SilvaWorld (2023), *2*(1), 50-59 https://doi.org/10.29329/silva.2023.518.06

SilvaWorld http://silvaworld.org

SilvaWorld
e-ISSN: 2822-6127

PRENSIP https://prensip.gen.tr

REVIEW ARTICLE

A Review on the Methodological Basis of Nature-Based Solution (NBS) Applications in Basin Restoration Projects

Erda Çeler[1] • Yusuf Serengil[2]

[1]UNFAO Subregional Office for Central Asia, Yenimahalle, Ankara/Türkiye
[2]İstanbul University-Cerrahpaşa, Faculty of Forestry, Department of Watershed Management, İstanbul/Türkiye

ARTICLE INFO

Article History
Received: 14.02.2023
Accepted: 24.02.2023
First Published: 30.03.2023

Keywords
Applications
Ecological functionality
Nature-based solutions
Watershed indicators

ABSTRACT

Nature-based solutions (NBSs), a sustainable landscape restoration approach, covers rebuilding ecological functionality and integrity in a watershed. The objective of restoration with NBSs is to revitalize the ecosystems to provide and sustain multiple services. Therefore, it is more than just planting trees or rewetting wetlands. NBSs can provide effective landscape restoration and management tools but should be applied on a methodological basis to get the full benefits. The methodological basis includes the type and nature of NBS, the application principles, and the tools to assess the efficiency of the set of NBS applied. However, most literature on NBSs is theoretical, while practitioners need applicable guidance. In this paper, we reviewed the latest literature on the NBSs and tried to connect the theory with some practical examples. We also underlined that NBSs applied in landscape restoration should relate to watershed processes since streamflow and/or stream quality are significant performance indicators. The NBSs should strengthen the resiliency towards multiple stressors and disturbances in a landscape. The widespread stressors in Türkiye landscapes are related to water balance that compares precipitation and evapotranspiration. Therefore, we suggest Budyko theory application in evaluating NBS options instead of typical climate models. Overall, this paper defines NBSs, provides examples, discusses possible methodologies, and comes up with some practical conclusions. The points we discuss are the resiliency assessment approach, scale, and location of the application, identifying the problems in a watershed through adequate quantitative indicators, and setting up the thresholds planned to be achieved.

Please cite this paper as follows:

Çeler, E., & Serengil, Y. (2023). A review on the methodological basis of nature-based solution (NBS) applications in basin restoration projects. *SilvaWorld*, *2*(1), 50-59. https://doi.org/10.29329/silva.2023.518.06

1. Introduction

Nature-based Solutions (NBSs) are methods that use and enhance nature (Seddon et al., 2019) to sustainably protect and restore natural or modified ecosystems. NBSs improve social and environmental challenges (*e.g.*, climate change, food, water safety, or natural disasters) in an effective and compatible manner for human welfare and biodiversity benefits (Cohen-Shacham et al., 2016), from job creation to enhanced well-being for citizens. It comprises various multifaceted actions that work sustainably to restore and protect the natural environment. The European Commission defines nature-based solutions as "*Solutions inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more diverse, nature and natural features and processes into cities and landscapes through locally adapted, resource-efficient and systemic interventions*" (EC, 2020). The International Union for Conservation of Nature (IUCN) defines NBSs as "*Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human*

Corresponding author
E-mail address: celererda@gmail.com

well-being and biodiversity benefits" (Cohen-Shacham et al., 2016).

Nature-based solutions can play a crucial role in addressing global challenges, such as mitigating (reducing carbon emissions) (Cohen-Shacham et al., 2016), and adapting to climate change (Seddon et al., 2020). They are practical and cost-efficient compared to engineered alternatives (Sowińska-Świerkosz & García, 2021). These solutions are living solutions and serve multiple benefits, such as empowering people and communities, combating biodiversity loss, enhancing resilience, disaster risk reduction, contributing to human physical and mental health, job creation, and business opportunities. Working with nature, people and communities can promote and implement solutions in a resilient, resource-efficient, and green economy.

NBS-related concepts that well-managed ecosystems have benefits and services for human well-being (Science for Environment Policy, 2021). Protecting, sustainably managing, or restoring natural or modified ecosystems and supporting their health, function, and biodiversity can become essential for simultaneously addressing economic, social, and environmental aims (IEEP, 2020). The issue of NBS-related concepts includes a whole range of ecosystem-based and related concepts. The main concepts are ecosystem-based adaptation, ecosystem-based mitigation, ecological engineering, forest landscape restoration, ecosystem-based disaster risk reduction, green infrastructure, climate adaptation services, natural infrastructure, area-based conservation, ecosystem-based management, and ecological restoration (Cohen-Shacham et al., 2016).

NBS approaches aim at sustainable development by enhancing the stability of ecosystems, renewal capacities, and effectiveness of ecosystem services for a better living environment. NBS forms part of the umbrella concept of ecosystem-based approaches that covers many measures (*e.g.*, protecting forests, improving agricultural practices, and bringing more green spaces into cities). Moreover, when combined with tools for green infrastructure, it is adaptable to many projects related to forestry and land use changing subjects. It can be included in all forestry policies and programs integrated with ecosystem services for an effective mitigation and adaptation framework.

Some examples of NBS (Cohen-Shacham et al., 2016) are:

- Restoration of the riparian corridor to reduce the risk of flooding
- Sustainable management of wetlands and paddy fields for flood control and conservation of biodiversity
- Conservation and restoration of flooded forests
- Protection of barrier islands and wetlands to lessen storm damage
- Development of green infrastructure and biodiversity plan for a city
- Manage transboundary waters with ecosystem-based measures

On the other hand, NBSs encompass natural solutions that can be used in many water-related issues and therefore envisage a watershed approach. *Watershed management* is a multidisciplinary land planning and management discipline that serves the hydrological cycle from an ecological perspective and is based on the watershed approach. This means that an ecological solution vision can be brought to environmental problems of any scale (matrix, landscape, basin, *etc.*). Furthermore, the watershed approach can enable an environmental problem to be evaluated for cause and effect because most downstream issues (*e.g.*, flood, landslide) are connected to upstream (deforestation, agriculture, *etc.*) issues or practices (Sunde et al., 2018).

Consequently, the problems related to climate change and the environment are associated with the hydrological cycle to be understood and resolved with the watershed approach. Ecological solutions are necessary for sustainability in the solution phase, whether called NBSs or expressed with traditional definitions and concepts.

1.1. NBSs for Multiple Ecosystem Services

NBSs can be applied to enhance multiple ecosystem services. For example, an artificial wetland may serve in erosion control, flood mitigation, water quality improvement, and groundwater recharge. Below are some of the NBS suggested for various land use types widely used and applicable to Türkiye (Table 1).

As seen from the table, the benefits of NBSs tend to get weaker despite the applicability and costs increasing in urban areas compared to forests and rangelands. Riparian management requires only technical knowledge and arrangements, while a detention basin, artificial wetland, or infiltration pool involves construction and maintenance costs and land to allocate.

It is crucial to choose the most effective NBSs in case of several possible options. Cost, applicability, social and legal issues, and technical constraints exist. However, one parameter that guides the planners is the ecosystem services the NBS may contribute or enhance. Below is an example of three NBS comparisons on multiple ecosystem services (Table 2).

Table 1. NBS examples for various land use types in Türkiye.

	NBS Type and Description	Benefits	Final Benefits
Grasslands	Terracing combined with revegetation with native species	Decrease surface runoff by increasing infiltration. Increase the lifespan of hydraulic infrastructure by reducing erosion and sedimentation. Increase the organic carbon content of the soils by enhancing organic matter accumulation. Improve water quality and reduce treatment costs by reducing sedimentation and filtering nutrients and pollutants.	Sustain livestock and range management. Erosion control Torrent and flood control Carbon removal Water quality improvement The longer life span for gray infrastructure
Forestlands	Riparian and stream corridor management	Habitat quality for wildlife. Biodiversity improvement. Reduce channel erosion substantially. Improvement of aquatic biota. Water quality amelioration by filtering sediments, nutrients, and pollutants.	A more sustainable low cost-high impact forest management scheme at the headwater.
Urban areas	Dry detention basins	Increase pervious area to enhance groundwater recharge. Improve stormwater management. Provide green space.	Support stormwater management and flood attenuation.

Table 2. A comparison of three NBS to produce multiple ecosystem services. Forest management towards water production, stream corridor restoration, and detention ponds/pools.

Forest Management	Stream Corridor Restoration & Management	Detention Ponds or Pools
Water production (quality, quantity, regime)	Water quality	Water quality
Flood mitigation	-	Flood mitigation
Biodiversity conservation	Biodiversity conservation	-
Eutrophication and sediment control	Eutrophication and sediment control	Eutrophication and sediment control
Carbon sequestration	Carbon sequestration	-
Habitat conservation	Habitat conservation	-
Surface erosion control	Surface and channel erosion control	-
Wood and non-wood products	Wood and non-wood products	-
Nutrient management	Nutrient management	-
-	Landscape value	-
Microclimate regulation	Microclimate regulation	-

Forest management is one of the best options since the technical expertise is generally already available; however, there is also the issue of tradeoffs between some of the services, such as water and timber production. Unlike the other two NBS options, forest management may contribute to all aspects of water production through a well-established litter layer. Among the three NBS, the detention pools provide flood attenuation service and contribute to water quality amelioration by reducing downstream sediment transport. Stream corridor restoration is one of the best options as it is easy to apply and contributes to landscape visual value and several benefits. These three options have different costs and benefits, and applicability. They can also be considered complementary measures.

1.2. Riparian and Stream Corridor Management for Flood Attenuation and Aesthetics

Flooding is a natural phenomenon and has been subject to even religious scripts. Every fluvial system floods in low (100-1000 years), medium (10-100 years), or high frequencies (0-10 years) based on precipitation conditions, topography, land use, and human interventions. The traditional engineering solution for flooding is to enlarge the channel capacity and increase water velocity downstream for quick drainage. This is the default approach for municipalities and government agencies. The enlarged channels work well to drain the water from uplands, but the concrete channels provide an inferior landscape value, especially during the low flow periods. Furthermore, the traditional channeling solution does not address mudflows, torrents, or landslides that may accompany floods.

As an alternative to the traditional downstream channelization approach that enhances fast drainage of the streamflow, upstream NBSs can be considered for the opposite, slower runoff travel time through increased roughness. This can be enabled through several NBSs, such as detention ponds, detention pockets (Figure 1), artificial wetlands, infiltration pools/trenches, or even vegetation management.

Figure 1. A detention pocket to enlarge the channel capacity on a piedmont tributary of a stream in North Carolina, USA (Photo by Yusuf Serengil).

2. Principles to Apply and Select NBSs

The NBS application steps for flood attenuation have been given World Bank (2017) as;

i. Define the problem, project scope, and objectives

This step seems simple, but it is a critical part of the process. In many cases, the problem is overlooked; therefore, a solution may even cause another problem.

ii. Develop financing strategy
iii. Conduct ecosystem, hazard, and risk assessments
iv. Develop a nature-based risk management strategy
v. Estimate the costs, benefits, and effectiveness
vi. Select and design the intervention
vii. Implement and construct
viii. Monitor and inform future actions

Sowińska-Świerkosz and García (2021) identified the concepts of the effectiveness of NBSs as stakeholder's participation, policy and management capability, economic efficiency, analysis of synergies and tradeoffs, adaptation to local conditions, adequate spatial scale, and performance in the long term.

Active participation of stakeholders is needed for the effective implementation and management of NBSs. A broad set of stakeholders must be engaged to realize the benefits of NBS, which must be considered part of NBS evaluations. NBS projects require bringing more comprehensive stakeholders with several preferences in implementation and operation. Building a joint approach can help the long-term design, implementation, and management of the NBS project. Choosing an appropriate NBS may be ideal from an environmental perspective, and stakeholders opinions and decisions can influence the development of NBS projects. According to the stakeholders, climate change is one of the main concerns in the urban context. Sharing the concerns about urban challenges with different stakeholders and including them in the planning and decision process is crucial to implement NBS projects efficiently. The stakeholders include policymakers, urban planners and other public agents, scientific community members, businesses, nature-based enterprises, impact investors and industries, non-governmental organizations, and civil society (Dumitru & Wendling, 2021). Because of the increasing global urbanization, cities meet many social and environmental challenges. Instead of grey infrastructure, nature-based solutions intend to use green infrastructure to enhance health and well-being. The design of urban environments requires different stakeholder perspectives and ideas (Ferreira et al., 2020).

A multi-level government strategy is required to integrate institutional structures since the relevance of incorporating local conditions for spatial planning, implementation, and management needs a multi-level government approach. Integrating the national vision, strategy, and policies to local implementation and management of NBS promote project acceptability and long-term stewardship. For instance, in Augsburg (Germany), the national water policy and regulation forced the local water provider to perform a three-point plan for water quality protection. This plan consists of land procurement and reforestation, voluntary partnerships with local farmers, and regulations on land use to evade establishing water treatment facilities. NBS should solve based on a flexible and transparent governance framework. It is possible to take the necessary action to modify and enhance the solution that has been embraced (Sowińska-Świerkosz et al., 2021). Management capability is essential to consider an NBS a practical instrument. An existing national policy framework, such as environmental protection measures, spatial planning, may help or impede the implementation of an NBS (Vignola et al., 2013). The NBS should intervene depending on the policy, legislation, and spatial planning (Santoro et al., 2019).

Economic efficiency refers to many natural-based solutions with multiple co-benefits for health, the economy, society, and the environment. Nature-based solutions promote economic growth in urban settings, heavily reliant on the quantity and quality of accessible natural resources. NBS can diminish water management costs in the short term (by eliminating the need for costly water treatment plants) and in the long term (by lessening operations and maintenance costs) (Liu et al, 2023).

Nature-based solutions have immense potential to be energy and resource-efficient and adaptable to change, but they must be tailored to local conditions to be effective. As the soil, climatic, and hydrological conditions alter, it is necessary to determine and manage how distinct restoration strategies, such as varied landscape designs, planning methods, and vegetation characters, are most suitable for local surroundings. As a result, the solution must consider local environmental factors and requirements. An effective NBS should be adapted to a given implementation area. The authors suggest assessing the effectiveness of different NBS under different environmental conditions before project implementation. In order to do that, the extent to which local variables alter effectiveness must be defined to select local solutions that fit the local context.

An effective NBS should cover an appropriate extent. The effectiveness of each intervention causing the problem and the expected thresholds should determine the scale of the solution implementation. The size of the area and configuration of vegetation affect (1) the durability of environmental methods; (2) the quantity of carbon captured; (3) the number of people who benefit; and (4) the long-term efficiency of resource utilization (EC, 2015). Consequently, the extent of the solution implementation should be determined by the amount of disturbance creating the problem and the expected thresholds.

Science for Environment Policy (2021) defines NBS that have three comprehensive sections from their aspects of interventions:

- Minimal or no intervention in ecosystems: The solution is to protect or enhance the ecosystem services such as conservation of the ecosystem and restoration strategies.
- Management approaches that involve some intervention: The solution is to develop the ecosystem services sustainably-for instance, sustainable agriculture and forestry.
- Extensive management of ecosystems: This type connects biodiversity protection and landscape structure and integrates novel approaches-for example, ecosystem creation, urban green areas, green walls, and green roofs.

To assess the quality and effectiveness of each intervention starts with choosing the correct type of NBS. Sowińska-Świerkosz and García (2021) demonstrated that identifying the framework of NBS project consists of three main steps: (1) formulation of purpose(s); (2) preselection of solution(s); and (3) examination of performance questions.

Preselection of solutions aim(s) of the action(s) helps eliminate solutions that cannot be implemented due to the actual capacity of NBS in environmental improvements, such as green parking that does not correspond to an increase in outdoor activities. Researchers also identified that some of the factors that also impact the selection of the solution to be implemented include (1) the size of the area available and its localization; (2) environmental characteristics such as climate, the amount of rainfall, temperatures, and soil type; (3) the funds available; (4) the human resources available; (5) the time factor; and (6) local needs and traditions (Kabisch et al., 2016; Xing et al., 2017; Dumitru & Wendling, 2021). The elimination process results in another part of the framework with feasible solutions pre-selected to be thoroughly analyzed, including new pure green solutions, NBSs implemented alongside existing green or grey infrastructure, or grey-green hybrid solutions (Science for Environment Policy, 2021).

Examination of the performance questions stage starts the formulation of the performance questions based on the main concepts related to the issue of NBS projects. This stage starts formulating the performance questions based on the main concepts related to the issue of NBS projects. Identifying critical features of NBS, and selecting indicators should have relevance to the problem to be solved, performance at a given scale, and availability of data, methods, and procedures. For example, in evaluating an NBS project, the selection of indicators should have a scientific basis (Science for Environment Policy, 2021), previous studies should prove their performance, and their formula and the method of interpretation should be broadly accepted. The calculation of indicators is based on direct and in-situ measures. Estimating indicators are based on surrogate measures and results conducted in other locations. The achieved outcomes would establish an estimate of the actual values and constitute a starting point for examining a given solution's effectiveness. The analysis of the synergies and tradeoffs between the benefits provided by analyzed solution based on NBS projects implementation, as it is impossible to detect all the pros and cons of any intervention a priori (Nesshöver et al., 2017).

NBS approach, which has three main pillars of green solutions, synergies, and tradeoffs between them (Sowińska-Świerkosz et al., 2021), does not indicate an 'optimal' solution but enables us to visualize each solution's impact on the different pillars. If there are enough funds and space, the best solution simultaneously applies more than one intervention type to address different dimensions.

2.1. Critical Questions and Guidance for Managing NBS Project Assessment

Green infrastructure should be valued equally as gray infrastructure and consider its unique qualities, risks, and possibilities. The planning step of performing NBS require site-specific evaluations of their technical, social, economic, and financial dimensions. Browder et al. (2019) explain the planning stage of NBS projects.

2.1.1. Technical dimension

The technical dimension question is if natural infrastructure lessens the cost, enhances the character, or develops the resilience of the service. There are four steps to decide whether the NBS project is appropriate for technical assessment. The first step is the identification of the project. Examining regional and master planning practices for opportunities is essential for identifying the project. The second step is planning. Conducting planning-level research utilizing broad evaluation methodologies to identify the basic scope, function, and cost of the "Infrastructure Master Plan." The third step is using best-practice systematic methods to assess the possible performance of the natural system and more accurate scope and life–cycle–cost estimates. The final step is the environmental benefit. It uses best-practice analytical techniques to identify the possible adverse outcomes that must be minimized.

2.1.2. Social dimension

The social dimension question is if it is possible to get various stakeholders for the suggested natural infrastructure design. This classification system includes land, communities, government and civil society partners, and social benefits. The definition of land is intended to assure that it is possible to acquire or influence land usage to promote the project. It is vital to obtain the support of the local community. Collaborate with local governments, appropriate government companies, and civil society groups to establish solid alliances in favor of natural systems. The final step is to improve win-win solutions for affected communities to profit from green infrastructure and identify and alleviate adverse social impacts.

2.1.3. Economic dimension

The economic dimension question is whether the natural infrastructure can be explained concerning cost and more comprehensive economic terms. The economic dimension may be classified into three main sub-groups: Cost-effectiveness, co-benefits, and multi-criteria. To analyze cost-effectiveness is to examine if the planned project would lessen or not dramatically raise service costs. To apply quantitative and qualitative factors values for environmental and social co-benefits. The multi-criteria analysis systematically assesses if the project is justified and analyzes all relevant elements, including monetary and nonmonetary advantages.

2.1.4. Financial dimension

The financial dimension question is whether the green infrastructure is financed and financially sustained over time. The financial dimension is classified into three broad types: Funding sources, developing green financing packages, and marketing the green infrastructure. The potential of green infrastructure to produce various public and private advantages may bring together the interests of varied investors and decision-makers, paving the way for financing, utilization, and large-scale promotion. Understanding financial circumstances is a crucial step in project development.

2.1.5. Enabling Policies

To enable the policies to consider for the planning step of performing NBS projects. The question is what the service provider can do to enhance the enabling environment for green infrastructure. Enabling policies are classified into two broad types: Proactive government engagement and development partners. Communicate with governments at all levels to help with policies, legislation, management, study, and social outreach. Engage development allies and professional civil society groups as needed to assist and fund the green infrastructure project.

3. Methodological Aspects of NBS Applications

3.1. Basin Perspective, Scale, and Prioritization

3.1.1. Resilience assessment and mitigation/adaptation indicators

The United Nations Office for Disaster Risk Reduction defines *resilience* as the ability of a system, community, or society exposed to a disturbance to resist, absorb, accommodate, and recover from the effects in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2009). In the NBS context, we may adapt resilience to define the ability of an ecosystem or landscape to resist a drastic (flood, landslide *etc*.) or prolonged (drought, warming *etc*.) disturbance (Aytekin & Serengil, 2022). The NBSs should address the need for resilience not just for ecosystems but also the society.

Resilience is directly related to vulnerability and risk. A basin-scale vulnerability and resilience analysis have been given by Aytekin and Serengil (2022). However, the author's procedure requires field measurements and long-term monitoring. A practical approach can be using the procedures developed by international corporates such as EBRD (European Bank of Reconstruction and Development) or Worldbank.

According to EBRD's Jasper's Guidance (JASPERS, 2017) the risk is expressed through;

Risk = f (Probability, Severity)

And Vulnerability;

Vulnerability = f (Exposure, Sensitivity)

or

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

The climate change-related hazards defined by EBRD (EBRD/CPI, 2018; EBRD, 2019), are given in Table 3.

Table 3. An example of a cost-benefit-population-based prioritization approach (EBRD, 2019).

Category	Chronic or Acute	Hazard
Temperature Related	Chronic	Increasing mean temperatures
	Acute	Extreme heat event Wildfires
Wind Related	Acute	Extreme wind event
Water Related	Chronic	Increasing water stress Sea-level rise
	Acute	Drought Flood
Solid Mass Related	Chronic	Erosion
	Acute	Extreme mass movement

3.1.2. Budyko theory

The NBS selection is strongly influenced by local ecologic conditions that drive disturbances and disasters. To make a general statement we should underline that the NBS selection and application should base on climate conditions. In this phase we suggest the Budyko theory given as follows (Budyko, 1974; Gao et al., 2016; Liu et al., 2017)

$EI = f\ (DI)$

$DI = E_0 / P$

$EI = E_a / P$

Where DI is the dryness index; EI is the evaporative index; P is the mean annual precipitation (mm);

E_0 is the mean annual potential evapotranspiration (mm), and E_a is the mean annual actual evapotranspiration (mm).

The E_0 can be estimated through Penman-Monteith method and the E_a through direct measurements or theoretical water balance models.

The Budyko theory considers only the hydrologic balance between the actual evapotranspiration and the precipitation, therefore reveals a direct connection between precipitation and the runoff. According to the approach (Liu et al., 2017) the

- *range identifies humid regions*
- *1-1.5 semi humid*
- *1.5- various intensities of aridity.*

3.1.3. Scale of implementation

The climatic assessment should flow into basin-scale assessments. Türkiye is divided into 25 river basins. There are significant differences among these basins in terms of land use, population, and natural resources due to the country's ecologic, social, and economic variations. Closed basins drain into lakes (*i.e.*, Van lake basin, Konya basin), transboundary basins (*i.e.*, Tigris, Euphrate, Meric-Ergene), dry Mediterranean basins, wet Black sea basins. The variations in basin attributes make the management to be basin specific. In other words, solutions in one basin could not be applied to the other. Therefore, NBS to be applied must be considered by considering local conditions. For example, in some eastern and southern basins, the locals apply free-range husbandry for a large part of the year by migrating seasonally for their livestock. This livestock management may face drought risks and other disturbances in the coming decades. On the other hand, pasture husbandry is controlled and implemented in western parts of the country. This difference in livestock management is crucial when developing NBS for rangelands.

A systemic approach is needed to comprehend and value the effects of Nature based Infrastructure (NBI) assets. Conventional infrastructure assets are provided a systemic view that captures the multiple co-benefits of NBI concerning the services. Relative to the engineered ones, the value for money of NBI delivers a more comprehensive assessment. Society and nature contain interdependent and interactive factors, implying that they are complex systems. Understanding how these factors change over time is crucial, and considering feedback loops between them is essential. For instance, Van Paddenburg et al. (2012) explain healthy forests. Healthy forests mitigate events of events like tropical rainstorms. The forests are home to various species, store carbon and reduce downstream flooding risks. The forests contribute to sustainable agriculture and fisheries by maintaining the hydrological cycle. This indicates that land transformation, such as deforestation, is not just a biodiversity issue but can also disrupt hydrological cycles and increase the risks of floods, landslides, erosion, and droughts. Looking at the entire socio-environmental system is essential to capture the importance of natural capital.

The 25 river basins are further divided into hundreds of subbasins and then thousands of micro catchments, which is the basic scale for the current implementation projects. Here we propose a simple algorithm for selecting and prioritizing the subbasins. The river basins are too heterogeneous, and the micro catchments are too much to compare in such an analysis.

3.1.4. Cost benefit

The cost-benefit ratio multiplied by the population in the subbasin: The investment is divided into the quantity of Ecosystem services (ESs) produced for the investment multiplied by the people that receive the services delivered.

For example, we compare a developed subbasin with a semi-urban and a rural basin. We allocate 10 M USD investment for various site-specific NBS applications. The investment produces a lower total ESs value since the possibilities are less expensive in developed areas. The 10 M USD investment produces a total ES value of around 50 M USD in the developed subbasin compared to 100 M USD in a semi-urban and 150 M USD in a rural subbasin. Therefore, the impact of the investment seems to be highest in the rural subbasin until we incorporate the population. When the cost-benefit rate is multiplied by the population rate, the urban and rural subbasins level up, as seen below (Table 4).

This simple algorithm is a straightforward but convenient approach to deciding on investments since the approach's objectiveness drops as the process becomes complicated. The quantification of ES approaches is still challenging because the methods for quantification of some ESs are still not very precise, accurate, and consistent.

According to the UNEP (2021) reports, approximately USD 133 billion/year of financing (using 2020 as a base year) goes to NBS annually. The investment in NBS needs to increase by at least triple by 2030, and financing from both public and private funds needs to rise four times the amount by 2050 if climate change, biodiversity, and land degradation targets can meet.

Table 4. An example of a cost-benefit-population-based prioritization approach.

	Subbasin 1	Subbasin 2	Subbasin 3	…….	Subbasin n
Investment M USD (I)	10	10	10		
ESs produced M USD (ES)	50	100	150		
Population 1000 people (P)	15	10	5		
I/ES * 1/P	0,0133	0,130	0,0133		

3.2. Key Indicators for the Effectiveness of NBSs

The effectiveness of NBS can be monitored and measured. Dumitru and Wendling (2021) reviewed the indicators of various types of NBSs (Table 5). The indicators have been grouped under the type and aim of the NBS. These indicators can be extended or limited based on the objective, scale, and resources.

Table 5. Key indicators for NBSs (Adapted from Dumitru & Wendling, 2021).

GHG Mitigation and Adaptation	Total carbon removed or stored in vegetation and soil per unit area per unit time Avoided GHG emissions from reduced building energy consumption Monthly mean value of daily maximum temperature (TXx) Monthly mean value of daily minimum temperature (TNn) Heatwave incidence: Days with temperature >90th percentile, TX90p
Water Management	Surface runoff in relation to precipitation quantity Water quality: general urban Water quality: total suspended solids (TSS) content Nitrogen and phosphorus concentration or load Metal concentration or load Water quality: total faecal coliform bacteria content of NBS effluents
Natural and Climate Hazards	Disaster resilience Disaster-risk informed development Mean annual direct and indirect losses due to natural and climate hazards Risk to critical urban infrastructure Number of people adversely affected by natural disasters each year Multi-hazard early warning
Green Space Management	Green space accessibility Share of green urban areas Soil organic matter content Soil organic matter index
Biodiversity Enhancement	Structural connectivity of urban green and blue spaces Functional connectivity of urban green and blue spaces Number of native species Number of nonnative species introduced Number of invasive alien species Species diversity within a defined area Number of species within a defined area
Air Quality	Number of days during which ambient air pollution concentrations in the proximity of the NBS (PM2.5, PM10, O_3, NO_2, SO_2, CO and/or PAHs expressed as the concentration of benzo[a]pyrene) exceeded threshold values during the preceding 12 months Proportion of population exposed to ambient air pollution (PM2.5, PM10, O_3, NO_2, SO_2, CO and/or PAHs expressed as concentration of benzo[a]pyrene) in excess of threshold values during the preceding 12 months
Health and Wellbeing	Level of outdoor physical activity Level of chronic stress (perceived stress) General well-being and happiness Self-reported mental health and well-being Prevalence of cardiovascular disease Incidence of cardiovascular disease Quality of life
New Economic Opportunities and Green Jobs	Valuation of NBS: Value of NBS calculated using GI-Val The economic value of urban nature Mean land and/ or property value in proximity to green space Change in mean house prices/ rental markets Average land productivity and profitability Property betterment and visual amenity enhancement Direct economic activity: Number of new jobs created

The critical indicators related to the watershed and landscape scales can be identified as;

- Avoided or removed carbon and/or GHG balance,
- Soil organic matter,
- Erosion, sedimentation, and surface runoff rates,
- Water quality and quantity,
- Low flow and ecological flows, including dry periods of streamflow,
- Biodiversity (Shannon index *etc*.)

4. Conclusion

Nature-based solutions provide nature's strength and ingenuity to transform environmental, social, and economic concerns into opportunities for innovation. They can contribute to green growth, "future-proofing" society, boost well-being, provide commercial possibilities, and position Europe as a global leader in various societal concerns (EC, 2015). Nature-inspired, nature-supported, or nature-replicated solutions are actions that are called Nature-based solutions. Knowing natural infrastructure is generally the first step in the upstream planning process. Since the adaptive character of ecosystems, predicting technical performance is sometimes vague. New techniques and methodologies for predicting the performance of green and blended green-gray infrastructure have emerged. Monitoring and evaluation are crucial through operations. The anticipated environmental co-benefits and possible adverse effects are critical to a project's viability.

During the last decade, ecological solutions in urban and rural landscapes have gained attention globally through nature-based solutions. However, they are not yet implemented widely due to various barriers. Xie et al. (2020) suggested ways to mainstream NBS. These included:

i. Aligning NBS with urban strategic priorities and rural development,
ii. Generating partnerships between public, private, and Non-governmental organizations (NGOs) and creating intermediaries to work across different sectors,
iii. Improving data and monitoring to prove the effectiveness of NBSs,
iv. Establishing demonstration projects to showcase the workings of NBS and advancing valuation models to estimate the cost of an NBS project,
v. Providing a public mandate – e.g., through tender and procurement policies, providing economic incentives, and building co-finance arrangements,
vi. Finally, it is also essential to develop practitioner expertise.

We think there is a gap between theory and practice in applying NBS. Therefore, integrating the theoretical concepts with the preparation of NBS can be possible with research and capacity building.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

Aytekin, M., & Serengil, Y. (2022). Assessment of vulnerability, resilience capacity and land use within the scope of climate change adaptation: The case of Balıkesir-Susurluk basin. *Kastamonu University, Journal of Forestry Faculty*, *22*(2), 112-124. https://doi.org/10.17475/kastorman.1179037

Browder, G., Ozment, S., Rehberger Bescos, I., Gartner, T., & Lange, G. M. (2019*). Integrating green and gray: Creating next generation infrastructure*. World Bank and World Resources Institute.

Budyko, M. I. (1974). *Climate and life*. Academic Press.

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). *Nature-based solutions to address global societal challenges*. IUCN. https://doi.org/10.2305/IUCN.CH.2016.13.en

Dumitru, A., & Wendling, L. (2021). *Evaluating the impact of nature-based solutions: A handbook for practitioners*. Publications Office of the European Union. https://doi.org/10.2777/244577

EBRD/CPI. (2018). *Implementing the EBRD green economy transition*. https://www.ebrd.com/documents/climate-finance/implementing-the-ebrd-green-economy-transition.pdf

EBRD. (2019). *A framework and principles for climate resilience metrics in financing operations*. https://publications.iadb.org/en/framework-and-principles-climate-resilience-metrics-financing-operations

EC. (2015). *Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities*. https://op.europa.eu/en/publication-detail/-/publication/fb117980-d5aa-46df-8edc-af367cddc202

EC. (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*. https://eurlex.europa.eu/resource.html?uri=cellar:a3c806a6-9ab3-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF

Ferreira, V., Barreira, A. P., Loures, L., Antunes, D., & Panagopoulos, T. (2020). Stakeholders' engagement on nature-based solutions: A systematic literature review. *Sustainability*, *12*(2), 640. https://doi.org/10.3390/su12020640

Gao, G., Fu, B., Wang, S., Liang, W., & Jiang, X. (2016). Determining the hydrological responses to climate variability and land use/cover change in the Loess Plateau with the Budyko framework. *Science of the Total Environment*, *557-558*, 331-342. https://doi.org/10.1016/j.scitotenv.2016.03.019

IEEP. (2020). *Workshop on mobilizing up-scaling of naturebased solutions for climate change throughout 2020 and beyond: Outcomes & recommendations*. https://ieep.eu/wp-content/uploads/2022/12/Summary-NBS-workshop-4_-5-Feb-Brussels.pdf

JASPERS. (2017). *The basics of climate change adaptation, vulnerability and risk assessment*. https://jaspers.eib.org/LibraryNP/JASPERS%20Working%20Papers/The%20basics%20of%20climate%20change.pdf

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology & Society*, *21*(2), 39. https://doi.org/10.5751/ES-08373-210239

Liu, J., Zhang, Q., Zhang, Y., Chen, X., Li, J., & Aryal, S. K. (2017). Deducing climatic elasticity to assess projected climate change impacts on streamflow change across China. *JGR: Atmospheres*, *122*(19), 10228-10245. https://doi.org/10.1002/2017JD026701

Liu, L., Dobson, B., & Mijic, A. (2023). Optimisation of urban-rural nature-based solutions for integrated catchment water management. *Journal of Environmental Management*, *329*, 117045. https://doi.org/10.1016/j.jenvman.2022.117045

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O. I., Wilkinson, M. E., & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of the Total Environment*, *579*, 1215-1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Santoro, S., Pluchinotta, I., Pagano, A., Pengal, P., Cokan, B., & Giordano, R. (2019). Assessing stakeholders' risk perception to promote nature based solutions as flood protection strategies: The case of the Glinščica river (Slovenia). *Science of the Total Environment*, *655*, 188-201. https://doi.org/10.1016/j.scitotenv.2018.11.116

Science for Environment Policy. (2021). *Future brief: The solution is in nature*. https://knowledge4policy.ec.europa.eu/publication/future-brief-solution-nature_en

Seddon, N., Turner, B., Berry, P., Chausson, A., & Girardin, C. A. (2019). Grounding nature-based climate solutions in sound biodiversity science. *Nature Climate Change*, *9*(2), 84-87. https://doi.org/10.1038/s41558-019-0405-0

Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B*, *375*, 20190120. https://doi.org/10.1098/rstb.2019.0120

Sowińska-Świerkosz, B., & García, J. (2021). A new evaluation framework for nature-based solutions (NBS) projects based on the application of performance questions and indicators approach. *Science of the Total Environment*, *787*, 147615. https://doi.org/10.1016/j.scitotenv.2021.147615

Sowińska-Świerkosz, B., Michalik-Śnieżek, M., & Bieske-Matejak, A. (2021). Can allotment gardens be considered an example of nature-based solutions (NBS) based on the use of historical green infrastructure? *Sustainability*, *13*(2), 835. https://doi.org/10.3390/su13020835

Sunde, M. G., He, H. S., Hubbart, J. A., & Urban, M. A. (2018). An integrated modeling approach for estimating hydrologic responses to future urbanization and climate changes in a mixed-use midwestern watershed. *Journal of Environmental Management*, *220*, 149-162. https://doi.org/10.1016/j.jenvman.2018.05.025

UNEP. (2021). *State of finance for nature*. https://www.unep.org/resources/state-finance-nature

UNISDR. (2009). *Terminology on disaster risk reduction*. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

Van Paddenburg, A., Bassi, A. M., Buter, E., Cosslett, C. E., & Dean, A. (2012). *Heart of Borneo: Investing in nature for a green economy*. WWF HoB Global Initiative.

Vignola, R., Mcdaniels, T. L., & Scholz, R. W. (2013). Governance structures for ecosystembased adaptation: Using policy-network analysis to identify key organizations for bridging information across scales and policy areas. *Environmental Science & Policy*, *31*, 71-84. https://doi.org/10.1016/j.envsci.2013.03.004

World Bank. (2017). *Implementing nature-based flood protection: Principles and implementation guidance*. https://openknowledge.worldbank.org/handle/10986/28837?show=full

Xie, L., Bulkeley, B., van der Jagt, A., Toxopeus, H., Tozer, L., Pearl-Martinez, R., Dorst, H., & Runhaar, H. (2020). *Pathways for systemic integration of nature-based solutions*. NATURVATION.

Xing, Y., Jones, P., & Donnison, I. (2017). Characterisation of nature-based solutions for the built environment. *Sustainability*, *9*(1), 149. https://doi.org/10.3390/su9010149