

Sustainability Framework for Revealing and Analysing the Co-benefits of Nature-based Solutions to Urban Water Challenges

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Abstract

The traditional approach towards urban water infrastructure elements is forced to change by the severe impacts of climate change. Nature-based solutions (NBS) addressing urban water challenges have recently prevailed for their potential to provide multiple co-benefits. However, the evaluation processes of NBS implementations usually lack the inclusion of co-benefits. This paper aims to assess the performance of flood-oriented NBS applications in delivering various co-benefits. To do this, we introduced a categorization of the identified challenges for the selected projects from NATURVATION Atlas. Eight challenges are associated with environmental, social and economic co-benefits. The governance features and costs were analysed as well as the expected co-benefits of the selected projects. The examined NBS projects indeed contributed to environmental sustainability. More than half of them achieve social benefits, and additional economic benefits can be found in less than a fifth of them. The participation of certain governmental bodies and civil society elements is more likely to bring co-benefits. The analysis implies that projects with multiple benefits require larger budgets. By raising the awareness of the importance of the inclusion of different societal challenges in the planning and implementation phase, the participating actors can promote the multiple benefits approach within the NBS projects.

Keywords: Nature-based Solution, Climate Change, Urban Water Challenges, Flood Protection, Co-benefits, Sustainability Assessment Framework

1. Introduction

Ecosystem-based approaches are promising instruments to serve breakthrough contributions to resilience and sustainability thanks to their functions and benefits. Accordingly, they have been recognized as keys to successful adaptation in the UNFCCC negotiations since 2009 meeting of the Conference of Parties (Uy et al., 2016). In addition, IPCC (2012) recognized investing in ecosystems as a low-regret measure (Uy et al., 2016). Ecosystem-based approaches can be categorized into five categories (i.e., restoration, issue-specific, infrastructure, management, and protection) and nature-based solutions (NBS) serve as an umbrella covering all of the implementations related to these categories (Cohen-Shacham et al., 2019). The concept evolved from previous concepts and principles such as sustainability, ecosystem services and green infrastructure with a focus on multiple benefits (Lafortezza et al., 2018). Therefore, they offer an integrated perspective to address environmental, social and economic challenges (Raymond et al. 2017a; Watkin et al. 2019; Hanson et al. 2020; Davies et al. 2021). They are likely to reduce the dependency on costly

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traditional infrastructure which consists of limited objectives, while providing various benefits through less costly and durable applications (European Commission 2013). The EU's research & innovation (R & I) policy suggests focusing on multiple benefits approach of NBS, such as biodiversity and ecosystem services for innovation, growth and job creation as research area (European Commission 2015). It is encouraged to move from the assessment and valuation of ecosystem services to a more comprehensive assessment of co-benefits of NBS through the lens of co-production of ecosystem services (Cohen-Shacham et al. 2016). NBS also play a critical role in the transition towards sustainability, and this requires a change in mindsets, structure and practices (Nevens et al. 2013; van de Jagt et al. 2020; Davies et al. 2021).

Green infrastructure in urban areas has the potential to respond to many societal problems once they flourish in terms of quality and quantity (Rizvi et al. 2015; Laforteza et al. 2018; Oen 2019; Zwierzchowska et al. 2019; Buzási & Jäger 2020). Conservation of biodiversity, the better quality of life, enhanced health, disaster or climate-related risk reduction, a stronger sense of community or even economic development are among these responses (European Commission 2013; Keniger et al. 2013; Hartig et al. 2014; Kabisch et al. 2016). Faivre et al. (2017), Hanson et al. (2020), Davies et al. (2021) and Castellari et al. (2021) point out the pivotal role of protecting biodiversity and introduce it as a prerequisite as well as an objective in NBS implementations. As a more specific research output regarding health benefits, research has shown a reduction in socio-economic inequality related to the health of people through wider access to recreational/green areas (de Vries et al. 2003). Based on new research results, the existence of green spaces within close vicinity of residents is pivotal for physical and mental health during COVID-19 related lockdowns (Tomasso et al. 2021). Regarding economic dimension, NBS project examples accomplish economic development in and around the implemented town or region through various improvements along with water bodies (European Commission 2016; Faivre et al. 2017; Oen 2019). These improvements can create business opportunities in diverse sectors such as tourism, fishing, and transportation thanks to better conditions in a revitalized natural asset and a more convenient infrastructure to manage business (Beilicci and Beilicci 2012). Urban water challenges such as stormwater management and flood protection are frequently tackled by employing traditional (grey) infrastructure elements such as lined trenches, catch basins, pipes, and concrete dikes (Watkin et al. 2019). These practices can solve water-related challenges in cities in return of disruptions in water cycle and habitat to varying extents. On the other hand, a number of concepts such as low-impact development can be considered as a sustainable approach that relates to NBS implementations regarding water related challenges. The implementation of NBS such as green roofs, rain gardens, green swales, permeable pavements, floodplain creation, river restoration and retention basins has shown success in responding to urban water challenges (Pappalardo et al. 2017, Versini et al. 2018; Castellanos et al. 2020) with minimal disruption or even positive impacts on natural hydrological features of the applied areas. Studies conclude that NBS applications perform better in terms of cost-effectiveness than traditional applications for various reasons (Raje et al. 2013, Liquete et al. 2016; Stefanakis 2019). In addition to this, the grey infrastructure elements are far from providing the co-benefits of NBS implementations meeting the same purpose regarding water management (Liquete et al. 2016; Dige et al. 2017; Watkin et al. 2019).

Europe has extensive pools of knowledge, implementation experience, scientific expertise, skills and technological capacity on NBS (Faivre et al. 2017; Frantzeskaki 2019; Hanson et al. 2020; Davies et al. 2021) thanks to the interests and initiatives above mentioned. On the other hand, most of the studies focus on the evaluation of a single service or benefit provided by NBS, whereas greater attention needs to be paid to the interlinkages between the NBS impacts on different sustainability aspects through delivered co-benefits (Raymond et al. 2017b; Meerow 2019). This holistic evaluation requires interdisciplinary work with multiple indicators and qualitative, quantitative and mixed-methods techniques (Raymond et al. 2017b). Analysing NBS characteristics with various indicators such as the ten challenges suggested in the EKLIPSE Expert Working Group Report (Raymond et al. 2017b) can fulfil a comprehensive sustainability co-benefits assessment of NBS projects. Each one of these challenges is considered as a contribution to climate resilience in urban areas, whereas some of them are likely to tackle more specific issues. The report suggests that identifying more challenges is possible to assess the multifunctionality of NBS. In this paper, we assessed the co-benefits of NBS projects with specific objectives through 8 challenges identified in the NATURVATION Atlas (<https://naturvation.eu/atlas>). This provides a more consistent insight into in which fields/sectors NBS applications are performing better in terms of delivering benefits in addition to their main target service to city dwellers and urban habitat. Furthermore, possible correlations with the delivered environmental, social and economic co-benefits and project features regarding governance and cost are investigated within the database and a few other data sources of the specific projects.

2. Material and Methods

A few repositories collect information on planned or applied NBS projects across the world. These databases with several NBS project information can provide a consistent sample to understand the possible correlations between multiple actors and project features of the NBS implementation. The NATURVATION Atlas is an NBS project database, and its data collection process was conducted between July-August 2017 (Almassy et al. 2018). This database notably offers an opportunity to conduct such analyses thanks to the variety of indicators identified for each project. It provides a convenient and useful platform to extract various information such as objectives, key challenges, expected impacts, and costs for up to 1000 applied or planned NBS projects from Europe (Table 1) (Almassy et al. 2018).¹

Table 1: The identified features of the projects in NATURVATION Atlas

Main Information Section		Main Information Section	
Basic info	Location	Governance	Type of initiating organisations
	City population		Management set-up
	Project duration		Participatory approaches/ community involvement
	Project cost		Details on the roles of the organisations involved in the project
	Financing source(s)		Relation with international/national/local adaptation plans

¹The Atlas started offering information on NBS projects from all over the world after the conduction of this research.

Main Information Section		Main Information Section	
Overview	Project Name & Description	Monitoring	Expected impacts
	Urban Setting		Details on impacts and indicators used
	Key challenges		Presence of formal monitoring system
	Main beneficiaries		Presence of indicators used in reporting
	Objectives		Presence of monitoring/ evaluation reports
	Implementation activities		Availability of a web-based monitoring tool

NATURVATION Atlas introduces up to twelve challenges -that NBS can respond- under the key challenges and expected impacts sub-sections for each project compatible with the suggestions made in the EKLIPSE Report. The identification of these challenges acknowledges the potential of NBS implementations in addressing various global development challenges in addition to sustainable urban development. Each challenge can be linked to one of the Sustainable Development Goals (SDGs) introduced by the United Nations. The project identifies the related key challenges and expected impacts for each project considering the referred objectives of the project description or related documents. For example, 'increase in quality of life' as an objective in an urban park project is considered as incorporation of 'health and well-being' challenge, which is aligned with SDG3. While ten challenges introduced in NATURVATION Atlas are complementary to the challenges in the EKLIPSE Report, two are additional challenges that can help identifying the social and economic benefits of the projects respectively.

In the analysis, we focused on projects concerning flood protection. Besides flood; pollution, erosion, and drought are concerns in some of the selected projects. The implementation types can be summarized under two main categories. The first one is the revitalization or restoration of an existing natural/semi-natural asset (e.g., river, floodplain, wetland, lake, park), while the second one is creating new green or blue areas in or around the urban area. In addition to this, building or reinforcing sustainable urban drainage systems through different types of implementations are in the objectives for some cases. Among the evaluation methods of ecosystem-based adaptation and NBS-related urban planning, both document and content analysis are popular tools (Bowen 2009; Rall et al. 2015; Kabisch et al. 2015; Mączka et al. 2016; Cortinovis and Geneletti 2018; Zwierzchowska et al. 2019) to highlight policy development in different cities or regions from this unique perspective. Our applied evaluation framework method is based on a more project-oriented perspective. Due to the conducted keyword-based document analyses, we identified all the projects mentioning flood in their name or description. Seventy-three projects from forty-eight cities were selected (see Figure 1), while altogether five projects were excluded because of either lacking any mention to flood protection, or missing implementation plans regarding flood protection even though the word was there. In the frame of the content analyses, expected impacts (via identified challenges), management models, links to an adaptation policy/strategy, type of initiators, and project costs are analysed for the entire sample.

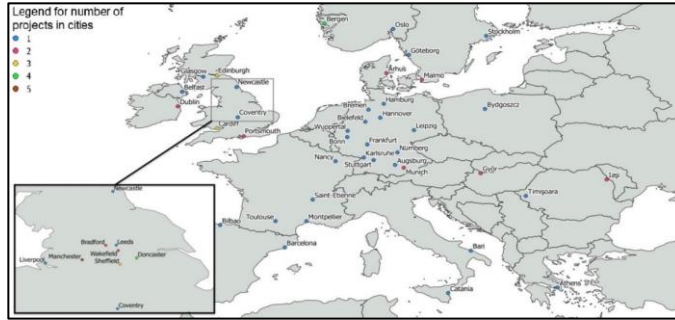


Fig. 1: The location of the cities where the examined NBS projects are planned or applied in.

Each NBS project reinforcing flood protection undoubtedly benefits the environment, society, and economy. Protecting habitats from inundations that do not often occur in consequence of the natural cycle depending on the climate of the given area is a benefit that we can correlate to ecosystem well-being and the environmental dimension of sustainability. Keeping lives, infrastructure, properties, and goods secure from flood danger is an explicit social and economic benefit. On the other hand, there is a need for further investigation to reveal co-benefits of NBS applications that can be related to one or more of the three pillars (i.e., aspects or dimensions) of sustainability.

This paper inquires about the existence of co-benefits through a new assessment approach. Various studies investigate either the effectiveness of projects regarding aimed climate/sustainability action or presents benefits in a sporadic way rather than categorized approach. The novelty of this assessment lies in the grouping of certain challenges under one of the three aspects. Eight challenges out of 12 are associated with a sustainability aspect to analyse the diversity of benefits (Table 2). These challenges were distinguished from the rest because their articulation in a project is likely to bring additional contributions to sustainability. Projects with expected impacts on these eight challenges emphasize the co-benefits of NBS, which not only boost climate resilience through flood protection but also help to realize sustainable development in different fields. For this reason, four challenges were excluded from the assessment based on sustainability aspects: 1) climate action for adaptation, resilience and mitigation; 2) water management; 3) coastal resilience and marine protection; 4) regeneration, land use and urban development. Besides, we considered that these challenges are so complex that the aspects they are covering may vary in every case and this variation can spoil the accuracy of sustainability assessment.

Table 2: The identified challenges with related sustainability aspects

Related sustainability aspect	Identified challenges
ENVIRONMENTAL	Green spaces, habitats and biodiversity Environmental quality, including air quality and waste management
SOCIAL	Health and well-being Inclusive and effective governance Cultural heritage and cultural diversity Social justice, cohesion and equity
ECONOMIC	Economic development and decent employment Sustainable consumption and production

The number of projects with specific challenges and related sustainability aspects was revealed at first to get an overview about the delivered co-benefits. Furthermore, possible correlations between the expected benefits and two project features (i.e., type of initiators and costs) were investigated. In the analysis on costs, the projects were categorized in terms of the sustainability aspects they are covering in greater detail by taking into account the co-existence of different aspects in the projects.

3. Overview of the Addressed Challenges and Sustainability Aspects

The outputs of the quantitative analysis conducted for the selected projects (n=73) reveal the challenges and sustainability aspects which the co-benefits of NBS projects thrive or fail to provide. Figure 2 indicates that water management and green space, habitats and biodiversity are the top two challenges addressed regarding expected impacts. Fifty-six of the selected projects challenge the existing water management infrastructure of the cities, an expected result considering the flood protection criteria in the project selection. Besides, the same number is also valid for the projects with an identified expected impact regarding green spaces, habitats and biodiversity. This remarks the prevailing co-benefits of NBS projects toward environmental sustainability.

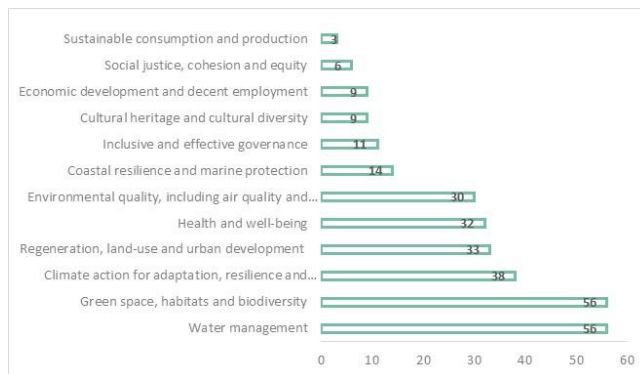


Fig. 2: Number of projects with identified challenges under expected impacts sub-section.

The third and fourth mostly addressed challenges as expected impacts are climate action for adaptation, resilience and mitigation, and regeneration, land-use and urban development, respectively. Even though these two challenges are among the excluded ones in the co-benefit analysis, their inclusion in about half of the selected projects implies the potential of multifunctionality of the NBS projects considering the fact that these challenges are related to a wide range of subjects from disaster protection to infrastructural transformation towards climate resilience and sustainability in cities. Regarding the four excluded challenges from the co-benefit analysis, coastal resilience and marine protection is the least addressed challenge with only 14 projects. However, this is probably because most of the analysed projects are from cities which are not settled along seacoast (Fig. 1). Health and well-being is the mainly addressed challenge regarding the social benefits of the selected projects. It is followed by a challenge that is associated with environmental benefits: environmental quality, including air quality and waste management. The numbers

of the projects addressing the rest of the challenges are below 15 -less than 20 percent of the selected projects- for each challenge. Inclusive and effective governance is the second most addressed challenge as an indicator of the social sustainability aspect with 11 projects. Another social benefit, the cultural heritage and diversity follows that with nine projects. The last three of the list consist of two economic and one social aspect related challenges. There are only six projects concerning social justice, cohesion, and equity, making it the least addressed challenge as a social benefit indicator. Economic development and decent employment, and sustainable consumption and production are the two challenges considered as economic co-benefit indicators and they are the last third (9 projects) and the last (3 projects) in the ranking, respectively.

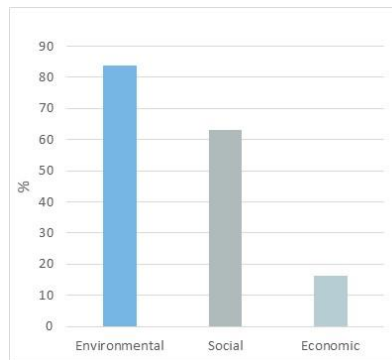


Fig. 3: Percentages of the projects addressing different dimensions of sustainability in the entire sample

The varying percentage shares of the projects concerning certain sustainability aspects identified through the classification in Table 1 can be seen in Figure 3. While more than 80 percent of the projects (61 out of 73) are identified with an expected impact concerning environmental sustainability, it would be expected to be higher for NBS. On one hand, the share of the projects with a social sustainability aspect is slightly above 60 percent with 46 projects, a result which shows multiple benefits of NBS implementations. On the other hand, economics is the sustainability aspect that the selected projects lag in to tackle. Only 12 projects have economic co-benefits as an expected impact in 73 projects, making less than 20 percent.

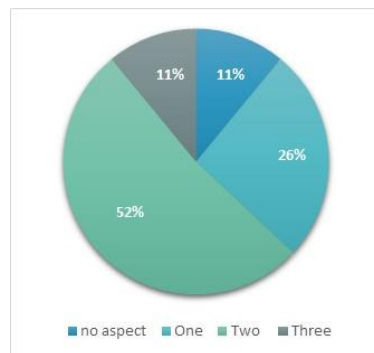


Fig. 4: Percentages of the addressed sustainability aspects

11 percent of the selected projects do not have the potential to provide a co-benefit (Figure 4). However, a little more than a quarter of the selected NBS projects were identified with expected impacts that benefit one of the sustainability aspects. More than half of the projects cover two of the three sustainability aspects. This implies the potential of NBS applications in addressing different sustainability aspects together. Besides, there is an 11 percent in the entire sample that is likely to benefit all dimensions of sustainability.

4. Governance Forms and Correlation with the Existence of Sustainability Aspects

The number of initiator types participated in the projects varies between one to four out of 12 different initiator types identified in the database. NATURVATION Atlas Report categorizes these 12 initiators as public, private and others (Almassy et al. 2018). We opted for an alternative categorization with four main categories in discussing the analysis results: governmental, civil, commercial, and others. EU bodies and national, regional, and local governments/municipalities are considered in the category of governmental initiators. Citizens/community groups, non-governmental organizations/civil society, private foundations fall under category of civil initiators. Private sector/corporates/companies are the initiator type label with commercial aspects in the database. Regarding the others, researchers/universities and public sector institutions (e.g., hospitals, schools) are two initiator types that participate in a few projects, but they do not explicitly fit any of the defined first three categories. The only transnational network that participated as an initiator in one of the selected projects is a fund for nature protection: World Wild for Nature (WWF). Other types of initiators are described as communities, individuals, or any other type of participant in the NATURVATION Atlas and these naturally fall under the others category in our analysis discussion.

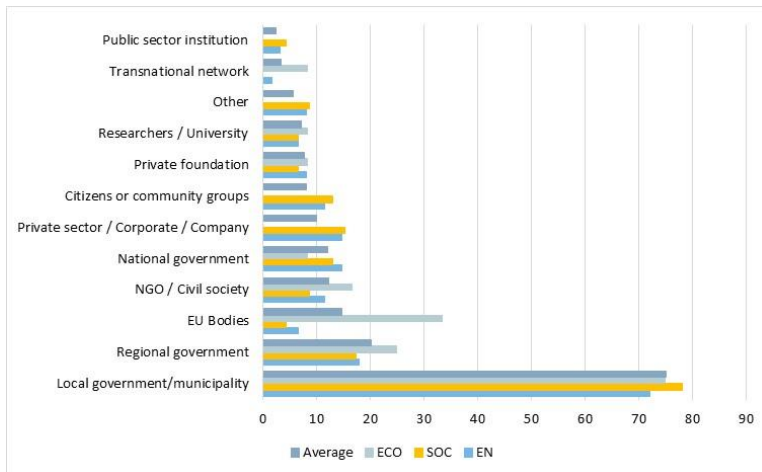


Fig. 5: Percentages of the participation of different actors as an initiator in the projects with respect to sustainability aspects (Ranking is based on averages)

Figure 5 summarizes the shares of the participation of different types of initiators regarding the total number of the projects addressing certain sustainability aspects. Local

governments/municipalities participate as an initiator in more than 70 percent of the projects concerning a defined sustainability aspect. While there is no significant difference between the three aspects in terms of the participation proportion of this type of initiator, there is a slightly higher participation rate in projects with expected social benefits. Regional governments appear as the second most participating initiator among all types of initiators and governmental initiators category on average, but their participation is still much smaller than that of the local governments/municipalities. Nearly one-fifth of the projects creating environmental, social or economic benefits have been initiated with the participation of regional governments. The regional government participation is highest in the projects with an economic sustainability aspect than its participation in the other two aspects.

The variation of the participating EU bodies implies an outlier in this figure considering the high share in the economic sustainability aspect. EU bodies play a part in more than 30 percent of the projects with an expected economic benefit, whereas the proportion is less than 10 percent for the projects with an expected environmental or social benefit.

Non-governmental organization/civil society participation is around 10 percent in the projects with an expected environmental or social benefit. They take part in projects concerning the economic sustainability aspect to a greater extent: more than 15 percent. Private sector/corporate/company and citizens or community groups are two initiator types from different categories with similar characteristics in terms of their participation in the selected NBS projects. They participate in little more than 10 percent of the projects concerning social or environmental aspects of sustainability. Besides, they are not in any project with an expected economic benefit. On one hand, it is unexpected to find out that a commercial type of initiator does not necessarily bring economic co-benefit in NBS applications. On the other hand, private foundations and researchers/universities also have similar participation characteristics as they cover every sustainability aspect to nearly the same level: slightly less than 10 percent.

Public sector institutions are another type of initiator that are not part of any project concerning the economic dimension of sustainability. Besides, less than five percent of the projects with an expected social or environmental benefit have a public sector institution as an initiator. As there is only one project that has a transnational network initiator in the entire sample, it is not possible to make solid inferences on the characteristics of their participation. The initiators under the category Other did not take part in any of the projects with expected economic benefits while they are present in nearly 10 percent of the projects with the other two dimensions of sustainability.

Eight projects among the selected projects address three dimensions of sustainability together. The dominant type of initiator in these projects with multiple benefits is local governments/municipalities as they participate in six of the projects as singles or co-initiators. EU bodies, regional governments, private foundations, and researchers/university are the other type of initiators, whereas there is no national government participation in the projects in this cluster. The only project with a regional government initiator (Eko City Augustenborg) was also identified with a local government/municipality initiator and a housing development company to participate in the development. This indicates that even though there is no project with an identified economic co-benefit and commercial type of initiator, businesses still participate in the

projects with economic co-benefits at different stages. Water Management in the Frihamnen River project from Göteborg is a far-reaching project with an EU body initiator alone. Another project with an EU Body participator is Greening of the Bega Channel. The local government/municipality is the other participator in this project which promises overarching, multi-sectoral and beyond border benefits. A project with a private foundation initiator, the Stavros Niarchos Foundation Cultural Centre, is located in Athens' waterfront and was completed thanks to the private foundation giving its own name to the centre in 2016. The site hosts the National Library of Greece and the Greek National Opera in addition to other various elements with an infrastructure serving multiple functions to realize sustainability and reinforce climate resilience in the area.

5. Project Costs and Correlation with the Existence of Sustainability Aspects

There are 17 projects in the entire sample with no cost information, while the rest 56 have an identified cost among six different ranges. The latter is divided into two: one half with a project cost more than 4 million euros, and the other half corresponding to a project cost less than 4 million euros with varying percentage share in five intervals (Figure 6). While 50 percent of the NBS projects with a flood protection objective is estimated to cost more than 4 million euros, only 33 percent from 632 projects had an identified cost range in the entire NATURVATION Atlas database (Almassy et al. 2018). However, the Atlas Report emphasizes that the projects concerning water management are likely to fall under this higher cost range (Almassy et al. 2018).

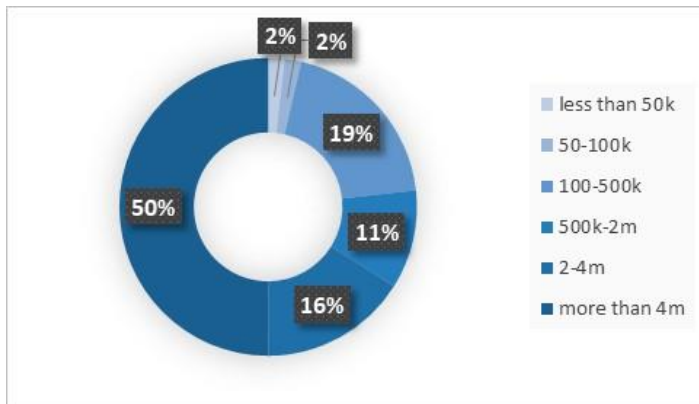


Fig. 6: Percentages of the projects regarding the total number of projects with an identified cost from six project cost range ($n=56$)

€100-500 thousand is the second most identified cost range (19%) heading the other four project cost ranges. The percentages of €2-4 million and €500 thousand – €2 million follow this range with 16 and 11 percent. The smallest project cost ranges, which refer to less than €100 thousand, correspond to only four percent of the projects with cost information. However, this percentage share is much higher for all projects in the database: 38.6 percent of the projects with an identified cost fall under the project cost range below €100 thousand (Almassy et al. 2018).

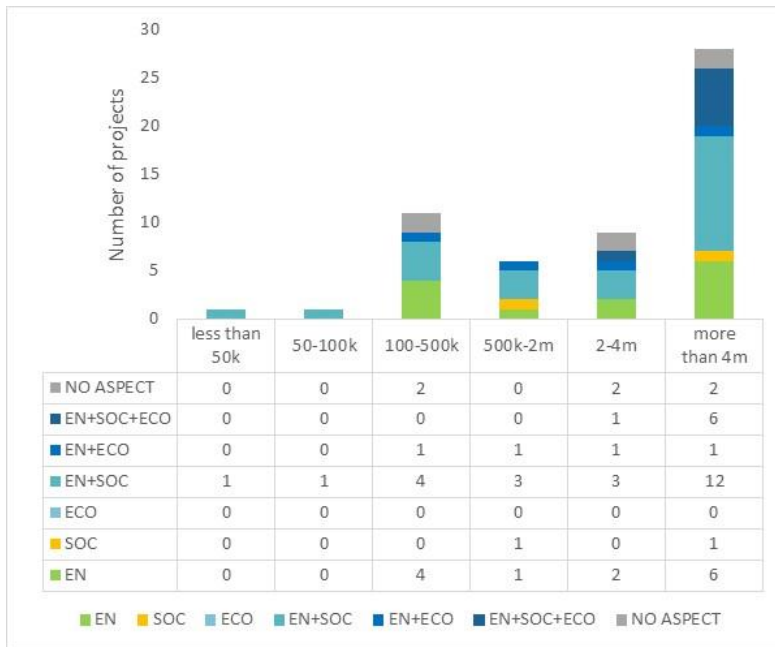


Fig. 7: Number of projects addressing different sustainability aspects concerning their cost range

The quantitative analysis of the prevalence of projects with or without various sustainability aspects in different project cost ranges has the potential to indicate correlations between costs and co-benefits. Figure 7 shows which sustainability aspects are covered by how many projects from different cost ranges. There are six projects with no attributed sustainability aspect from three different project cost ranges: €100-500 thousand, €2-4 million, and more than €4 million. On the other hand, the rest of the projects concerning one or more sustainability aspects are prevalent in all six project cost ranges.

There are seven projects with an expected impact reinforcing all sustainability pillars among the projects with an identified cost. Six of these projects are estimated to cost more than €4 million while the other one falls under the €2-4 million range. It is likely that a higher amount of investment covers every aspect of sustainability altogether considering NBS projects.

Four projects from four project cost ranges over €100 thousand are expected to contribute to environmental and economic sustainability in the cities they are implemented. The lowest project cost with an economic benefit (Restoration of Braid Burn) falls under the €100-500 thousand range and it is actually a small part of a wider flood alleviation scheme funded by the Scottish Government and City of Edinburgh Council. The project with the second lowest cost with an economic benefit (Wetland Expansion in Potteric Carr) is in €500 thousand – €2 million range and it is a joint project of Yorkshire Wildlife Trust and WWF. However, the exact cost of this project is £1 million, and this amount approximated to €1.5 millions by the project finish date in 2006. These facts imply that the required

budget of an entire NBS project concerning flood and aiming economic co-benefits starts around €1.5 million.

Projects concerning environmental and social sustainability are in every project cost range while most of them fall under the highest range. There are 12 projects costing more than €4 million with an expected benefit on environmental and social dimensions of sustainability. The estimated cost distribution of the projects with these two benefits is relatively identical among three ranges corresponding an amount between €100 thousand and €4 million. Four projects have been identified with a cost between €100-500 thousand, while there are three projects in each of the other two ranges (i.e., €500 thousand-€2 million and €2-4 million).

Even though only two projects cost less than €100 thousand, it is noteworthy that they are likely to benefit from more than one dimension of sustainability: environmental and social. The project with the lowest cost range (River Restoration on Guphill Brook) is initiated by non-governmental actors (i.e., private foundations and others). Nevertheless, local and national government actors involve in the project through funding. The participatory approach is employed in the project, and the implementation activities include local community and volunteers. This involvement can be the key to achieve such an elaborate project with a small budget. The project in the €50–100 thousand cost range (Riverbanks restoration of Janon River) is a government-led project with no explicit civil society participation, whereas its objectives are alike to the cheapest one. A detailed assessment of these two projects based on comparison with quantitative indicators (e.g., average cost per maintained area) can provide a more precise understanding of the impacts of the participatory approach in planning and implementation.

6. Conclusion

The conducted assessment provides an understanding of the level of delivered multiple benefits of NBS projects with flood protection objectives in Europe. The inquiry on project features adds another dimension to the discussion from sustainability perspective. Ultimately, there are still many open considerations, but this study offers an opportunity to have an insight on possible correlations between delivered benefits and project features. The findings can be summarized as follows:

- The environmental aspect of sustainability is the most addressed aspect in the selected projects.
- More than half of the selected NBS projects serve social benefits mainly linked to enhanced health and well-being whereas most of the projects lack objectives that can contribute to economic sustainability.
- There is no project covering only the economic sustainability aspect. It co-exists with either environmental co-benefits or environmental and social co-benefits together.
- From a policy perspective, local government/municipality, regional government, EU body, and NGO/Civil society participation as initiators are likely to bring economic benefits.
- Projects addressing every sustainability dimension concentrate at the highest cost range. The last finding can be perceived as a drawback in the beginning. However, a robust

investigation revealing any kind of economic returns due to various benefits is necessary to obtain a full insight on this matter. Once the effectiveness, efficiency and multiple benefits of the NBS applications are proven thanks to well-prepared and standardized analyses; decision-makers, society, and businesses would embrace this concept and involve in its implementations. Comprehensive cost-benefit analysis with different indicators examining co-benefits is pivotal to achieve this instrument to promote NBS. Dick et al. (2020) highlights the gap in monetary valuation of health and well-being benefits of NBS and this is particularly crucial as this study shows that they prevail in most of the projects. Nevertheless, several factors affect cost, such as size of the maintained area, worker wage level, involvement of volunteers in implementation, and the division of traditional infrastructure elements in the project. These factors should be taken into account for further investigation into relations between cost and other project features in NBS applications

Increasing the co-benefits in NBS applications concerning flood protection is a challenge that requires action from governmental bodies, civil society, and businesses. For example, there is a necessity for more clear-cut implementation recommendations in policy and strategy documents that will lead effective and holistic solutions. This can facilitate both promoting NBS applications and identifying the inadequacies of the policy or strategy. On the other hand, each actor should seek possible contributions to various societal challenges in NBS project planning and implementation. Institutions, communities, and individuals can boost the quantity and variety of benefits by promoting them in NBS applications and participating in the projects. Collaboration of different level governmental bodies among themselves as well as with other public institutions, companies and civil society can create a synergy that allows NBS implementations to provide more benefits.

Considering the recent sustainability-oriented assessment concerning the co-benefits of nature-based solutions research aspect in practice, it shows a diverse picture according to urban water challenges. Our in-depth urban-level evaluation highlighted that the co-benefits of NBS actions are significantly underrepresented in the evaluated projects. It is pivotal to embed this aspect into urban planning and development-related strategies. From a sustainable urban planning perspective, embedding different tools regarding the diverse urban water challenge-related actions and projects can support the effective implementation of a plan; thus, it is also pivotal to integrate the co-benefit perspective.

The different types of sustainable urban development strategies can be an appropriate and effective tool for the local decision-makers; however, the different climate planning documents can also secure positive synergies and foster the more effective practical implementation of moving towards a sustainable urban pathway.

According to the NBS-related co-benefits, also the knowledge about the perception and attitudes of the local inhabitants can be informative for the municipalities. Application of the contingent evaluation method in future studies could reveal the attitude towards integrating of water-related NBS actions into sustainable urban development strategies to enhance the possible co-benefits. Furthermore, based on relevant NBS-related indicators, the co-benefits can be grasped more efficiently to help decision-makers work in the monitoring phase. The monitoring phase can also be seen as a crucial point in further developments for a more resilient and sustainable future on the urban level, especially in case of urban water challenges.

This paper takes no consideration of trade-offs such as the possible gentrification owing to the applied projects, a phenomenon that would work against social cohesion and bring exclusion. The analyses performed in this study do not pretend to be universal for the NBS concept. In addition to the limitation at the continental level, there are geographical, cultural and historical differences regarding climatic and infrastructural characteristics within Europe. As the delivery of co-benefits through NBS implementations is a reflection of such local features, further investigation of NBS co-benefits with a focus on mentioned local aspects is required to understand the potentials and obstacles.

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