions have been queried, enlarging the perspective of the research domain. In fact, it addressed the dimension of social participation. Therefore, the question asked is the following:

- "Nature-based solutions" AND "stakeholders' participation" = 21 results. In this case, the time reference is from 2019 to 2023.

Therefore, discussing and providing some critical reflections about the developed literature review is possible.

First of all, the exploration of this topic is very recent, as underlined by the time scales of the results and the small number of papers.

Secondly, most of the considerable papers propose a qualitative evaluation framework constructed by interviews and questionnaires, such as the case study of Barcelona [33, 34].

Thirdly, the stakeholders engagement is the most discusses topic dealing with NBS and the social sphere, due to the fact that the participation of stakeholders is crucial for the effective implementation and management of NBS [14, 35]. In fact, a solution should be ideal from an environmental point of view but it may not be accepted by society [35].

Moreover, it is also necessary to underline that most of the social issues of NBS are evaluated through the ES approach [20].

4 Conclusion and Future Perspectives

This paper has explored the most relevant evaluation approaches suitable to assess NBS impact in the social, economic, and environmental spheres, according to the fact that NBS implementation aims to achieve sustainable development in its multidimensionality [1, 4, 36]. Existing research supported the state of the art of the fact NBS and have the potential to simultaneously provide multiple benefits [14, 37].

NBS can play a very important role within strategic guidelines and recommendations being defined such as for superordinated spatial planning (e.g. metropolitan level, or basin level), to be adopted as technical references within the revision of regulatory planning and in the design of the vision of new municipal plans. This can help public authorities to define the most performing solution in terms of environmental, social, and economic sustainability [38].

The review on the environmental sphere has highlighted that pre-assessment of ecological indicators is more commonly practiced than of socio-economic indicators as the mirror of the global challenges of socio-economic data collection and availability. At the same time, certain direct environmental impacts of NBS have been more researched and documented (e.g. flood protection, habitat conservation) and often focused on their effectiveness to mitigate climate change effects on urban areas. However, frameworks on

how to integrate climate change scenarios into NBS impacts assessment in terms of bio-physical effects are missing and the research on this topic is still scarce and fragmented [14].

The main findings of the performed reviews concern the evidence of major gaps in the field of NBS evaluation, especially in the economic and social spheres. On the other hand, the most examined topic concern the assessment of the environmental impacts.

As a future perspective to follow the extended research of the authors, the next steps will use the same approach for the three spheres, thus looking for potentially different results.

The study proposed by Dimitru and colleagues (for reference please see the paper [14]) states that environmental impacts are specifically addressed in 60% of the reviewed articles, while only about 30% address social and health-related impacts, and about 10% economic impacts [14].

Therefore, from this preliminary insight, it is possible to state that the evaluation of the potential impacts of NBS on social, and economic outcomes are understudied and not systematically evaluated today.

A fruitful exploration of the economic frontiers emerges: revenue streams, fiscal interventions (e.g. Tax Increment Financing [39]) flood risk insurance [40], carbon credits [41], Biodiversity-Net Gain (BNG), and nutrient neutrality; public-private partnership to decrease the risk of investment, integrating NBS within traditional projects to influence the size of the investment.

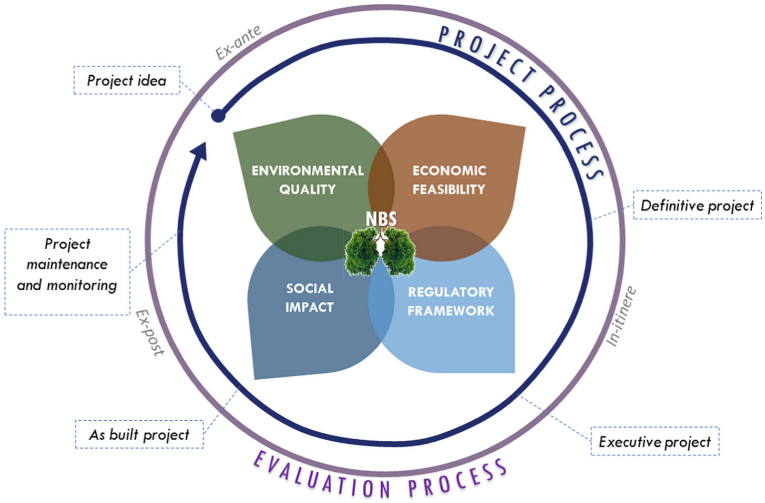

Fig. 2. NBS integrated assessment within real project and evaluation processes.

The multi-directional effects of NBS underline the importance of a holistic approach to their design, construction, and implementation in spatial context by considering both synergies and potential trade-offs [20, 42–45] (Fig. 2).

Co-participation, co-evaluation, and co-design are three fundamental pillars for a winning NBS [46]. In this sense, frameworks like Geo-design can help the communication and the integration of NBS intervention in a territory according to landscape and urban characteristics. Geodesign can promote merging economic, social, and environmental interests into shared solutions [47].

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References

1. Davis, M., Naumann, S.: Making the case for sustainable urban drainage systems as a nature-based solution to urban flooding. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (eds.) Nature-based Solutions to Climate Change Adaptation in Urban Areas. TPUST, pp. 123–137. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-56091-5_8
2. Landholm, D., et al.: Unlocking nature-based solutions in Colombia: Technical Report Unlocking nature-based solutions in Colombia TECHNICAL REPORT Unlocking nature-based solutions in Colombia: Technical Report (2022)
3. Serra-Llobet, A., et al.: Restoring Rivers and Floodplains for Habitat and Flood Risk Reduction: Experiences in Multi-Benefit Floodplain Management From California and Germany. Frontiers Media S.A. (2022). https://doi.org/10.3389/FENVS.2021.778568/BIBTEX
4. Stafford, R., et al.: Nature-based solutions for climate change in the UK: a report by the British ecological society the British ecological society (2021)
5. European Environmental Agency (EEA): Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction. , Copenhagen, Denmark (2021)
6. Hagedoorn, L.C., Koetse, M.J., van Beukering, P.J.H., Brander, L.M.: Reducing the finance gap for nature-based solutions with time contributions. Ecosyst. Serv. **52**, 101371 (2021). https://doi.org/10.1016/J.ECOSER.2021.101371
7. European Environmental Agency (EEA): Urban adaptation to climate change in Europe - Challenges and opportunities for cities together with supportive national and European policies. , Luxembourg (2012). https://doi.org/10.2800/41895
8. Grêt-Regamey, A., Altwegg, J., Sirén, E.A., van Strien, M.J., Weibel, B.: Integrating ecosystem services into spatial planning—a spatial decision support tool. Landsc. Urban Plan. **165**, 206–219 (2017). https://doi.org/10.1016/J.LANDURBPLAN.2016.05.003
9. Langemeyer, J., Wedgwood, D., McPhearson, T., Baró, F., Madsen, A.L., Barton, D.N.: Creating urban green infrastructure where it is needed – a spatial ecosystem service-based decision analysis of green roofs in Barcelona. Sci. Total Environ. **707**, 135487 (2020). https://doi.org/10.1016/j.scitotenv.2019.135487
10. Quagliolo, C., Roebeling, P., Mendonça, R., Pezzoli, A., Comino, E.: Integrating biophysical and economic assessment : review of nature-based adaptation to urban flood extremes. Urban Sci. **6**, 1–23 (2022)
11. Aerts, J.C.J.H.: A review of cost estimates for flood adaptation. Water (Switzerland) **10**, 1646 (2018). https://doi.org/10.3390/w10111646
12. Godet, M.: The art of scenarios and strategic planning: tools and pitfalls. Technol. Forecast. Soc. Change. **65**, 3–22 (2000). https://doi.org/10.1016/S0040-1625(99)00120-1

13. Amer, M., Daim, T.U., Jetter, A.: A review of scenario planning. Futures **46**, 23–40 (2013). https://doi.org/10.1016/J.FUTURES.2012.10.003
14. Dumitru, A., Frantzeskaki, N., Collier, M.: Identifying principles for the design of robust impact evaluation frameworks for nature-based solutions in cities. Environ. Sci. Policy. **112**, 107–116 (2020). https://doi.org/10.1016/j.envsci.2020.05.024
15. Sarabi, S., Han, Q., de Vries, B., Romme, A.G.L.: The nature-based solutions planning support system: a playground for site and solution prioritization. Sustain. Cities Soc. **78**, 103608 (2022). https://doi.org/10.1016/j.scs.2021.103608
16. Kumar, B.M., Kunhamu, T.K.: Nature-Based Solutions Nature-based solutions in agriculture : a review of the coconut (Cocos nucifera L .) -based farming systems in Kerala, the Land of Coconut Trees. Nature-Based Solut. **2**, 100012 (2022). https://doi.org/10.1016/j.nbsj.2022.100012
17. Santoro, S., Pluchinotta, I., Pagano, A., Pengal, P., Cokan, B., Giordano, R.: Assessing stakeholders' risk perception to promote Nature Based Solutions as flood protection strategies: the case of the Glinščica river (Slovenia). Sci. Total Environ. **655**, 188–201 (2019). https://doi.org/10.1016/j.scitotenv.2018.11.116
18. Ommer, J., et al.: Quantifying co-benefits and disbenefits of nature-based solutions targeting disaster risk reduction. Int. J. Disast. Risk Reduct. **75**, 102966 (2022). https://doi.org/10.1016/j.ijdrr.2022.102966
19. Kumar, P., et al.: Nature-based solutions efficiency evaluation against natural hazards: modelling methods, advantages and limitations. Sci. Total Environ. **784**, 147058 (2021). https://doi.org/10.1016/j.scitotenv.2021.147058
20. Raymond, C.M., et al.: A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environ. Sci. Policy. **77**, 15–24 (2017). https://doi.org/10.1016/j.envsci.2017.07.008
21. Hall, C.: Nature-based Solutions "Good Value for Money" – UN – ESG Investor, https://www.esginvestor.net/nature-based-solutions-good-value-for-money-un/. Accessed 05 Apr 2023
22. Kosolapova, E., Rosen, T., Templeton, J., Wagner, L.: State of Global Environmental Governance. International Institute for Sustainable Development Earth Negotiations Bulletin (2022)
23. United Nations: UN Environment Programme Annual Report. https://wedocs.unep.org/bitstream/handle/20.500.11822/37946/UNEP_AR2021.pdf. Accessed 31 Mar 2023
24. Wild, T., Bulkeley, H., Naumann, S., Vojinovic, Z., Calfapietra, C., Whiteoak, K.: Nature-based solutions: State of the art in EU-funded projects (2020). https://doi.org/10.2777/236007
25. Bottero, M., Mondini, G.: Valutazione e sostenibilità. Piani, programmi, progetti. CELID (2009)
26. World Bank: A Catalogue of Nature-Based Solutions for Urban Resilience. , Washington D.C. (2021)
27. Han, S., Kuhlicke, C.: Barriers and drivers for mainstreaming nature-based solutions for flood risks: the case of South Korea. Int. J. Disast. Risk Sci. **12**(5), 661–672 (2021). https://doi.org/10.1007/s13753-021-00372-4
28. Wild, T.C., Henneberry, J., Gill, L.: Comprehending the multiple 'values' of green infrastructure – valuing nature-based solutions for urban water management from multiple perspectives. Environ. Res. **158**, 179–187 (2017). https://doi.org/10.1016/J.ENVRES.2017.05.043
29. Debele, S.E., et al.: Nature-based solutions for hydro-meteorological hazards: revised concepts, classification schemes and databases. Environ. Res. **179**, 108799 (2019). https://doi.org/10.1016/J.ENVRES.2019.108799
30. Menon, J.S., Sharma, R.: Nature-based solutions for co-mitigation of air pollution and urban heat in Indian cities. Front. Sustain. Cities. **3** (2021). https://doi.org/10.3389/FRSC.2021.705185

31. Vail Castro, C.: Optimizing nature-based solutions by combining social equity, hydro-environmental performance, and economic costs through a novel Gini coefficient. J. Hydrol. X. **16** (2022). https://doi.org/10.1016/J.HYDROA.2022.100127
32. Pauleit, S., Zölch, T., Hansen, R., Randrup, T.B., Konijnendijk van den Bosch, C.: Nature-based solutions and climate change – four shades of green. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (eds.) Nature-based Solutions to Climate Change Adaptation in Urban Areas. TPUST, pp. 29–49. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-56091-5_3
33. Ramírez-Agudelo, N.A., Badia, M., Villares, M., Roca, E.: Assessing the benefits of nature-based solutions in the Barcelona metropolitan area based on citizen perceptions. Nature-Based Solut. **2**, 100021 (2022). https://doi.org/10.1016/j.nbsj.2022.100021
34. Giordano, R., Pluchinotta, I., Pagano, A., Scrieciu, A., Nanu, F.: Enhancing nature-based solutions acceptance through stakeholders' engagement in co-benefits identification and trade-offs analysis. Sci. Total Environ. **713**, 136552 (2020). https://doi.org/10.1016/j.scitotenv.2020.136552
35. Sowińska-Świerkosz, B., García, J.: A new evaluation framework for nature-based solutions (NBS) projects based on the application of performance questions and indicators approach. Sci. Total Environ. **787**, 147615 (2021). https://doi.org/10.1016/j.scitotenv.2021.147615
36. Commission, E., et al.: Nature-based solutions : state of the art in EU-funded projects. Publications Office of the European Union (2020). https://doi.org/10.2777/236007
37. Haase, D., et al.: A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. Ambio **43**(4), 413–433 (2014). https://doi.org/10.1007/s13280-014-0504-0
38. Stanganelli, M., Torrieri, F., Gerundo, C., Rossitti, M.: A strategic performance-based planning methodology to promote the regeneration of fragile territories. In: La Rosa, D., Privitera, R. (eds.) INPUT 2021. LNCE, vol. 146, pp. 149–157. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-68824-0_16
39. Toxopeus, H., Polzin, F.: Reviewing financing barriers and strategies for urban nature-based solutions. J. Environ. Manag. **289**, 112371 (2021). https://doi.org/10.1016/J.JENVMAN.2021.112371
40. Vannucci, E., Pagano, A.J., Romagnoli, F.: Climate change management: a resilience strategy for flood risk using Blockchain tools. Decis. Econ. Financ. **44**, 177–190 (2021). https://doi.org/10.1007/S10203-020-00315-6/TABLES/4
41. Uzsoki, D., Casier, L., Wuennenberg, L.: Financial instruments to create and maintain NBS. In: Croci, E., Lucchitta, B. (eds.) Nature-Based Solutions for More Sustainable Cities – A Framework Approach for Planning and Evaluation, pp. 255–266. Emerald Publishing Limited (2021). https://doi.org/10.1108/978-1-80043-636-720211021
42. Bravi, M., Bottero, M., Dell'Anna, F.: An application of the life satisfaction approach (LSA) to value the land consumption and ecosystem services. J. Knowl. Econ. (2023). https://doi.org/10.1007/S13132-023-01150-X
43. Dell'ovo, M., Bassani, S., Stefanina, G., Oppio, A.: Memories at risk: How to support decisions about abandoned industrial heritage regeneration. Valori e Valutazioni. **2020**, 107–115 (2020)
44. Caprioli, C., Bottero, M., De Angelis, E.: Combining an agent-based model, hedonic pricing and multicriteria analysis to model green gentrification dynamics. Comput. Environ. Urban Syst. **102**, 101955 (2023). https://doi.org/10.1016/J.COMPENVURBSYS.2023.101955
45. Colucci, E., et al.: Documenting cultural heritage in an INSPIRE-based 3D GIS for risk and vulnerability analysis. https://doi.org/10.1108/JCHMSD-04-2021-0068

46. Kumar, P., et al.: Towards an operationalisation of nature-based solutions for natural hazards. Sci. Total Environ. **731**, 138855 (2020). https://doi.org/10.1016/J.SCITOTENV.2020.138855
47. Somma, M., Campagna, M., Canfield, T., Cerreta, M., Poli, G., Steinitz, C.: Collaborative and sustainable strategies through geodesign: the case study of bacoli. In: Gervasi, O., Murgante, B., Misra, S., Rocha, A.M.A.C., Garau, C. (eds) Computational Science and Its Applications – ICCSA 2022 Workshops. ICCSA 2022. Lecture Notes in Computer Science, vol. 13379, pp. 210–224. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10545-6_15