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Evaluating Nature-Based Solutions for Water Management in Peri-Urban Areas

Sarah E. Hale [1,*], Loretta von der Tann [1], Alanna J. Rebelo [2,3], Karen J. Esler [3], Ana Paula Morais de Lima [4,5], Aline F. Rodrigues [4,5], Agnieszka Ewa Latawiec [4,5,6,7], Nancy Andrea Ramírez-Agudelo [8], Elisabet Roca Bosch [8], Lina Suleiman [9], Nandita Singh [10] and Amy M. P. Oen [1]

1 Norwegian Geotechnical Institute (NGI), Ullevål Stadion, P.O. Box 3930, N-0806 Oslo, Norway
2 Agricultural Research Council, Natural Resources and Engineering, Water Science Unit, Cedara 3245, South Africa
3 Department of Conservation Ecology & Entomology, Stellenbosch University, Private Bag x1, Matieland 7602, South Africa
4 International Institute for Sustainability, R. Dona Castorina 124, Rio de Janeiro 22460-320, Brazil
5 Department of Geography and Environment/Rio Conservation and Sustainability Science Centre, Pontifical Catholic University of Rio de Janeiro, R. Marquês de São Vicente, 225-Gávea, Rio de Janeiro 22451-000, Brazil
6 Faculty of Mechanical Engineering, Opole University of Technology, ul. St, Stanisława Mikołajczyka 5, 45-271 Opole, Poland
7 Norwich Research Park, University of East Anglia, Norwich NR4 7TJ, UK
8 Institute for Sustainability Science and Technology, Universitat Politècnica de Catalunya, Jordi Girona 1-3, 08034 Barcelona, Spain
9 Department of Urban Planning and Environment, School of Architecture and the Built Environment, KTH, Royal Institute of Technology, 10044 Stockholm, Sweden
10 School of Natural Sciences, Technology and Environmental Studies, Södertörn University, 141 89 Huddinge, Sweden
* Correspondence: sarah.hale@ngi.no

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Abstract: The term nature-based solutions (NBS) has gained traction in recent years and has been applied in many settings. There are few comprehensive assessment frameworks available that can guide NBS planning and implementation while at the same time capturing the short- and long-term impacts and benefits of the NBS. Here a recently presented framework, which builds on the theory of change and was developed to assess NBS at different phases of the project cycle, was applied to seven diverse case studies. The case studies addressed water quality and quantity issues in peri-urban areas across the global north and south. Framework indicators covering the sustainability dimensions (environmental, social and economic) were assessed at three stages of the framework: context, process and results. The work sought to investigate the following research objectives: (1) Can this framework be robust and yet flexible enough to be applied across a diverse selection of NBS projects that are at different phases of the project cycle and address different kinds of water challenges within varied ecological, social and economic contexts? (2) Is it possible to draw generalisations from a comparative analysis of the application of the framework to the case studies? Results showed that the framework was able to be applied to the case studies; however, their diversity showed that NBS projects designed in one context, for a specific purpose in a specific location, can not necessarily be transferred easily to another location. There were several process-based indicators that were universally significant for the case studies, including expertise, skills and knowledge of the involved actors, roles and responsibilities of involved actors and political support. The result-based indicators were case study-specific when environmental indicators were case study-specific, and important social indicators were environmental identity and recreational values. Overall, the use of the framework benefits the recognition of the implementation's advances, such as the change in context, the processes in place and the results obtained.

Keywords: peri-urban; case study; indicators; environmental; social; economic

1. Introduction

Against the backdrop of global challenges such as climate change and ongoing urbanisation, nature-based solutions (NBS) have emerged as systemic interventions that, inspired and supported by nature and adapted to their local setting, contribute to both sustainability and resilience [1]. The use of the term "solutions" in NBS suggests that these interventions respond to a problem, or something perceived as such. "Nature based" describes the fact that they draw on natural processes in contrast to grey or built solutions. By stating that interventions need to be systemic, the European Commission highlights that any intervention will necessarily impact a larger socio-ecological system. In cases where interdependencies between different challenges and our responses to them are not identified, unintended consequences may arise [2]. Recognising these interdependencies, on the other hand, can facilitate interventions that result in multiple benefits beyond the initial purpose they were designed to respond to. These "co-benefits for health, the economy, society and the environment" [1] have become a guiding feature of NBS [3]. Considering co-benefits thus emphasises the systemic nature of the respective interventions, highlighting that each intervention will necessarily have multiple impacts. A systems approach is needed to design and evaluate NBS so that lasting benefits to nature, including biodiversity and society, are realised.

The establishment of NBS as an umbrella concept has its roots in research primarily related to urban challenges [4]. The concept is also inherently related to other established concepts such as ecosystem-based adaptation (EbA), ecological infrastructure (EI) [5] and green infrastructure (GI) [2], and in recent years many worldwide organisations have embraced NBS as an integrated approach that addresses a wide variety of challenges. The Intergovernmental Panel on Climate Change included the term in their recent report on impacts, adaptation and vulnerability as an innovative idea that can "expand the climate solution space" but added a few words of caution related to NBS being construed as providing a stand-alone solution to climate change as well as to the use of NBS for large-scale conversion of land use [6].

Several authors have expressed the need for a comprehensive assessment framework that can guide NBS planning and implementation while at the same time capturing the short- and long-term impacts and benefits of the NBS [7–10]. These authors emphasise that such a framework should provide a basis for comparison between, and for learning from, different case studies and ultimately could be used to increase confidence in NBS [7,8]. Many frameworks that have been suggested in the literature address different project phases [9] or specific areas of concern, such as climate-proofing of NBS [7] or circularity challenges [10]. Recent evaluation frameworks [7,8] use the Theory of Change (ToC) to address challenges of prioritisation and increase understanding of impacts for particular case studies. ToC builds on backcasting, a planning methodology which begins with a vision of the future [11]. Somewhat inverse to the idea of forecasting that starts with a description of the present and then analyses what changes specific interventions might bring about, backcasting starts from a description of the desired future. It then explores what specific steps need to be taken in the short or mid-term for the desired future scenario to materialise [12]. Through backcasting, causal pathways or result chains can be traced that lead to the desired change and which help to identify necessary actions for moving from the current situation to an intended outcome [13]. For a specific project, the development of a ToC can provide a concrete method to identify desired outcomes and ways to achieve them and take into consideration the wider context of the intervention. The ToC has been used under different contexts; however, a vast resource database has been built by the United States Agency for International Development, including a workbook and examples [14].

Two of the main objectives of NBS are that they address societal challenges and that they provide multiple benefits beyond their primary purpose [15]. To evaluate whether these objectives are met, specific indicators need to be formulated such that baselines can be established and the performance of a specific NBS can then be measured at a later stage. Applying a ToC approach can support this formulation and the development of evaluation and monitoring schemes by making expected outcomes and impacts explicit [16]. Few authors have used ToC in the development and evaluation of NBS. One example, the Connecting Nature Impact Assessment Framework [8], aims to create a joint vision between different stakeholders, map different viewpoints of how NBS could contribute to this vision and select specific indicators that can be measured to monitor the impact of NBS. Calliari et al. [7] do not mention ToC, but apply systems analysis and backcasting to map out the overall objective of the NBS based on the current situation, external factors that might influence the desired future and different intervention alternatives that could contribute to reaching the defined objectives. Arlati et al. [17] describe how developing a ToC guided the process of co-designing NBS interventions in Hamburg, particularly for moving from an initial problem understanding to the formulation of a shared understanding of objectives. All three examples emphasise the ToC or backcasting as a valid methodology to capture the transformation of an area or community that a specific NBS is expected to bring forth over the long term.

The current paper presents the application of a novel framework recently developed by de Lima et al. This framework, which also builds on the ToC, was developed as a comprehensive, adaptive framework which can be applied to assess NBS at different phases of the project cycle, namely, planning, implementation, monitoring and evaluation phases. The framework can be used to show if, or how, the NBS resulted in medium and/or long-term changes. The context within which the framework can be applied is wide, and includes different water management scenarios in different contexts [18].

The above framework was developed within the scope of a project called 'NATWIP: Nature based solutions for Water Management in the Peri-Urban' (http://www.natwip.solutions/accessed on 15 December 2022), where it was further applied to assess various NBS case studies concerning water management in peri-urban areas. Peri-urban areas are transition zones between cities and their rural surroundings. They are located in between, and generally in close proximity to, both an urban environment dominated by infrastructure and high-density residential areas and a more natural environment, such as a forest [19] or agricultural landscapes. Peri-urban areas provide a range of ecosystem services (ES) to the city and, owing to vast and rapid urban development, are often in a dynamic transition process [20]. Yet, peri-urban areas often have smaller populations compared to urban areas, and therefore finance for NBS and their governance can be weaker than in the large urban hubs [21]. In addition, the complex setting of peri-urban areas also implicates uncertainties that need to be met with comprehensive communication, monitoring and accounting of the delivered benefits [4].

This paper aims to build knowledge based on the application of the de Lima et al. [18] NBS assessment framework for seven case studies from across the world. The research aimed to address two basic research questions: (1) Is this framework robust yet flexible enough to be applied across a diverse selection of NBS projects that are at different phases of the project cycle and address different kinds of water challenges within varied ecological, social and economic contexts? (2) What generalisations can be drawn from a comparative analysis of the application of the framework to diverse case studies regarding planning, designing, implementing, monitoring and evaluating NBS? The case studies presented in this work span five countries and different phases of the project cycle, from planning to evaluation. For all the case studies, the framework was applied either retrospectively, meaning that the NBS had already been implemented, or it was applied to the NBS project at a specific project phase. This work builds on previous studies and moves the scientific field further through the following novel aspects; the use of a framework rooted in ToC, the application of this framework to seven very diverse case studies, and the methodological freedom in the assessment of indicators.

2. Materials and Methods

This study comprised the application of the de Lima et al. framework [18] on case studies based on water-related challenges in peri-urban areas. Towards this end, local researchers with different disciplinary backgrounds applied the framework to seven case studies (all in peri-urban areas) in five countries, addressing various water challenges to obtain the dataset used in this work.

2.1. The Framework

The framework developed by de Lima et al. [18] is composed of three stages to assess the context, the NBS implementation process and the results. For each stage (hereafter: context, process and results), the framework guides the case study description and the development of indicators. Figure 1 provides a schematic of the stages of the framework showing how they fit together with the project phases, indicators and steps taken in the actual application of the framework to the case studies. Predefined indicators are grouped into the three dimensions of sustainability: environmental, economic and social indicators. When the original list of indicators was being developed, a screening process was carried out to establish where data could be collected for each of the case studies. Those areas where the greatest amount of data (both qualitative and quantitative) could be collected across the case studies then became the focus of further indicator development. In accordance with the ToC, the framework allows for the development of additional categories and indicators that describe the intended future outcome(s) for each specific case study the framework is applied to.

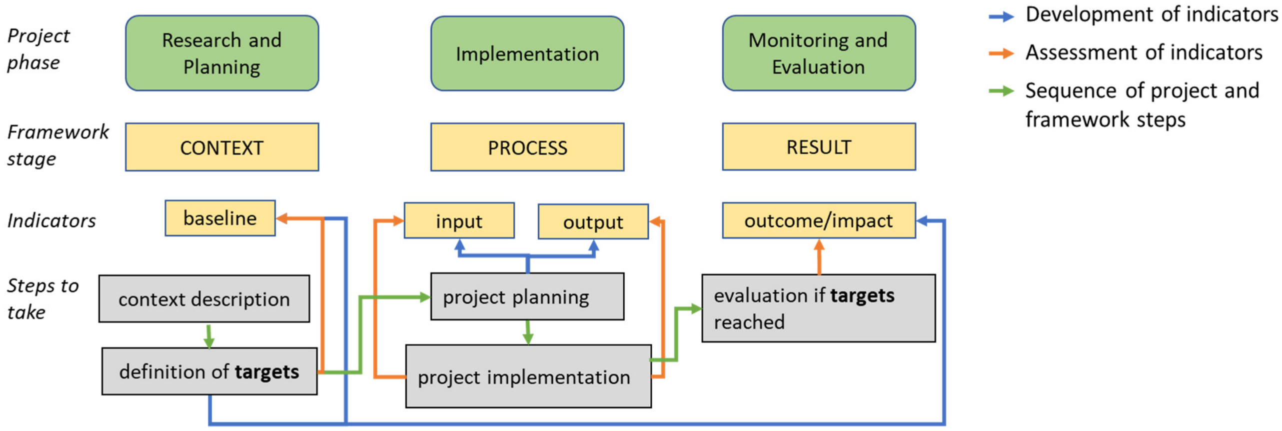

Figure 1. The figure shows the way in which the project phases, framework stages and indicators fit together, as well as the steps that are taken when applying the framework. The ToC is reflected in the way the framework was developed and subsequently applied.

The first stage of the framework, the context, serves to provide a wider description of the environmental and socio-economic setting the NBS is situated in and responds to. The description of the context may include many aspects, such as household income, property value or water treatment costs. In this stage, targets can also be defined that describe the desired outcome of the project. To facilitate the evaluation of these targets, outcome indicators need to be developed. If these indicators require comparison to the status before the project, the same indicators should be evaluated as a baseline in the context stage.

For the implementation stage of the framework, covering the detailed project planning and implementation, process-based indicators, describing inputs and outputs of the project are developed and assessed to evaluate the NBS. The input indicators are used to quantify and qualify the resources invested in the project, for example, number of seedlings planted, number of green roofs implemented and campaigns that are launched to support the socio-cultural values within NBS. The output indicators are used to describe and quantify direct short-term results that arise as a result of the NBS [22], for example, the area of alien trees cleared or the quantifiable area of artificial wetlands created (Table 1).

Table 1. Process indicators developed for the framework proposed by de Lima et al., 2022.

Dimension	Category	Input/Output Indicators
Environmental	Intervention	Number of seedlings planted Number of green roofs implemented Number of roads recovered Area that received the green and blue infrastructure Rate of plants planted survival Area of alien trees cleared Area of active rehabilitation Number of propagules planted Number of pipes installed Greywater water disposal points constructed Vertical wetlands constructed Tree gardens (water filtering sites) constructed Stormwater management (improved road surface with permeable paving) Collection and separation of household solid waste in wheelie bins (compostables, recyclables, non-recyclables) Fabrication of ecomachines (which are water treatment systems using plants and microbes most often housed in a greenhouse) Number of water harvesting structures created and/or restored (e.g., lake, pond, tank) Number and types of watershed structures created and/or restored Number and area of encroachment cleared from water harvesting structures and their network Number and types of nature-based wastewater treatment units installed and/or renovated Location of intervention—individual property or community level Wetlands Permeable paving Water harvesting structures and their network Infiltration facilities Other
Social governance	Project Management	Driving forces for the NBS project The design of NBS Expertise, skills and knowledge of the involved actors Personal values and attributes that facilitate the NBS process
Social governance	Governance	Roles and responsibilities of involved actors Power Societal groups' role in the NBS at the different phases of planning cycle and whether it is top-down or bottom-up
Social governance	Political support	Political support and commitment to driving, planning and implementation of the NBS Political support and commitment after implementation of the NBS—in maintenance, monitoring, evaluation phases
Social governance	Cultural awareness or education	Identified societal/cultural values that are incorporated in the planning and designing of NBS Activities/campaigns that are launched to support the socio-cultural approach/values within NBS Identified local knowledge that is incorporated in the planning and designing of NBS Identified awareness and educational programs for system users and relevant societal groups that are associated with the planning cycle processes of the NBS
Social governance	Working culture	Conflictual/tension/collaborative interaction among actors involved Co-design Joint and integrated authorship of NBS Single/divided ownership of NBS
Economic	Risk	Non-secure financing
Economic	Benefit	Possibility for co-financing from other sources

Table 1. *Cont.*

Dimension	Category	Input/Output Indicators
Economic	Financial Support	Who pays What kind of costs are supported Business model to support private involvement
Technical	Learning	Integrating the learning outcomes by actors involved and their representative organisations for adjustment of NBS, standardisation, producing guidelines, etc. Integrating the learning outcomes by actors involved and their representative organisations for adjustment of NBS in the existing NBS or new NBS Recommendations by community members
Technical	Challenges	Challenges like technical uncertainty, hydrology, soil, geology, lack of technical expertise, lack of space or space optimisation

For the results stage, result-based indicators are developed to support the evaluation and monitoring of the NBS following implementation. These indicators are used to assess whether the planned NBS results in the desired outcome and impact and whether the indicators capture benefits and longer-term challenges that might not have been foreseen (Table 2). They focus on medium- and long-term results and include aspects such as water quality change, which can be quantified by the concentration of pollutants and saved costs associated with water treatment. The result indicators should ideally be developed during the research and planning phase so that baselines can be established and the project assessed against the expectations project participants had at the beginning of the project. They also include information about the wider long-term results and changes promoted by the NBS, which can be more difficult to place a value on. Results can be assessed at several time points and over longer time periods to monitor the project impact, given that the measured indicators might continue changing over different timescales.

Table 2. Results indicators developed for the framework proposed by de Lima et al., 2022.

Dimension	Category	Outcome/Impact Indicators
Social	Cultural	Environmental identity Recreational values Cultural values and practices
Social	Health and well-being	Effects of water quality Effects of water supply
Social	Improving water-related social values and services	Equitable water access for daily use Water availability for different productive uses Gender equity Crime Social cohesion
Social	Social learning and institutionalisation	Policies related to NBS
Social	Threats identified	Lack of legislation, absence from the state
Social	Opportunities identified	Labour, participatory community Recreational use Aesthetic improvement Social/cultural values for ecosystems and biodiversity Spiritual, symbolic and other interactions with natural environment Tourism (aquatic, farm, Forest)
Environmental	Measures (qualitative/quantitative) showing improvement (augmentation) of water quantity (groundwater, surface water)	Amount of standing water Depth to groundwater Water Table Level Number of springs recharged Streamflow improved/revived Other surface water bodies revived, e.g., pond, lake Streamflow variation Reduction in groundwater abstraction for human use Soil moisture (green water improvement) Increased water availability Improved groundwater quality Sediment load

Table 2. *Cont*.

Dimension	Category	Outcome/Impact Indicators
Environmental	Measures (qualitative/quantitative) showing improvement/maintaining of water quality of both surface and groundwater	Turbidity Dissolved oxygen concentration Nutrient (N, P) concentration Cyanobacteria bloom events Biochemical Oxygen Demand (BOD) Total coliforms Total nitrogen (Kjehldahl N) Nitrates Nitrite Nitrate & Nitrite combined Ammonium Dissolved inorganic phosphate (PID) Total dissolved phosphates (PTD) Heavy metals (Nickel (Ni), Lead (Pb), Zinc (Zn)) Pesticides: Chlorpyrifos μg/L, Diazinon (ng/L), PCE (μg/L), TCE (μg/L) Dissolved organic carbon (DOC) Dissolved inorganic carbon (DIC) pH Cations SUM(cations): (sodium (Na), calcium (Ca), potassium (K), magnesium (Mg)) Anions SUM(anions): (carbonates (CO3), bicarbonates (HCO3), chlorides (Cl), Sulfates (SO4), nitrates (NO3)) Total hardness Chlorophyll Oils and greases Salinity: Sodium (Na), Potassium (K), Chlorides (Cl), Sulfates (SO4), Electric conductivity (20 °C) Electric conductivity (field)" Alkalinity: Bicarbonates (HCO3), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K) Presence of aquatic macrophytes Hormones Antibiotics Surfactants Chemical Oxygen Demand (COD) *Escherichia coli* Virus Salmonella Electric conductivity Phytoplankton Algae Colour Biotic Indices of Environmental Quality (IBI) Total Suspended solids
Environmental	Soil Regulation and Maintenance Services	Soil Permeability Erosion prevention (% bare ground)
Environmental	Ecosystem Services	Food Water Provisioning Materials Energy Genetic Medicinal Ornamental Water Purification Water Regulation Air Quality Maintenance Soil Quality Maintenance Soil Retention Climate Regulation Pollination Life Cycle Maintenance Biological Control Recreation Science & Education Heritage Aesthetic Symbolic

Table 2. *Cont.*

Dimension	Category	Outcome/Impact Indicators
Environmental	Enhancing or conserving biodiversity	Diversity Index Composition—aquatic and terrestrial species Presence of bioindicators species—fauna and flora Habitat Connectivity (unitless) Aquatic species richness Percentage of cover native vegetation Benthic organisms Percentage of Invasive exotic vegetation
Economic	Income and jobs	Income-generating activities created directly/ indirectly Jobs created directly/indirectly Property value Household income
Economic	Avoided costs	Water treatment costs Fertilizers costs Water supply costs Irrigation costs

2.2. Case Studies

The case studies are located in Brazil, Norway, South Africa (two case studies), Spain and Sweden (two case studies) [18], and with this geographical scale include both the Global South and Global North. The Norwegian case study is in the research and development and planning phases, the two Swedish case studies are in the planning or construction and implementation phases, and the Spanish, Brazilian and both South African case studies are in the monitoring and evaluation phases. The case studies represent a divergent mixture of NBS for water management focused on issues such as water excess, water shortage and water quality (Figure 2).

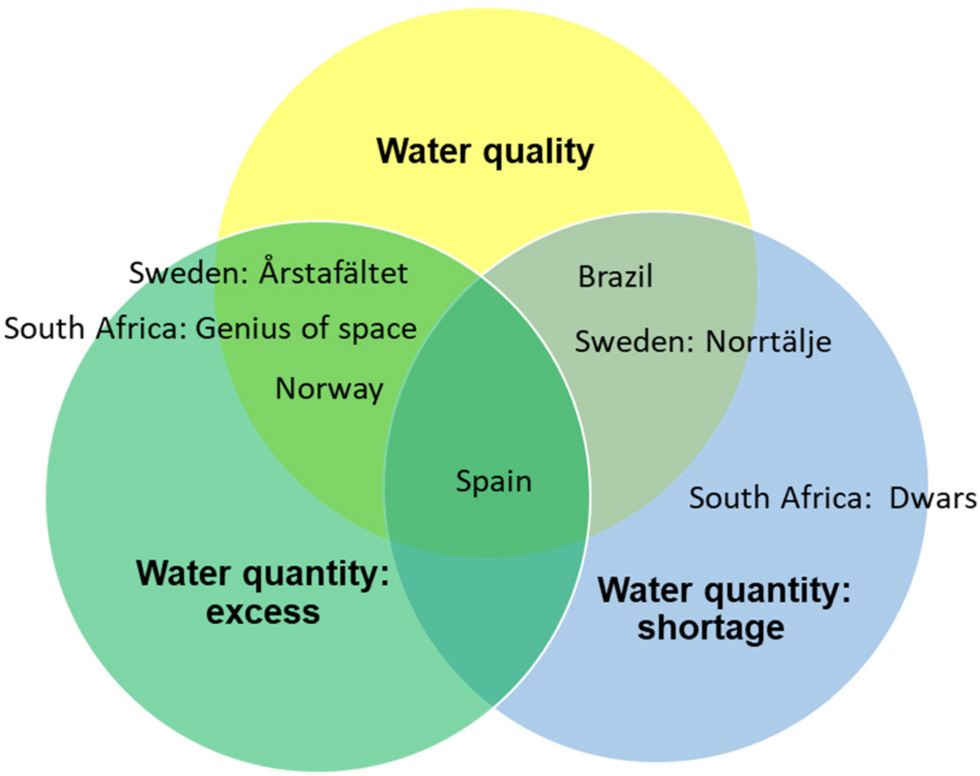

Figure 2. The case studies grouped according to whether the NBS addresses water quality, water excess or water shortage problems.

The NBS that were planned, under consideration or implemented in the case studies included a planned river opening with landscape alteration and leachate treatment, a riverside park and constructed wetlands, water ponds integrated into a city park, the restoration and conservation of degraded land and native vegetation, respectively, establishing tree gardens and riparian rehabilitation. Detailed descriptions of each case study can be found in previous publications [4,23–28] and in NATWIP project case study briefs (http://www.natwip.solutions/Pages/publications.html (accessed on 7 January 2023)). A description of the case studies can be found below.

2.2.1. Brazil—Water and Forest Producers Project

In 2009, the Water and Forest Producers Project in Rio Claro, Rio de Janeiro State began, with the aim of improving the quality and quantity of water in a stretch of the Guandu River basin. The river basin is a vital source of drinking water for 12 million people. The Water and Forest Producers Project was designed as a tool for environmental management, and the NBS used in the program were twofold: forest conservation and restoration; and payment for ecosystem services to improve water quality and quantity in the basin. In the first five years of project operation, USD 1.6 million was invested. In total, 4562 hectares of conservation areas and 564 hectares of restored area are now included in the follow-up monitoring, which is supported by 70 rural landowners [29–34].

2.2.2. Norway—Kjørbekk Stream

Kjørbekk stream is located in the Skien municipality, Norway, and is 4 km long. The water in the Kjørbekk stream is led into a pipe that was constructed in the 1960s, and then travels via the pipe system to the Skien River. The piped system is buried up to 15 m deep and, in certain places, is buried under two disused landfills that received mixed waste and that do not have bottom membranes. The main challenge at the site is related to the possibility of excess surface water resulting from increases in precipitation caused by climate change, or stream water leaking from the ageing pipe infrastructure, coming into contact with waste in the disused landfills, and being contaminated. The case study is in the planning phase where NBS are being considered as part of a strategy to open up the buried stream. More details about this case study can be found in Hale et al. [23].

2.2.3. Spain—Besòs River

The Spanish case study is located in the Besòs River, Barcelona. The project was initiated in response to poor water quality (and general degradation) and problems with water quantity in the river [35]. Water quality was impaired in the river due to industrial pollution, and water quantity issues were seen with both a shortage due to extraction and an excess due to flooding caused by heavy rainfall events [36]. The surrounding Metropolitan area has a higher concentration of socially vulnerable inhabitants, with a much lower income, compared to Barcelona city [37]. The large-scale restoration project began in 1996 in order to address these issues as well as open up the river's banks for passive recreational activities. The restoration project included two types of NBS, namely constructed wetlands and a riverside park. The constructed wetlands were used to improve water quality in the lower river basin by removing phosphorus through natural depuration. The riverside park is 9 km long and combines urban and natural landscapes via blue–green infrastructure. The park has become an area of high multifunctionality, providing opportunities for relaxation and as a meeting space, integrating different municipalities at the metropolitan level. This approach is explained by the leadership of the *Consorci Besòs*, a technical support consortium that promoted "The Agenda Besòs", a shared and agreed-upon action strategy between the five municipalities comprising the end of the Besòs river axis [38].

2.2.4. South Africa—Genius of SPACE (Systems for People's Access to a Clean Environment)

Langrug is a relatively recently formed and continuously expanding informal settlement (slum) near Franschhoek, South Africa [39]. The Stiebeuel River drains the Langrug Catchment (about 4.37 km^2) and enters the Berg River, which is an important agricultural river for the Western Cape (predominantly winter wheat, vineyards and fruit) entering the sea at the Velddrif Estuary (St Helena Bay), supporting important fisheries [40]. The settlement suffers from several problems, including the accumulation of wastewater and solid waste in its streets due to lack of service provision and sewerage and localised flooding. These factors combined increase the risk of disease and other associated health issues [41]. The problems in Langrug result in eutrophication and pollution of the Berg River, which creates further problems for agriculture downstream, especially in relation to import standards of overseas trading partners [42]. The Genius of SPACE project used a number of NBS to attempt to treat and manage wastewater and greywater entering the storm water system, to manage solid waste, to empower local community members and to improve the living conditions and promote social upliftment [43–46]. The NBS used were the installation of 27 greywater disposal points to manage greywater run-off, the installation of underground wastewater pipes to reduce local flood risk and storm water management and the establishment of 15 tree gardens for water infiltration [47].

2.2.5. South Africa—Dwars River

The Dwars River is a tributary of the Berg River in the Western Cape, South Africa. The area suffers from an infestation of the riparian zone by invasive alien trees and weeds, which consume a lot of water relative to the indigenous vegetation and thus reduce water supply, increase fire risk and negatively impact biodiversity [48,49]. The NBS that has been implemented to manage the infestation includes clearing invasive alien trees from the riparian zone and active rehabilitation via planting indigenous riparian vegetation [24]. Running parallel to the NBS was a scheme to engage the community, where employment opportunities were created through this rehabilitation programme, a recycling scheme was set up and a native tree growing program was trialled [27].

2.2.6. Sweden—Årstafältet

Årstafältet is a large, open grass field located in a suburb in southern Stockholm, Sweden, where an NBS project encompassing several solutions spanning the planning, design and construction project phases is being carried out. Initially, a water dam or pond, a distribution ditch and a small stream "valla" were constructed that were planned to be integrated into a landscape park for purifying run-off water from the surroundings, thus restoring the natural water flow and maintaining the ecological value of the grass field [50]. However, due to the huge housing demand, the landscape plan was altered towards urbanising the area and constructing residential buildings. The new plan, 'New Årstafältet', replaced the landscape plan but was substantially challenged by civic groups' opposition and appeals [25]. In the new plan, the city decided to capitalise on existing NBS. It has enlarged the water pond and redesigned the "valla" stream into three water ponds, integrating them into a city park. Furthermore, the city extended the existing NBS to include rainfall management parks, open ditches, trees being planted along roads, green rooves and courtyards, swales (shallow channels), allotment gardens and deciduous forests. These NBS run in parallel with plans to urbanise the area in order to counterbalance the negative effects of the desired urban development. However, the planning and construction of the NBS, mainly the water ponds, have been greatly challenged by technical uncertainties, high cost and investments and contestation over roles of actors in planning and design, financing issues, ownership, division of responsibilities for maintaining NBS, but also the very dynamic and long-term planning process that is exposed to contingencies and change.

2.2.7. Sweden—Norrtälje

Norrtälje is a municipality in the Stockholm Archipelago—the second-largest one in the Baltic Sea. The municipality has the largest number of summer cottages (13,900), many of which lie outside the reach of municipal water supply and sewerage. This poses challenges of access to safe water in adequate quantities for the inhabitants, while also contributing to the eutrophication (excessive increase in nutrients and minerals) of the Baltic Sea. The conversion of many of these houses into permanent residences and the impact of climate change on the precipitation pattern further aggravate the problem. Given this context, it is imperative to implement solutions that can sustainably address the water cycle gap in this coastal municipality. According to Swedish law and municipal regulations, this responsibility lies with the property owners, who can act individually or as collectives. A large variety of technical solutions exist in the market, and though not explicitly marketed as a category, many of these solutions can be described as 'nature-based.' This case study aimed to gain an understanding of the major opportunities, barriers and benefits related to nature-based solutions as a means for greywater treatment at a decentralised scale.

2.3. Application of the Framework to the Case Studies

Owing to the diverse nature of the seven case studies, the way in which the local researchers applied the framework varied. As has been mentioned, the framework was applied either retrospectively, meaning that the NBS had already been implemented, or it was applied to the NBS project at a specific project phase (Figure 2). Thus, the framework was applied at a defined moment in time under a static situation, rather than it being used as a dynamic tool running alongside the conception, design and implementation of the NBS. This research setting meant that it was not possible for an assessment of the same indicators before and after implementation to be made. Thus, the achievement of targets could be assessed in a qualitative or quantitative manner for those case studies that were already implemented, for example, by asking the affected community if they had seen or perceived changes.

For the context stage, information was gathered for each case study related to the project area and the type of affected settlement. Threats, opportunities, problems (and their scales), as well as the involvement of stakeholders, were mapped and recorded. For the implementation stage of the framework, the specific NBS intervention was described (for all case studies except the Norwegian one, which is still in the planning stage), both in terms of type and scale. Process indicators were chosen or developed to capture the resources invested and direct short-term results of the NBS. These indicators were assessed for those case studies that were already implemented, and estimates for required resources were given for those still in the development phase. Relevant stakeholders that were identified and mapped in the context stage were included in the assessment of the process indicators where possible. For the third stage of the framework—the results stage—result-based indicators were used. These could only be assessed for the case studies where the NBS were in the monitoring or evaluation stages to show how, or if, the NBS resulted in medium and/or long-term change.

The local researchers were given freedom in how to apply the framework so that it could be used as a tool to enhance their understanding of their case study. As each of the case studies had its own environmental, social and economic settings, this was important. This approach enabled learning not only about the specific case studies but also about the flexibility and applicability of the framework in a study setting. In addition, the approach inspired some innovation and variation in how the data were gathered. The methods used to develop and assess the indicators in the different case studies are summarised in Figure 3. Different methods were used, including consulting literature and reports, sending out questionnaires and carrying out surveys and interviews with stakeholders. In Brazil, interviews and meetings were conducted with relevant stakeholders who are currently working on monitoring and evaluating the implementation of the NBS project. In addition, reports and academic literature were consulted [29–33]. In Norway, the context was assessed by drawing upon reports and publicly available databases. Certain process indicators, mainly the actors involved and their roles, could be assessed via discussions with the main Norwegian stakeholder involved at the site. In both South African case studies, the NBS was fully implemented at the time the study was conducted. In these case studies, a semi-structured interview was carried out with community members and implementers to assess the defined indicators. Feedback for specific interview questions was captured in a database, and all interviews were recorded for transcription. In Spain, data were gathered from academic literature, policy instruments, direct observation, interviews with various stakeholders, including citizens and surveys [51]. In the Swedish case studies, key municipal, private and community-level actors involved in the planning and implementation of NBS were identified, along with an analysis of relevant policy and planning documents. Thereafter, in-depth semi-structured interviews were carried out with the identified actors. In the Norrtälje case study (Sweden), interviews with local property owners (who are key actors in this NBS) were preceded by a survey administered to a larger group which helped identify a varied representation of actors. Given the fact that the researchers were able to select the indicators that were most suitable for their case studies and their settings, a direct quantitative comparison between indicators could not always be made. Further methodological details can be found in the NATWIP project handbook [52].

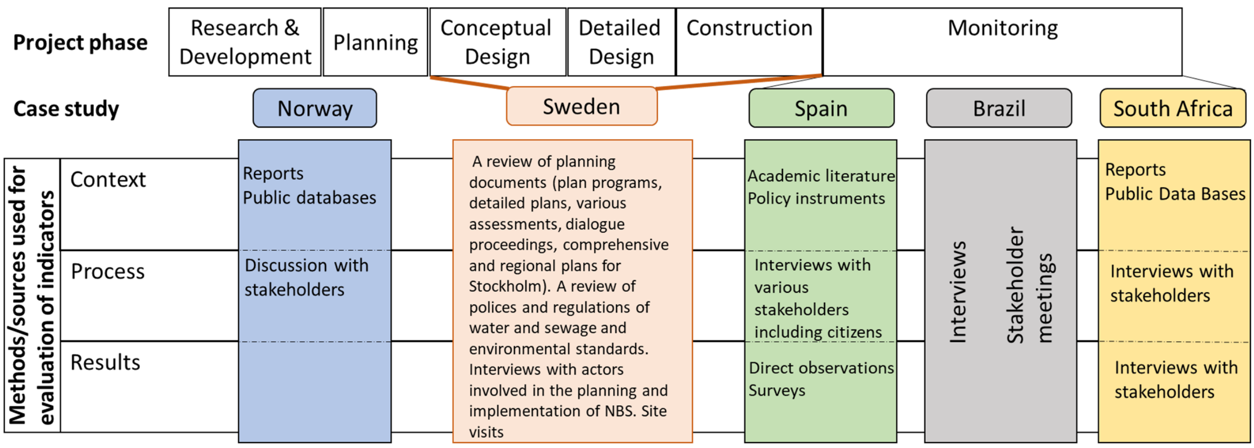

Figure 3. The way in which the case studies are distributed in terms of project phases and the methods used for the definition and evaluation of indicators.

3. Results and Discussion

3.1. Context Stage

The results of the first stage in the framework application describing the context of the case studies are summarised below in Table 3.

The information collected in the context stage of the framework (Table 3) demonstrates that NBS can be adopted as a solution for addressing a wide range of water-related challenges in peri-urban areas. Here the challenges were water excess or shortage as well as water quality degradation. The case studies were mostly at the local or neighbourhood scale, and this was also mirrored in the scale at which the effects of the NBS implementation were felt. The information collected showed that a wide range of actors may be involved with the NBS process, including government at local and national levels, industry, local businesses, civil society, and local communities. Ownership of NBS can be public (government) as well as private (local community). The case studies indicated a need for a more explicit emphasis on NBS within relevant policy frameworks. In many countries, there are overarching policies concerning water quality, though the link to NBS is more often felt on a smaller scale. The majority of case studies described social benefits arising, which were felt with recreation, physical and mental health improvements and social inclusion. The most common barriers to the adoption of NBS were seen as institutional, financial, political (governance), technical, as well as societal.

Table 3. Summary of the main information collected in the context stage of the framework.

Case Study/ Context Information	Brazil	Norway	South Africa–Genius of Space	South Africa–Dwars River	Spain	Sweden–Årstafältet	Sweden–Norrtälje
Location	Rio Claro	Skien	Langrug	Pniel	Barcelona	Årstafältet - Stockholm	Norrtälje
NBS type	Restoration and conservation of degraded land and native vegetation	Planned river opening, landscape alteration and leachate treatment	Green infrastructure (permeable paving, integrated grey water disposal points with tree and herb gardens)	Riparian rehabilitation through alien tree clearing and replanting of indigenous vegetation	Restoration including constructed wetlands and a riverside park	Blue and Green Infrastructure: Water ponds integrated in city parks	Variety of NBS for greywater treatment, e.g., infiltration with/without biomodule, bio-treatment plant, greywater dam (wetland)
NBS scale	Local to municipal	Neighbourhood	Local	Neighbourhood	Municipal to National	Local to Regional	Individual property to Neighbourhood
NBS project phase	Monitoring	Research and development	Monitoring	Monitoring	Monitoring	Planning, conceptual design, detailed design and early construction of the city park and water ponds	Planning, design and monitoring
Supporting policy considered of relevance	Supporting policies for embarking on NBS include the forest code, the water resources and National Plan for the recovery of Nature Vegetation.	National planning guidelines highlight the importance of considering NBS	Lessons learnt from the NBS demonstration phase were used to facilitate policy learning [53] for other informal networks elsewhere.	At the local level there is the National Environmental Management Act 107 of 1998 through which penalties should be enforced for those who don't comply with the act (i.e. clearing invasive alien vegetation from their properties). In reality these penalties are poorly enforced.	European Water Framework Directive. National policy related to water quality including criteria for monitoring and evaluating the quality of surface water. Metropolitan support in the form of the proposed Urban Master Plan to enable and create a global green and blue infrastructure, which reinforces ecosystem functions, and functions for public use and leisure. Local via a document that integrates territorial concerns and the different aspects of the area.	The European Water Framework Directive is enforced in Sweden through Environmental Quality Norms (MKN in Swedish) and is written into the Swedish Environmental Act. The regional plan for Stockholm indirectly mentions NBS by highlighting the importance of innovations, green and blue infrastructure, circular and blue green cycles, and using ecosystem services. The Comprehensive plan of Stockholm mentions the intention to implement ecosystem services and green infrastructure. The Stockholm stormwater strategy promotes locally managed stormwater approaches. "A greener Stockholm" is a strategic document that discusses where nature can help with climate change and water issues such as storm water and floods However; the Water Services Act and accompanying documents as well as the Planning and Building Act and the Environmental Code are not coherent in supporting the NBS and stormwater strategy. The political budget sets a framework for NBS possibilities.	EU Water Framework Directive, the Baltic Sea Region Action Plan, the Environmental Code, 2000 enacted by the Swedish Parliament, 1992 Swedish Local Government Act. Though none of them explicitly mention NBS, the need and obligation of property owners to install sustainable solutions for wastewater/greywater treatment is evident.

Table 3. *Cont.*

Case Study/ Context Information	Brazil	Norway	South Africa–Genius of Space	South Africa–Dwars River	Spain	Sweden–Årstafältet	Sweden–Norrtälje
Challenge and pressure addressed by the NBS	Water shortage, water is polluted which creates a health threat, reduced property value due to water pressures	Water excess due to climate change and pipes being unable to accommodate, leachate water becoming contaminated as it flows over the disused landfills and threatens water quality, ground stability when re-opening the river is a challenge	Water excess and water quality. Other challenges cited: lack of (and theft of) water related infrastructure, health issues due to water pollution, crime	Water shortage. Other pressures are related to social issues such as litter, drug and alcohol abuse	Water excess due to torrential rains as a result of climate chain. Water shortage as a result of Mediterranean dry conditions. Pollution in the form of moderate eutrophication and mineralisation.	Water excess, flooding risk and pollution of stormwater and run off reaching the recipient. The area is being developed via urbanisation / housing needs and the NBS needs to be able to tackle the increase in water due to more impervious surfaces	Degraded groundwater quality as well as eutrophication of the Baltic Sea caused by discharge of contaminated greywater into nature due to inefficient and/or inoperational decentralized greywater treatment systems. Also, water shortage during summer (dry period) due to over-withdrawal of groundwater.
Actors involved	Government at the municipal level and civil society.	Government at the municipal and national levels, industry and civil society	Government, industry, civil society, universities, other water related actors	Government, industry, civil society, universities, other water related actors	Government at the regional, municipal and local levels, water related actors, universities, industry and civil society	Government at the municipal, national and local levels, industry and civil society	Private property owners as individuals and collectives, companies producing NBS technologies, entrepreneurs who help install these systems, other private actors, government at municipal and county scales
Similar projects	One: Rio Claro Amphibians	None	The Water Hub (green infrastructure), Alien Clearing Programmes, Wetlands for water filtration	The Water Hub (green infrastructure), Alien Clearing Programmes, Wetlands for water filtration	None	Yes similar projects in Stockholm	Yes, in other coastal municipalities

Table 3. *Cont.*

Case Study/ Context Information	Brazil	Norway	South Africa–Genius of Space	South Africa–Dwars River	Spain	Sweden–Årstafältet	Sweden–Norrtälje
Expected social benefits	Not described	The blue-green corridor is expected to have a positive effect on environmental identify, pathway for walking and cycling to be included along sections of the river, cultural heritage (buildings and monuments) along Kjørbekk, a restoration would be viewed positive, urban flooding can be an issue	Expected to support health and wellbeing through a reduction in runoff of grey water, and resultant reduction in health risk (through water-borne diseases). Job creation through the project was expected to improve gender equality within the community.	Expected to support recreation and well-being by providing an area for relaxing, swimming, walking/hiking, picnicking. Job creation through the project is expected to improve gender equality within the community.	Not described	The NBS are expected to safeguard the water quality and quantity in the recipient Årstaviken. Biodiversity increase in certain areas, added value caused by recreation and social inclusion	Compared to grey infrastructural solutions, NBS have higher aesthetic and recreational value, help maintain physical and mental health (directly and indirectly), and empower users through participation in sustainable environmental stewardship
Main challenges/barriers for NBS planning and implementation	Legal, financial, technical, political, and societal	Financial and societal	Institutional, financial, technical, and societal (governance)	Institutional, financial, technical, and societal (governance)	Institutional, financial, political, and societal	Institutional, organisational arrangement and technical	Financial, political, and societal (lack of awareness and education)
Ownership	Public (government), as well as private	Public/government	Public (government), as well as private	Public (government), as well as private	Public/government	Public/government	Private (property owners as individuals or collectives)
Scale of impacts	Currently local	Regional	Local	Local	Local and regional	Local and regional	Local and regional (Baltic Sea)

3.2. Process and Result Stages

Following the context, process and results stages of the framework, which cover the detailed planning and implementation, the evaluation and monitoring phases of the project can be assessed (see Figure 1). A full list of processes and results-based indicators in the framework, and additional indicators developed, is given in Tables 1 and 2. Of this list, input indicators are used to quantify and qualify the resources invested in the project and output indicators used to describe and quantify direct short-term results that arise because of the NBS. Result-based indicators provide information about the results of the implemented activities in the medium and long term and changes (direct or indirect and intentional or unintentional) resulting from the NBS. The most relevant input, output, outcome and impact indicators for each of the case studies were assessed according to the methods described in Section 2.3. Owing to the varying nature of the assessment process, standardised quantitative classification schemes were not always used. Despite this, the use of the framework rooted in the ToC and the indicators developed are considered suitable for this analysis. The European Commission has recently published a Practitioner Handbook entitled "Evaluating the impact of Nature-based solutions", which aims to provide detailed information to guide the development and implementation of an NBS monitoring and evaluation plan and the use of the NBS impact indicators presented as a query tool [54]. The handbook also contains a very comprehensive list of suggested indicators reflecting economic, environmental and social aspects of NBS implementations. These indicators draw on qualitative and quantitative methods of assessment, and there are many parallels with the indicators developed here.

The indicators selected for this study range from very specific project-related information to very general, descriptive assessments of the process and changes that were induced or realised by the project at the time when this study was carried out. In addition to the predefined indicators, some additional indicators were developed for specific case studies. For the Norwegian case study where the NBS had not been implemented, expected impacts were described for the result stage, and descriptions were by category rather than by indicator.

The indicators listed as environmental, both in the process and result stages of the framework (see Table 1), are mostly well established and can be measured in a quantitative manner. Tables 4 and 5 show the environmental indicators for the process and results stages of the framework and which case studies were able to obtain information to assess them. For example, water quality can be monitored by determining the concentration of specific chemicals and additional water parameters. Water quantity can also be measured. Yet, the application of the framework to the case studies shows that such data are not always readily available. A range of measures showing improvement in water quantity was only described in the three European case studies, and measures showing an improvement in water quality were only described for the Swedish and Spanish case studies. Two indicators describing water quantity (tourism and streamflow improvement) and three indicators describing water quality (pH, electric conductivity and total suspended solids) were considered relevant for the Brazilian case study. For both of the South African case studies, a list of ecosystem services was introduced as environmental indicators in the result stage and assessed by asking community members and implementers about their perceived improvement. This was because monitoring was not explicitly budgeted for as part of these NBS projects, and therefore no quantitative approaches could be used. Therefore, water quantity and quality were assessed in a qualitative manner by asking community members and implementers their perceptions about whether water provision and purification had improved following the project (roughly half of the respondents answered "yes" for both points in both projects). Monitoring the impacts of NBS in South Africa is not always explicitly budgeted for in implementation projects, and this is characteristic of many finance-constrained countries.

Table 4. Process-based environmental indicators according to whether each case study considered the indicator as relevant to be assessed (indicated with ‘Y’ for yes).

CATEGORY	Inputs/Outputs Indicators	Brazil	Norway	Spain	South Africa—Genius of Space	South Africa—Dwars River	Sweden—Årstafältet	Sweden—Norrtälje
Interventions	Number of seedlings planted	Y					general description of interventions given rather than specific indicators	
	Number of green roofs implemented							
	Number of roads recovered							
	Area that received the green and blue infrastructure	Y		Y				
	Survival rate of plants planted	Y				Y		
	Area of alien trees cleared					Y		
	Area of active rehabilitation			Y		Y		
	Number of propagules planted					Y		
	Number of pipes installed							
	Compliance with health & safety plans?							
	Greywater water disposal points constructed				Y			
	Vertical wetlands constructed				Y			
	Tree gardens (water filtering sites) constructed				Y			
	Stormwater management (improved road surface with permeable paving)				Y			
	Collection and separation of household solid waste in wheelie bins (compostables, recyclables, non-recyclables)				Y			
	Fabrication of ecomachines							
	Number of water harvesting structures created and/or restored (e.g., lake, pond, tank)							
	Number and types of watershed structures created and/or restored (e.g., gabion, checkdam, water absorption trench (WAT), etc.)							
	Number and area of encroachment cleared from water harvesting structures and their network							
	Number and types of nature-based wastewater treatment units installed and/or renovated			Y				Y
	Wetlands			Y				Y
	Water harvesting structures and their network							
	Infiltration facilities							Y
	Other: Reduction of critical water floods			Y				
	Other: Re-meandering of river			Y				

Table 5. Result-based environmental indicators according to whether each case study had data available to assess them (indicated with 'Y' for yes).

Category	Outcomes/Impacts Indicators	Brazil	Norway	South Africa—Genius of Space	South Africa—Dwars River	Spain	Sweden—Årstafältet	Sweden—Norrtälje
Measures (qualitative/quantitative) showing improvement (augmentation) of water quantity (groundwater, surface water)	Recreational use		Y			Y		Y
	Aesthetic improvement		Y			Y		Y
	Social/cultural values for ecosystems and biodiversity		Y			Y		Y
	Spiritual, symbolic and other interactions with natural environment		Y			Y		
	Tourism (aquatic, farm, Forest)	Y				Y		
	Amount of standing water							
	Depth to groundwater					Y		
	Water Table Level		Y			Y		
	Number of springs recharged		Y			Y	Y	
	Streamflow improved/revived	Y	Y			Y		
	Other surface water bodies revived, e.g., pond, lake							
	Streamflow variation					Y		
	Reduction in groundwater abstraction for human use							
	Soil moisture (green water improvement)							
	Increased water availability							
Measures (qualitative/quantitative) showing improvement/maintaining of water quality of both surface and groundwater	Improved groundwater quality					Y		Y
	Sediment load							
	Turbidity							
	Dissolved oxygen concentration					Y		
	Nutrient (N, P) concentration					Y		Y
	Cyanobacteria bloom events					Y		
	Biochemical Oxygen Demand (BOD)							
	Total coliforms					Y		
	Total nitrogen (Kjehldahl N)							
	Nitrates					Y		
	Nitrite					Y		
	Nitrate & Nitrite combined							
	Ammonium					Y		
	Dissolved inorganic phosphate (PID)							
	Total dissolved phosphates (PTD)							
	Heavy metals: (Nickel (Ni), Lead (Pb), Zinc (Zn))					Y		
	Pesticides: Chlorpyrifos μg/l, Diazinon (ng/l), PCE (μg/l), TCE (μg/l)					Y		
	Dissolved organic carbon (DOC)							
	Dissolved inorganic carbon (DIC)							
	pH	Y				Y		
	Cations SUM(cations): (sodium (Na), calcium (Ca), potassium (K), magnesium (Mg))					Y		
	Anions SUM(anions); (carbonates (CO_3), bicarbonates (HCO_3), chlorides (Cl), Sulfates (SO_4), nitrates (NO_3))					Y	Y	
	Total hardness					Y		
	Chlorophyll							
	Oils and greases							
	Salinity							
	Sodium (Na)							
	Potassium (K)							
	Chlorides (Cl)					Y		
	Sulfates (SO_4)							
	Electric conductivity (20 °C)							
	Electric conductivity (field)							

Table 5. *Cont.*

Category	Outcomes/Impacts Indicators	Brazil	Norway	South Africa—Genius of Space	South Africa—Dwars River	Spain	Sweden—Årstafältet	Sweden—Norrtälje
	Alkalinity: (Bicarbonates (HCO3), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K))					Y		
	Presence of aquatic macrophytes					Y		
	Hormones							
	Antibiotics							
	Surfactants							
	Chemical Oxygen Demand (COD)					Y		
	E. coli					Y		Y
	Virus							
	Salmonella							
	Electric conductivity	Y				Y		
	Phytoplankton Algae							
	Colour							
	Biotic Indices of Environmental Quality (IBI)					Y		
	Total Suspended solids	Y				Y		
Soil Regulation and Maintenance Services	Soil Permeability		Y				Y	
	Erosion prevention (% bare ground)		Y			Y		
	Food			Y	Y			
	Water Provisioning			Y	Y			Y
	Materials			Y	Y			
	Energy			Y	Y			
	Genetic			Y	Y			
	Medicinal			Y	Y			
	Ornamental			Y	Y			
	Water Purification			Y	Y			Y
	Water Regulation			Y	Y			Y
	Air Quality Maintenance			Y	Y			
Ecosystem Services	Soil Quality Maintenance			Y	Y			
	Soil Retention			Y	Y			
	Climate Regulation			Y	Y			
	Pollination			Y	Y			
	Life Cycle Maintenance			Y	Y			
	Biological Control			Y	Y			
	Recreation			Y	Y			Y
	Science & Education			Y	Y			
	Heritage			Y	Y			
	Aesthetic			Y	Y			Y
	Symbolic			Y	Y			
	Diversity Index		Y			Y		
	Composition (aquatic and terrestrial species)		Y			Y		
	Presence of bioindicators species (fauna and flora)	Y	Y			Y		
Enhancing or conserving biodiversity	Habitat Connectivity (unitless)						Y	
	Aquatic species richness							
	Percentage of cover native vegetation					Y		
	Benthic organisms					Y		
	Percentage of Invasive exotic vegetation		Y			Y		

Whilst many environmental aspects tend to be represented by a defined numerical parameter, social aspects—and the assessment of social and governance indicators—often rely on surveys or interviews. In a study setting such as the one here (used by the researchers in the NATWIP project), the impact of a (NBS) project on, for example, well-being or power struggles, can be investigated by asking survey participants about their perception of change related to these aspects. To assess these points during a project, it could be beneficial to provide guidelines that can support aspects such as survey scale, types of interview questions and format, especially whether these factors were to be assessed before and after implementation. Thus, awareness of data availability and the planning of data collection and assessment alongside the development of indicators is particularly important for these aspects. By considering and building in monitoring aspects at the start of an NBS project, the overall assessment and evaluation of the NBS implementation and results can be carried out both before and after implementation. Tables 6 and 7 show the social indicators for the process and results stages of the framework according to which case studies were able to compile data to assess them. Overall, there are more apparent data available for the social indicators for the case studies used here. This may be because the formulation of the social indicators allowed more room for interpretation and for the researchers to assess them in a more flexible manner. In addition, it may have been because it was possible for the researchers to ask questions to probe social indicators that applied to the before and after scenarios.

As for the environmental aspects, some economic indicators are well established and can be assessed in a quantitative manner, for example, the number of jobs or the training opportunities created through a project. However, especially if done retrospectively, data availability may be scarce, as can again be seen for the South African case studies where the evaluation of indicators was conducted with interviews. When carrying out the data collection for this study, it became apparent that many case studies had not measured and publicly reported specific data. For example, the indicator framed around jobs as: "jobs created directly/indirectly from the NBS project" was assessed by asking different stakeholders the following questions: "Did the project create new jobs in your community?", "Were you directly employed in the project?" and "Were jobs created indirectly through tourism?". In the Spanish case study, a numerical value was reported for the number of indirectly created jobs. There are many reasons for this difference in reporting that may be centred around financial, political and social support for the implementation of the NBS.

The comparison of the process-based environmental indicators (Table 4) shows that a wide variety of environmental indicators may be relevant for assessing the process of planning, designing, constructing and monitoring NBS. These generally tend to be case study specific. Among the process-based social indicators used for assessing the case studies (Table 6), expertise, skills and knowledge of the involved actors, as well as their personal values and attributes, were found to be universally significant for project management. Among governance-related social indicators, roles and responsibilities of involved actors, importance of power, and societal groups' role in the NBS at the different phases of planning cycle and its character as top down or bottom up were found to be universally relevant for assessment. Political support is yet another social indicator found to be critically important for all the case studies, being important for driving, planning and implementation of the NBS as well as for maintenance, monitoring and evaluation. Among the cultural indicators, identified societal/cultural values that are incorporated in the planning and design of NBS and identified awareness and educational programs for system users and relevant societal groups were found to be important in the majority of case studies. Indicators related to working culture were also found to be significant in most of the case studies, particularly the ones regarding conflictual/tension/collaborative interaction among actors involved and co-design.

Table 6. Process-based social indicators according to whether each case study considered the indicator as relevant to be assessed (indicated with 'Y' for yes).

Category	Inputs/Outputs Indicators	Brazil	Norway	South Africa—Genius of Space	South Africa—Dwars River	Spain	Sweden—Årstafältet	Sweden—Norrtälje
Project Management (throughout all stages: research and development, planning, pilot study, conceptual design, construction and monitoring)	Driving forces for the NBS project						Y	Y
	The design of NBS						Y	Y
	Expertise, skills and knowledge of the involved actors	Y	Y	Y	Y	Y	Y	Y
	Personal values and attributes that facilitate the NBS process	Y	Y	Y	Y	Y	Y	Y
Governance	Roles and responsibilities of involved actors	Y	Y	Y	Y	Y	Y	Y
	Power	Y	Y	Y	Y	Y	Y	Y
	Societal groups' role in the NBS at the different phases of planning cycle and whether it is top down or bottom up		Y	Y	Y	Y	Y	Y
Political support	Political support and commitment for driving, planning and implementation of the NBS	Y	Y	Y	Y		Y	Y
	Political support and commitment after implementation of the NBS in maintenance, monitoring, evaluation phases	Y	Y	Y	Y			Y
Cultural/Awareness or educational	Identified societal/cultural values that are incorporated in the planning and designing of NBS		Y	Y	Y		Y	
	Activities/campaigns that are launched to support the socio-cultural approach/values within NBS		Y	Y				Y
	Identified local knowledge that is incorporated in the planning and designing of NBS		Y	Y			Y	
	Identified awareness and educational programs for system users and relevant societal groups that are associated with the planning cycle processes of the NBS			Y			Y	Y
Working Culture	Conflictual/tension/collaborative interaction among actors involved		Y	Y	Y	Y	Y	Y
	Co-design			Y	Y		Y	Y
	Joint and integrated authorship of NBS					Y	Y	Y
	Single/divided ownership of NBS					Y		Y

Table 7. Result-based social indicators according to whether each case study considered the indicator as relevant to be assessed (indicated with 'Y' for yes).

Category	Outcomes/Impacts Indicators	Brazil	Norway	South Africa—Genius of Space	South Africa—Dwars River	Spain	Sweden—Årstafältet	Sweden—Norrtälje
Cultural	Environmental identity		Y	Y	Y	Y		Y
	Recreational values	Y	Y	Y	Y	Y	Y	Y
	Cultural values and practices		Y	Y	Y	Y		
Health and well being	Effects of water quality		Y	Y	Y	Y	Y	Y
	Effects of water supply		Y			Y		Y
Improving water-related social values and services	Equitable water access for daily use			Y	Y			Y
	Water availability for different productive uses			Y	Y	Y		Y
	Gender equity			Y	Y		Y	
	Crime			Y	Y			
	Social cohesion			Y	Y			
Social learning and institutionalisation	Policies related to NBS		Y	Y		Y	Y	Y
Threats identified	Lack of legislation, absence from the state		Y	Y		Y	Y	Y
Opportunities identified	Labour, participatory community		Y	Y		Y	Y	Y

The comparison of result-based environmental indicators across the different case studies (Table 5) shows that these are case-specific and can relate to one or more of the following categories: qualitative/quantitative measures showing augmentation of water quantity, improvement/maintenance of water quality, soil regulation and maintenance services, ecosystem services, enhancing/conserving biodiversity. The comparison of result-based social indicators (Table 7) shows that under the category of cultural indicators, environmental identity, recreational values, as well as cultural values and practices were found to be almost universally relevant for assessment. Under the category of health and well-being, the effect of water quality was similarly found to be universally relevant. The social learning and institutionalisation category was found to be important for consideration, under which the existence of policies related to NBS was considered significant. Among threats, lack of legislation and lack of involvement from the state were found important, while among opportunities, labour and participatory community were most highlighted.

The above presentation of results demonstrates that the framework for planning and evaluation of NBS for water in peri-urban areas developed by de Lima et al. [18] is robust and yet flexible. In this study, the framework was successfully applied to seven different NBS projects located across the Global North and South. The case studies are at different phases of the project cycle, namely, planning, design, construction and monitoring/evaluation, and address a variety of water challenges.

The results also demonstrated the process that needs to be adopted for applying the framework to assess pragmatic NBS case studies. For example, for the context stage, information should be gathered in relation to the project area, the type of affected settlement, threats, opportunities, problems (and their scales) as well as the involvement of stakeholders. For the process and results stages of the framework, appropriate process-based and result-based indicators should be chosen/developed to capture the details. The framework should also be used in a flexible setting in order to allow each NBS project that uses the framework to develop specific indicators to use. It is also clear that making generalisations across such diverse case studies can be difficult. This must not be viewed as a negative point but should merely highlight the importance of ensuring that the framework used to assess a case study consists of relevant indicators in order that as much information as possible can be obtained.

3.3. Lessons Learnt

Per definition, NBS should bring about "co-benefits for health, the economy, society and the environment" (EC, 2015). Considering the interdependencies between challenges and our response to them, by working systemically, these co-benefits of NBS can be realised [55]. Indeed, it becomes apparent that NBS should be included in decisions taken related to water resources. The varied nature of the case studies presented here shows just how complex the design, implementation and monitoring processes for NBS projects in peri-urban areas can be. Indeed, the use of NBS in any area (be they urban or rural) can present challenges owing to the highly variable environmental, economic, social, cultural and health settings. This only serves to highlight the importance of ensuring the goals of the NBS match those of the local setting. Experts with different backgrounds, working in different sectors, must come together with practitioners working on the ground as well as other relevant stakeholders to facilitate a successful process [56,57]. Co-benefits become greater if, for example, economic feasibility can be linked to social improvements and environmental benefits can be linked to overall economic performance. In order to link these dimensions, it is important that experts with the correct backgrounds are bought together and work in close exchange with the local communities [53,58]. It is also crucial that the local community is involved in the development of the NBS as well as the indicators by which it will be evaluated [59], as their engagement will also bring about a sense of ownership and facilitate long-term success. Despite the diversity of the case studies, it is important to acknowledge that both quantitative and qualitative approaches that foster learning are needed. By identifying the positive aspects and longer-term benefits of NBS, it should be possible to show that, given time, the NBS may be able to provide a more economic and sustainable solution.

An important finding from the case studies in Brazil and South Africa (Dwars River) was that different understandings of the general principles, e.g., ecological principles, at play could be a barrier to an NBS project. For example, there are misperceptions of the universal value of trees [60]. Understanding the negative impacts of invasive alien trees on nature, water and fire risk in South Africa can empower communities to more constructively participate in NBS projects. Conversely, knowledge transfer in this area is a potential benefit of an NBS project [61]. The local people participating in the interviews carried out in South Africa stated that they would have benefited from training related to the ecological principles and the potential ecological benefits that could be achieved by implementing the NBS prior to the project start. This would also have given them an opportunity to reflect and comment on the chosen solution as well as the potential effects it might generate. Assuming all local actors have a good understanding of ecological principles or that their understanding is similar to the local implementers' applying the framework, may not hold true. Rather, language needs to be found that allows mutual exchange amongst project participants. Topics such as how natural systems work (e.g., ecological functions and ecosystem services), their value to society and different techniques that can be used to implement NBS lend themselves to training and education. Related to this is the way in which the data were collected, as using interviews to collect perceptions can be a very powerful process and one that other case studies may employ. By empowering people by giving them the possibility to share insights, resistance to the implementation of an NBS can be reduced as the advantages and disadvantages of the given NBS are contemplated and tested. Of importance from the economic side is that funding is often difficult to come by and even more difficult to maintain throughout the duration of an NBS project. Taking these aspects into consideration from the outset of the project was highlighted as being beneficial by the Norwegian and the Spanish case studies in order to be able to plan accordingly. The South African case studies noted sustainable funding for NBS to be a particular challenge. If diverse funding sources are targeted and flexible funding models are used to support the implementation of the NBS, outcomes could potentially be more positive. The Norwegian case study also identified the importance of linking economic benefits such as increase in property value to be reinvested in the development of the project as common goods [62] and the ability of the landscape to be able to resist natural climatic negative events to the implementation of NBS. By promoting positive economic benefits and the feasibility that are relevant in the specific case study country or region, a positive financing loop may be created and assessed [63].

Many countries in the global North are beginning to recognise the importance of NBS in policies at the local level. For example, in Norway, key government planning guidelines for adaptation encourage municipalities and counties to use NBS in their land-use and general planning processes. Indeed, in 2018, a requirement was introduced whereby municipalities must consider NBS, and if they are not chosen, they must justify why not [64] (Table 1). The policies detailed in Table 1 for Sweden, Spain and Brazil show that there are currently no specific policies for NBS and that the supporting policies identified address specific topics such as water quality. The connection of these topics is then captured in urban and regional plans, such as in the formulation of the Metropolitan Masterplan in Barcelona, in which the Besòs implementation is recognised as a key GI for the water cycle [51]. In Sweden, the interplay of policies that support water quality, climate change adaptation and GI is captured by the national and regional documents of relevance. Despite this, there is no coherent policy that is able to push system change towards NBS [65]. Working with NBS can reveal these interdependencies and lead to an increased understanding of the local situation and even to changes in, or the introduction of, new policies. For example, the processes around the Swedish case study, even if not implemented yet, have led to stricter regulation for stormwater management.

4. Conclusions

The framework designed by de Lima et al., [17] is an effective tool for considering a variety of case study contexts from around the world, both the Global South and North. The framework can be applied at any phase of an NBS project to develop and structure indicators that allow the NBS to be assessed in terms of whether the planned outcome and desired impact materialise. It can also be used to identify co-benefits and unintended consequences that might not have been foreseen, but that could inform future projects of the same kind or in a similar context. As a result, the use of the framework benefits the recognition of the implementation's advances, such as the change in context, the processes in place and the results obtained, as well as the specific arrangements, tools and perceptions that have supported, or are still needed for this purpose.

The clear diversity of the case studies used in this work shows that NBS projects designed in one context, for a specific purpose in a specific location, can not necessarily be transferred easily to another location and thus generalisations can be difficult to draw [66]. Each NBS project addresses a problem that is specific to the area where the NBS will be implemented and thus it must be designed to match the local environmental, socio-political and economic context. However, some similarities between diverse case studies exist. All of the case studies described here act on and/or are planned at a local or municipal governance level and participating actors and project ownership are mostly public and this indicates that the described NBS are of importance to their respective cities of implementation. It is also clear that these peri-urban projects are complex, as they deal with a multitude of interdependent inputs and effects and thus have to be overseen on a public level and revisited in time.

The importance of establishing multi-level collaboration and engagement at different governmental levels and with all stakeholders from the start of the project, has been repeatedly emphasised in the literature [67]. This is particularly true for building a ToC, as involving the affected people in the development of a desired future as well as the path to it will ensure more active involvement during implementation and evaluation and stronger identification with the project in general. The integration of quantitative data and qualitative descriptions by various stakeholders can help us to understand the complex interrelations that can hinder or support the development and implementation of an NBS as well as potential feedback loops [68]. In the current study, the description of the process carried out in most of the discussed case studies was stated as "top down" (apart from one South African case study—Genius of Space), which stands somewhat in contrast to this idea of co-design. These findings suggest that there is still a way to go until inclusive, participatory processes are established around NBS interventions. Overall, it is important to remember that even if not directly transferrable, a consistent framework allows for mutual learning.

It is also worth considering the broad experience that different parts of the world have with NBS, both in terms of implementation and monitoring. The Global Environment Facility (GEF) is a multilateral fund dedicated to confronting biodiversity loss, climate change, pollution and strains on land and ocean health and GEF has vast experience in monitoring water projects. GEF's work focusing on marine and freshwater ecosystems and their conservation and management involves a strong element of monitoring. The United States Agency for International Development is another organisation leading with experience related to the use of NBS for water management. Learning from such organisations is of great benefit.

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