The Economics of Nature-based Solutions

Opportunities for Mediterranean coastal wetlands

Part I - Nature-based Solutions: state of the art on implementation and key challenges to initiate operationalization

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IUCN

WETLAND BASED SOLUTIONS

With support from MAVA FONDATION POUR LA NATURE

The following report consists of two parts: Part I is a state of the art on the implementation of Nature-based Solutions and their key operationalization challenges, from a global perspective with a focus on economic features for coastal wetlands. Part II is a handbook for a socioeconomic and environmental assessment of Nature-based Solutions. This report is published as part of the MAVA funded project to improve and share knowledge in order to promote the scale-up of Nature-based Solutions in the Mediterranean, and in particular, to bring to light economic and business arguments for Nature-based Solutions in the Mediterranean wetlands.

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The **International Union for Conservation of Nature (IUCN)** is the world's leading authority on the state of nature and conservation measures. This is a union of governments and civil society members.

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Table of content

- List of acronyms 2
- Executive summary 3
- Introduction 5

Section 1: What are Nature-based Solutions (NbS)? An introduction to the concept. 6

I.1.a. Nature-based concepts in the framework of the IUCN Global Standard 6
I.1.b. NbS and ecosystem services (ES): introducing a valuation method 10

Section 2: How do NbS provide answers to tomorrow's challenges? 14

I.2.a. NbS are able to tackle today and tomorrow's ecological and climatic stakes 14
I.2.b. NbS are cost-effective and sustainable in the long term 15
I.2.c. NbS sustain jobs that are not relocatable 18
I.2.d. NbS represent a high economic value potential 19
I.2.e. NbS represent interesting finance opportunities for investors 21

Section 3: Why are NbS not already broadly implemented? 23

I.3.a. NbS are still emerging solutions and are unevenly implemented on the planet 23
I.3.b. NbS need more funding for its scaling up 24
I.3.c. The need for a framework is impeded by the variability of NbS characteristics 25
I.3.d. The absence of regulatory and juridical framework limits NbS implementation 26
I.3.e. To implement NbS, more technical knowledge and training needs to be shared 28
I.3.f. Technical and economic tools have been developed to assess NbS and need to be adopted 28

- Conclusions 31
- Discussion 32
- Glossary 33
- References 34

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List of acronyms

CARE	Comprehensive Accounting in Respect of Ecology
ES	Ecosystem services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LIFE	L'Instrument Financier pour l'Environnement (European Union's funding instrument for the environment and climate action)
MEA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
NbAS	Nature-based Adaptation Solution
NbI	Nature-based Infrastructure
NbS	Nature-based Solutions
NCP	Natural Capital Protocol
OFB	Office Français de la Biodiversité (French Biodiversity Agency)
TEEB	The Economics of Ecosystems and Biodiversity
TESSA	Toolkit for Ecosystem Service Site-based Assessment
UN	United Nations
UNEP	United Nations Environment Programme
UN SEEA EA	United Nations System of Environmental-Economic Accounting

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Executive summary

Nature-based Solutions (NbS) are defined by the IUCN as "*actions to protect, sustainably manage, and restore (create) natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".* Those solutions provide multiple ecosystem services, which make them more relevant than conventional solutions for tackling global societal, climatic, and environmental challenges in the long term. NbS represent a major alternative to conventional built infrastructures which account for more than 60% of global emissions and are a major driver of natural species and habitat loss.[1] There now exists an opportunity to assess the monetary value of those ecosystem services to better understand the economic opportunity of NbS and demonstrate the benefits of investing in NbS.

According to scientific experts at UNEP, $US 133 billion per year is currently invested in NbS, with this investment set to triple by 2030 in order to reach global climate targets.[2] Within this current investment, 86% is from public funds, with the mos part granted for climate actions, with a smaller proportion for biodiversity. There is a pressing need that political decision-makers and investors direct their efforts now towards NbS in order to obtain effective social and ecological benefits from their investments. This investment could also be beneficial to sustain non-relocatable jobs, create local economic value and provide ecosystem services for territories. Thanks to NbS implementation, 295 million jobs could be created by 2030.[3] All those benefits can be considered as concrete and tangible returns on investment for investors and public actors.

Despite their multifunctionalities, the implementation of NbS remains limited and uneven around the world. They are mostly studied in the Global North (e.g. North America, Europe), while they could represent a major answer to hazards and challenges faced by countries in the Global South. In Europe, decision-makers are aware of the opportunity that NbS represent. European policy institutions decided to pick up on the NbS issue in order to apply it concretely and systematically in the field. Numerous EU-funded projects have been developed as a consequence of the identification of the concept of NbS as a strategic framework to aid the development of sustainable territories. This shows that understanding the concept of NbS is a key factor in arguing for their implementation, especially in relation to the design of projects and actions, both in the socio-political and conservationist spheres. In particular, with regard to developing responses to the the Mediterranean region's environmental and climate challenges, exploring the application of the NbS has proved to be essential in efforts to improve the well-being of Mediterranean communities and to ensure long-term sustainability.[4]

To upscale the uptake of NbS, Part I of this document was produced with an aim of promoting the multiple socioeconomic and environmental interests of NbS. It is directed towards policy decision makers, businesses and both public and private investors, demonstrating the concrete

[1]Bassi A.M., Bechauf R., Casier L., Cutler E., International Institute for Sustainable Development and United Nations Industrial Development Organization, 2021. How can Investment in Nature Close the Infrastructure Gap?
[2] United Nations Environment Programme, 2022. The State of Finance for Nature in the G20. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/37919/NatureG20.pdf?sequence=3&isAllowed=y
[3] Financial Sector Guide for the Convention on Biological Diversity, 2021. Key Actions for Nature. Available at: https://www.cbd.int/doc/c/8e24/f151/326b69024f014a8fb9684a8d/cbd-financial-sector-guide-f-en.pdf
[4] IUCN, 2019. Towards Nature-based Solutions in the Mediterranean.

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implications of NbS on the ground and from a socioeconomic perspective. To complete this guidelines document, Part II provides the tools to measure and assess NbS benefits and costs through a cost-benefit approach to argue for incentives in favor of NbS implementation by promoting the economic stakes of those actions. More precisely, this document targets conservation practitioners, businesses, NGOs, research centers and think-tanks to operationalize the assessment of NbS and upscale their implementation.

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Introduction

The effects of climate change are already visible. There is conclusive evidence documenting the glaciers the shrinking of glaciers, the early breaking up of ice on rivers and lakes, the shifting of plant and animal ranges and the early flowering of trees flowering.[5] From a day-to-day perspective, people around the world have suffered from more extreme weather events in recent decades such as heat waves, heavy precipitation, river floods, windstorms, landslides, droughts, forest fires, etc., which are predicted to be more and more frequent and extreme. In the Mediterranean basin, the effects of climate change are occurring extremely rapidly: the temperature in the Med region is expected to rise by up to 20% more than the average world temperature.[6] Globally, and from an IPCC perspective[7], the evidence is clear: it is time to take action.

Simultaneously, we are also facing biodiversity loss. Indeed, both climate and biodiversity crises are closely linked, biodiversity being both threatened and part of the solution to confront the consequences of climate change. The latest IPCC report has proposed that Nature-based Solutions (NbS) or ecosystem-based approaches should be considered as one of the three main mitigation strategies, along with reducing or changing energy and material use towards more sustainable production and consumption and switching to low-emission energy sources. NbS are defined as "*actions to protect, sustainably manage, and restore (create) natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*". The role of NbS is thus broadly acknowledged, in the same way stakeholders seem to be increasingly engaging with this issue. Yet, it will take more than pledges. The question we ask in this report is how to mainstream NbS.

This report stands as a global guidance to support NbS implementation and favor their scaling up. It is divided into two parts. The first part (**Part I**) states the facts and gathers the arguments in favor of NbS implementation. It is intended to be broadly shared among the stakeholders, regardless of their position. The second part (**Part II**) is a handbook for conducting socioeconomic assessments of NbS, intending at giving clues and methods to future designers of NbS, as well as economic arguments. **The current report presents the first part of the global guidance.**

Part I reviews literature on the economics of NbS in order to set a common framework on the subject before going into the technicity of the assessment methods. After defining what should be understood by Nature-based Solutions (Section 1), we focus on gathering and quantifying the many benefits found in the literature (Section 2). To amplify their implementation, it is also crucial to identify what the barriers to NbS are (Section 3).

[5] NASA's Jet Propulsion Laboratory, California Institute of Technology, 2022. Available at: https://climate.nasa.gov/effects/
[6] Cramer W., Guiot J., Marini K., MedECC Climate and Environmental Change in the Mediterranean Basin, 2021. Current Situation and Risks for the Future. First Mediterranean Assessment Report, Union for the Mediterranean, Plan Bleu, UNEP/MAP.
[7] IPCC, 2019. Climate change and land — An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for policymakers. Available at : https://www.ipcc.ch/site/assets/uploads/2019/08/Edited-SPM_Approved_Microsite_FINAL.pdf

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Section 1: What are Nature-based Solutions (NbS)? An introduction to the concept.

I.1.a. Nature-based concepts in the framework of the IUCN Global Standard

The theory of System Thinking constitutes the basis of NbS approaches. System thinking has been defined as thinking in wholes rather than in terms of the properties of individual elements and how they interact; understanding the emergent behaviour of a system - as opposed to a reductionist approach. [8] Taking this into account, NbS has been defined by the European Commission as "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*".[9] Similarly, the IUCN[10] defines Nature-based Solutions (NbS) as "*actions to protect, sustainably manage, and restore (create) natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*". From both perspectives, as well as from related research by a number of other scholars, NbS appear to be **multi-functional**, meaning they are able to address multiple societal and environmental challenges[11] simultaneously – such as climate change mitigation and adaptation, disaster risk reduction, economic and social development, human health, food security, water security, environmental degradation, or biodiversity loss – while providing multiple co-benefits.

More specifically, the **IUCN NbS Global Standard**[12] establishes that a diversity of NbS can generate income for local communities while benefiting municipalities that depend on natural resources for their health and well-being. In that sense, they contribute to human well-being and biodiversity enhancement. In particular, from a socio-economic perspective, the IUCN believes that mainstreaming nature conservation into key economic sectors is essential. Increasingly, governments and businesses alike recognize that NbS are not only useful tools, but also necessary to address the global crises on biodiversity loss and climate change.

[8] Keesstra S. et al., 2018. The superior effect of Nature-based Solutions in land management for enhancing ecosystem services. Science of The Total Environment. Volumes 610–611. Pages 997-1009. ISSN 0048-9697 https://doi.org/10.1016/j.scitotenv.2017.08.077
[9] European Commission, 2016. Policy Topics: Nature-Based Solutions.
[10] Cohen-Shacham et al., IUCN, 2016. Nature-based Solutions to Address Global Societal Challenges.
[11] IUCN, 2016. Public consultation of the IUCN Global Standard, 2020.
[12] For more information, please refer to: https://www.iucn.org/theme/nature-based-solutions/resources/iucn-global-standard-nbs

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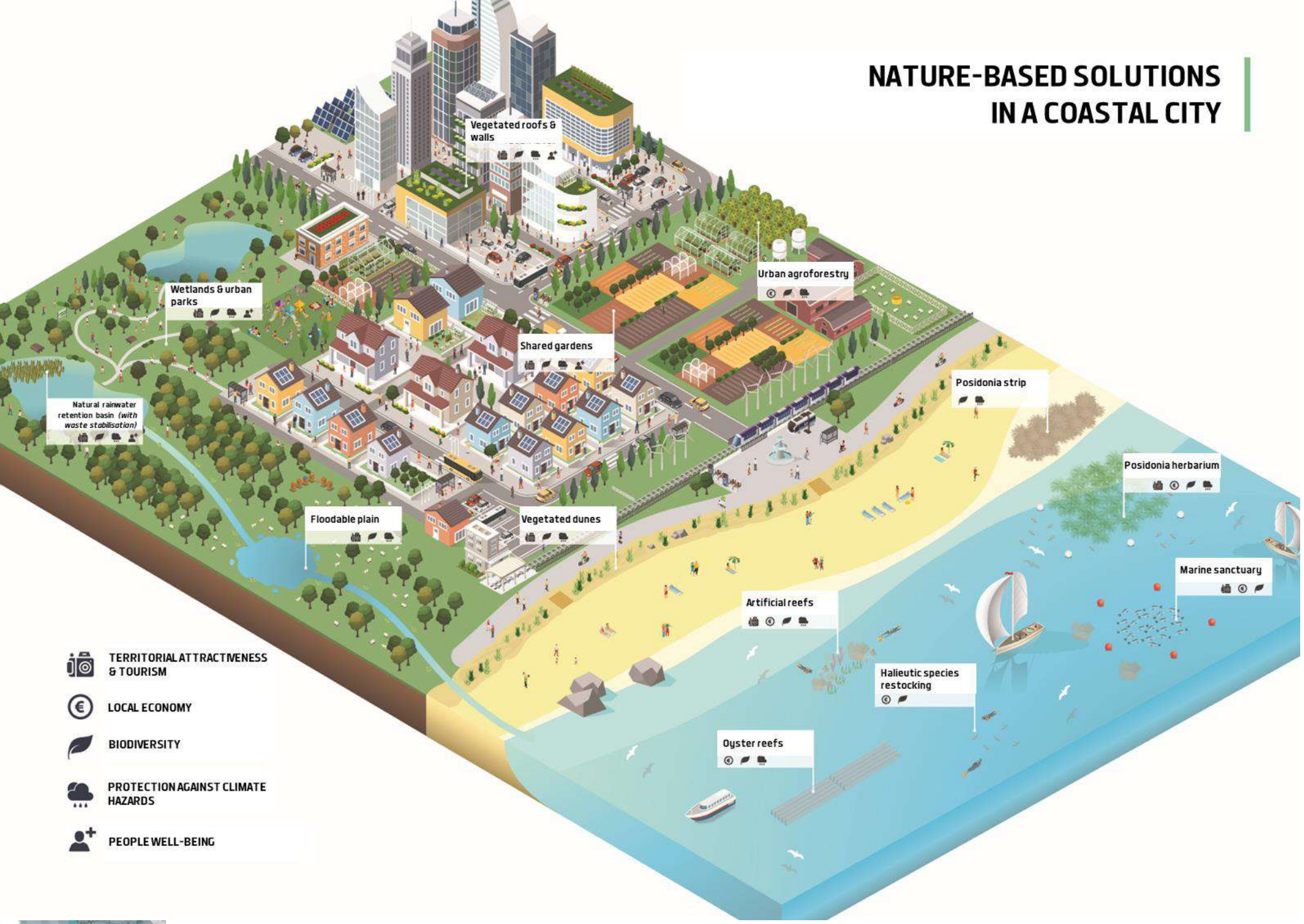
NATURE-BASED SOLUTIONS IN A COASTAL CITY



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According to the IUCN Global Standard, NbS correspond to actions that lean on **ecosystem-based approaches** (as shown in Figure 2).

The principal categories of approaches regarding policy plans are.[13]

- **Protection:** Area-based conservation approaches, including protected area management, (e.g. marine area, dunes protection);
- **Issue-specific:** Ecosystem-based adaptation, Ecosystem-based mitigation, Climate adaptation services, Ecosystem-based disaster risk reduction (e.g. sand stabilization with vegetation for flood protection and coastal erosion reduction);
- **Infrastructure-related:** Natural or green infrastructure (e.g. green roofs) ;
- **Management:** Integrated coastal zone management, integrated water resources management (e.g. integrated management strategies);
- **Restoration:** Ecological restoration, Ecological Engineering, Forest landscape restoration (e.g. natural saltmarshes restoration for biodiversity and hydrological functioning).

Figure 2: NbS Standard schematic definition (IUCN, 2020)

Those approaches of NbS, illustrated by the mountain, forest, river, city and farm drawings in Figure 2 above, tackle specific societal challenges represented by the seven icons (climate change mitigation and adaptation, disaster risk reduction, economic and social development, human health, food security, water security, environmental degradation and biodiversity loss), providing benefits for humans as well as for biodiversity. The multiple facets of NbS make them interesting solutions for a diversity of stakeholders.

[13] IUCN Website, 2022: https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions

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Box 1: Overview of nature-based concepts

As introduced beforehand, NbS are characterised by their multiplicity. Consequently, several nature-based related terms have been developed, depending on scientific research and practice, as well as policy contexts. For all these terms, NbS appear to be an "umbrella concept", including a variety of actions which could be classified under the 5 ecosystem-based approaches introduced by the IUCN Global Standard as stated in Figure 2. Independently, the EEA[14] referenced a dozen nature-based related terms as follows:

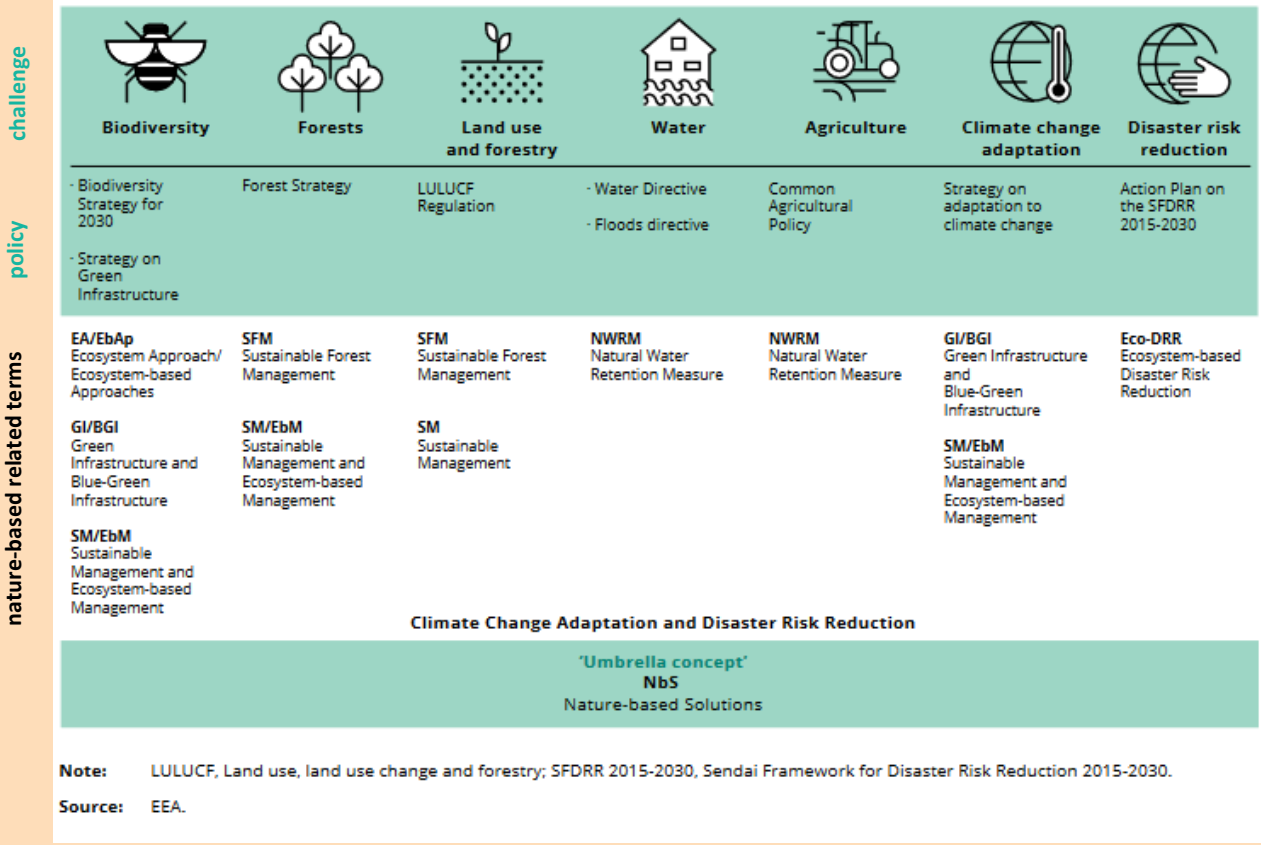

Figure 3: Overview of nature-based concepts and their related EU policy sectors. ©EEA, 2021

In addition, the French EU-LIFE project "ARTISAN" focuses on mainstreaming "**Nature-based Adaptation Solutions**" (NbAS) which tackles the societal challenge of Climate change adaptation and mitigation.

Also, "**Nature-based Infrastructures**" (NbI) are of great interest in shared and recognized studies: the National Oceanic and Atmospheric Administration (NOAA) uses this term to describe "*natural systems or engineered systems that mimic natural processes built to minimize flooding, erosion, and runoff. Nature-based infrastructure projects may include features that are completely natural, such as open lands and trees (e.g., coastal mangroves), or may incorporate varying degrees of hard or "gray" steel and concrete structures, such as seawalls*". The NbI Global Resource Centre has thus been created to promote NbI and is a major reference regarding the economics and finance of NbS.

Those concepts may be mentioned in this report.

[14] European Environment Agency (2021). Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction. doi: 10.2800/919315

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Besides ecological and climate targets, NbS are also meant to be coherent and compatible with societal and ecological targets, such as human health and well-being, food and water security. Consequently, the IUCN Global Standard for NbS comprises 8 criteria associated to several indicators in order to operationalize NbS best-practices of and increase their uptake. The eight criteria are the following: societal challenges; design at scale; biodiversity net gain; economic feasibility; inclusive governance; balance trade-offs; adaptative management, mainstreaming and sustainability (for more details, please refer to Part II, Section 4). A guidance[15] helps users in self-the assessment of a NbS project: the goal is to design the most appropriate NbS, upscale pilots by identifying gaps, or verify past projects and future proposals. The outcome of this tool is a percentage, qualitative and quantitative indicator results (depending on the data availability) and a traffic light system giving the user insights on whether the proposed NbS adhere(s) to the IUCN Global Standard. It also gives ideas on how to improve it so it can be aligned with its definition.

In this report, NbS refer to actions that represent sustainable solutions to address multiple societal challenges that occur in the Mediterranean area in the context of this project such as climate regulation, water provision and water-related hazards, as well as environmental degradation and biodiversity loss. The concept is not limited to adaptation or biodiversity stakes, but takes into consideration food security, global and local climate regulation, water provision, and water-related hazards, in accordance with the official IUCN definition.

I.1.b. NbS and ecosystem services (ES): introducing a valuation method

Another way to consider and evaluate NbS is to approach them through the **ecosystem services** (ES) they provide. Indeed, IUCN and many other scholars relate NbS to the concept of ES and Natural Capital[16,17,18,19,20,21] (See Box 3). The Millennium Ecosystem Assessment (MEA) defines Ecosystem Services as "the benefits people derive from ecosystems".[22] It can be considered as outputs, flows, conditions or processes of natural systems that directly or indirectly benefit humans from a social, economic and environmental point of view. That said, ES are the "benefits people derive from ecosystems", whether directly or indirectly. Depending on the benefits that ecosystems provide thanks to their functionalities, they can be categorized in different frameworks (see Box 3).

[15] Guidance available here : https://portals.iucn.org/library/node/49071
[16] Babi Almenar J., Elliot T., Rugani B. et al., 2021. Nexus between Nature-based Solutions, ecosystem services and urban challenges, Land Use Policy. https://doi.org/10.1016/j.landusepol.2020.104898
[17] Cohen-Shacham et al., IUCN, 2016. Nature-based Solutions to Address Global Societal Challenges.
[18] Eggermont H. et al., 2015. Nature-based Solutions: new influence for environmental management and research in Europe.
[19] European Commission, 2015. Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-Naturing Cities. Final Report of the Horizon2020 Expert Group on Nature-based Solutions and Re-naturing Cities.
[20] Maes J., Jacobs S., 2017. Nature-based Solutions for Europe's sustainable development. Conserv. Lett., 10 (1) (2017), pp. 121-124, 10.1111/conl.12216
[21] Nesshover C. et al., 2017. The science policy and practice of Nature-based Solutions: an interdisciplinary perspective. Sci. Total Environ., 579 (2017), pp. 1215-1227, 10.1016/j.scitotenv.2016.11.106
[22] Millenium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being, A Framework For Assessment. Available at: https://islandpress.org/books/ecosystems-and-human-well-being?prod_id=474

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Box 2: The concept of Natural Capital

Natural Capital is the "stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people" (adapted Atkinson G., Pearce D., 1995; Jansson et al., 1994) - Natural Capital Protocol[23]. Society uses and exploits Natural Capital, providing numerous benefits (goods and services). This Natural Capital plays a primary role in the existence and maintenance of human lives, which justifies the pertinence of assessing its value in monetary terms, like other capital types (e.g. financial, human). Natural Capital is a useful concept to link natural assets and economic features and could enable the integration of nature into accounting systems in order to influence decisions.[24] For this assessment, a standard methodology is needed. Several accounting models or toolkits exist, such as UN SEEA EA (United Nations System of Environmental-Economic Accounting), NCP (Natural Capital Protocol), CARE (Comprehensive Accounting in Respect of Ecology), or TESSA (Toolkit for Ecosystem Service Site-based Assessment). [25]

Box 3: Presentation of existing frameworks for ES (MEA / CICES advantages and limits)

The Millennium Ecosystem Assessment framework in 2005 was one of the first publication demonstrating the range of ecosystem services that contribute to human well-being. It classified ES into four categories: provisioning, regulating, cultural and supporting services. Supporting services are the support for the three other types of services, and are subsequently now often removed from more recent conceptualization frameworks to minimize the risk of double-counting services.
Other frameworks have since emerged, classifying ES in categories which help to avoid double-counting, such as the Common International Classification of Ecosystem Services (CICES: provisioning, regulation and maintenance, and cultural services [26]) and The Economics of Ecosystems and Biodiversity (TEEB: provisioning, regulating, cultural services, and habitat or supporting services[27]). It is up to the users to apply the relevant framework to the context of the site and their study. It is recommended to use a framework avoiding double-counting.

Accordingly, scientific research and expert groups have reached a consensus on the distinction between three types of NbS. This classification aims to help systematize their implementation. It is based on the characterization[28] of:

- the level of engineering applied to biodiversity and ecosystems,
- the diversity of ecosystem services provided by the NbS,
- the level of contribution of the NbS to the ecosystem services provision.

[23] Natural Capital Protocol, 2022. Natural Capital Coalition Available at: https://capitalscoalition.org/capitals-approach/natural-capital-protocol/
[24] Professor Sir Partha Dasgupta, 2021. The Economics of Biodiversity: The Dasgupta Review.
[25] WWF, 2019. Natural Capital and Organizations strategies: an overview of available tools, Guidebook.
[26] Haines-Young RH., Potschin M., 2011. Ecosystem Services. Available at: https://cices.eu/content/uploads/sites/8/2009/11/CICES_Update_Nov2011.pdf
[27] TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. http://teebweb.org/publications/teeb-for/synthesis/
[28] Babi Almenar J., Elliot T., Rugani B. et al., 2021. Nexus between Nature-based Solutions, ecosystem services and urban challenges, Land Use Policy. https://doi.org/10.1016/j.landusepol.2020.104898

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A typology of NbS has been established accordingly and can be schematized as the following:

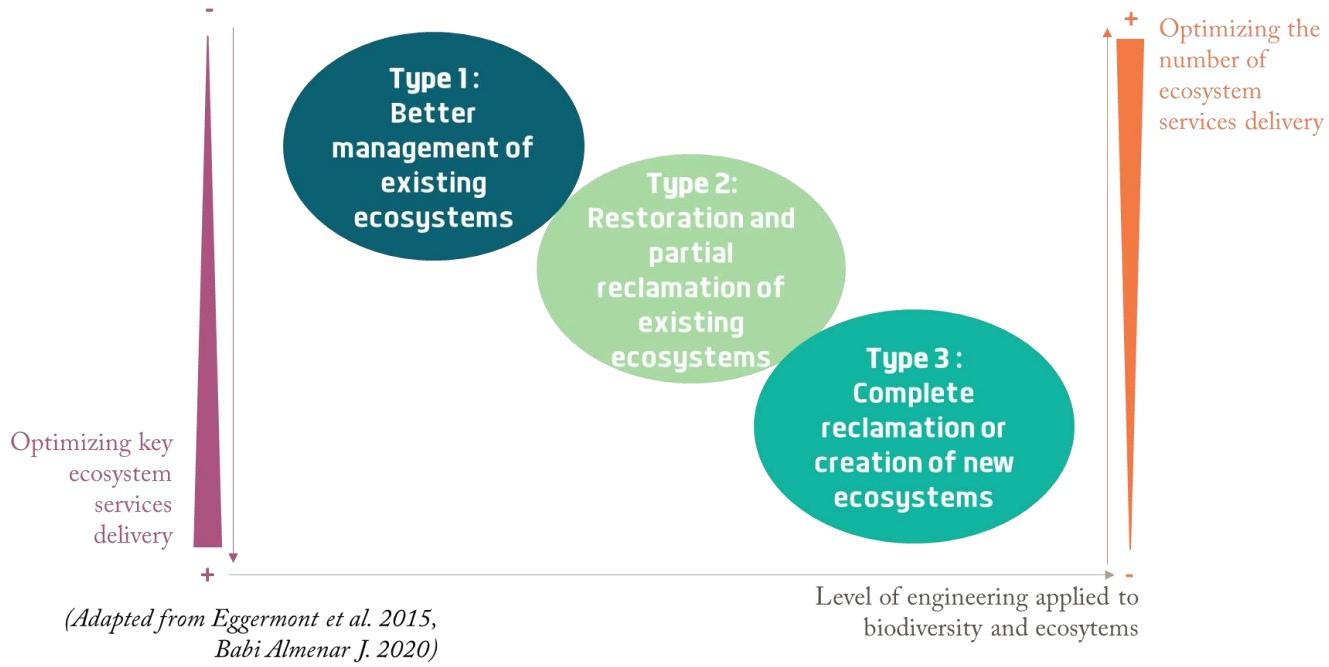

Figure 4: Schematic representation of the range of NbS approaches. ©Vertigo Lab, 2022. Adapted from Eggermont H. et al. 2015, Babi Almenar J. 2020.

This classification enables an understanding that the more an NbS is focused on the optimization of key ecosystem services delivery, the more it will imply biodiversity engineering techniques, going into type 3 (Figure 4).

Those engineering works may be costly at the investment phase but require less financial follow-up than a more conventional solution in the long term.

For either type, NbS enable the provision of ecosystem services which can be evaluated in monetary as well as non-monetary terms and represent advantages for their beneficiaries. Even though evaluating the benefits of services in monetary terms is not always necessary, especially for specific services such as cultural ones that are better assessed qualitatively, this type of approaches provides information on the economic return of investment in NbS. Beneficiaries can be defined as the people or category of people that benefit from the ecosystem service delivered by the interested solution. For instance, creating an urban above-ground farm in a building courtyard enables to create relationships between the inhabitants, sensitize all generations to agriculture, and reduce heat island phenomena. It can also create jobs to manage the urban gardens and be linked to the sale of the cultivated produce, creating tangible economic value.

Economically speaking, those ecosystem services have a high value that can be assessed using environmental valuation methods. For capturing the value of ecosystem services, one specific way is through monetization, which will be discussed more thoroughly in this guidelines document.

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The application of such methods can help to make the benefits of NbS concrete and systematize the investment in those solutions. As seen in Figure 5 below, NbS can address the loss of ecosystem services and tackle climate and societal challenges. Those solutions are intertwined with ecosystem services and play a significant role in the social-ecological system as seen in Figure 5 below.

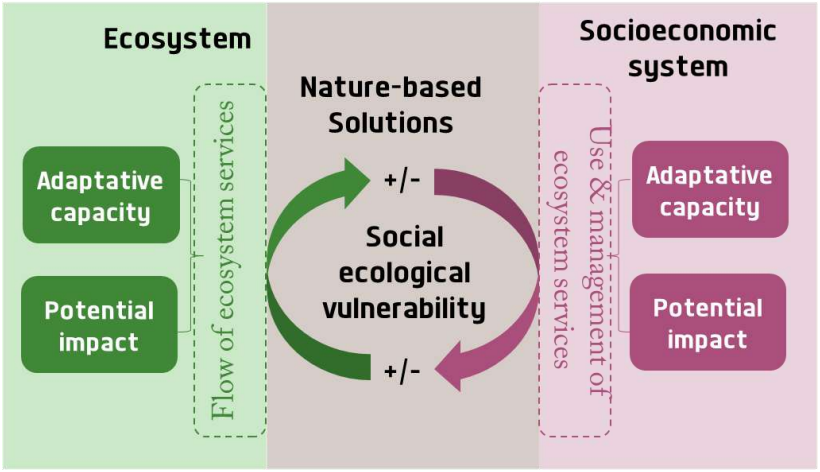

Figure 5: Link between ES and NbS (Adapted From Seddon et Al. 2019[29])

Here, the purpose is to highlight how NbS can support ecosystems to maintain a greater adaptive capacity and counteract impacts from external pressures (e.g. floods, drought etc.). Those pressures can alter ecosystem functions and processes, as well as their resulting flows of ES that provide socio-economic benefits to society. Therefore, there is a need to maintain NbS in businesses operations to ensure their long-term sustainability. For instance, if implemented in a way to increase the resilience of coastal ecosystems with the ES flow, NbS can effectively provide work opportunities and empower society and communities in efforts to conserve ecosystems through sustainable socioeconomic development.

[29] Seddon N., Chausson A., 2020. Understanding the value and limits of Nature-based Solutions to climate change and other global challenges.

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Section 2: How do NbS provide answers to tomorrow's challenges?

I.2.a. NbS are able to tackle today and tomorrow's ecological and climatic stakes

NbS are **sustainable from environmental and climatic perspectives**. They represent a major alternative to conventional built infrastructures which account for more than 60% of global emissions and are a major driver of natural species and habitat loss.[30] The interrelation between climatic and ecological stakes is shared among the scientific community: [31] climate change impacts and biodiversity loss are two major challenges and risks for human societies, while at the same time climate and biodiversity are interrelated in their overall operation. This is one of the reasons why NbS can be an answer to those issues, as they are multifunctional and provide co-benefits. Indeed, not only do NbS answer the Sustainable Development Goals (SDGs) of the United Nations,[32] but they also provide concrete solutions for a diversity of societal challenges faced by humanity. Unlike gray infrastructures, NbS are not centered on one or two single societal challenges. As a result, NbS are a good opportunity to both increase and maintain a diversity of ecosystem services, which make such solutions sustainable and economically viable in the long term.

For instance, restoring a coastal wetland is an NbS which involves recreation of a natural ecosystem which could thus enable an increase its capacity to store water in wet periods, protecting people from flooding, providing shelter to native species and sequestering and storing carbon. On the other hand, a traditional infrastructure consisting of a simple dike would help to regulate water flows and flooding events but would not enable a coastal ecosystem to readapt itself to change such as sea level rise or strong eroding events.[33] Furthermore, such infrastructures participate in landscape artificialization and are linked to material and mining extraction.[34]

In addition, NbS are **adaptable** solutions with regard to changing environments. Coastal ecosystems such as the ones existing in the Mediterranean area (saltpans, marshes, *Posidonia oceanica*, vegetated dunes) may enable coastal protection, waves intensity reduction, as well as acting as a nursery for species of interest.

[30] Bassi A.M., Bechauf R., Casier L., Cutler E., International Institute for Sustainable Development and United Nations Industrial Development Organization, 2021. How can Investment in Nature Close the Infrastructure Gap?
[31] Pörtner H.O. et al., 2021. Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change. doi:10.5281/zenodo.4659158
[32] United Nations Environment Programme, 2021. Adaptation Gap Report.
[33] CDC Biodiversité, Mission Économie de la Biodiversité Et Vertigo Lab, 2019. Évaluation socioéconomique des solutions fondées sur la nature.
[34] Tour du Valat, 2018. La restauration des anciens salins de Camargue : une solution fondée sur la nature pour s'adapter à l'élévation du niveau marin. Available at : https://tourduvalat.org/dossier-newsletter/ la-restauration-des-anciens-salins-de-camargue-une-solution-fondee-sur-la-naturepour-sadapter-a-lelevation-du-niveau-marin/

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I.2.b. NbS are cost-effective and sustainable in the long term

Besides responding to a multiplicity of societal and environmental challenges, NbS comprise an economic dimension which situates them in a particularly competitive position compared to more conventional planning or engineering solutions[35].

Regarding the **temporal aspects of sustainability**, NbS tend to have a long lifetime compared to grey solutions and are cost-effective, having more "positive consequences than [solutions] that are engineering-based"[36]. For instance, a concrete coastal dike implies significant management and maintenance costs (monitoring, vegetation control, concrete checks and replacement etc.). On the other hand, natural dune restoration with vegetation plantation and limitation of access only requires limited recurrent investments (vegetation and restriction infrastructure monitoring).[37] In addition, this NbS efficiency with regard to the provision of ecosystem services increases with time as the planted vegetation adapts to and colonizes the area, increasing its natural presence on the site.

Box 4: Elements of comparison between gray infrastructures and Nature-based Infrastructure funding needs

Recent studies have compared the efficiency between Nature-based Infrastructure and conventional infrastructure.[38] They have highlighted that:

- NbI provide the same services as traditional infrastructure, as well as additional services,
- NbI is up to 50% cheaper than traditional infrastructure,
- NbI provide 28% better value for money invested.

However, investing in NbI is limited, while those could create **additional benefits up to $US 248 billion per year** if stakeholders act now. Precisely, the average **investment need** in infrastructure was estimated at $US **4.29 trillion per year over 20 years**. Those infrastructures include water and sanitation, energy, transportation, agriculture, irrigation, and climate resilience investments. Out of this amount, **11.4% or $US 489 billion per year** could be covered by **investing** in Nature-based Infrastructure[39].
In particular, for the challenge of climate resilience including flood protection and the strengthening of coastal zones, **$US 28.62 billion per year** would be needed. This would include actions such as adapting roads to make them more resilient. For this thematic investment gap, 50% or **$US 14.31 billion per year** could be invested by implementing NbI rather than conventional infrastructure. Those include mangroves, reefs, dunes, and coastal marshes to reduce storm waves and surges. More than answering to climate resilience, those NbI can also accumulate sediments, avoid erosion, and provide a habitat for diverse species. Those NbI also provide co-benefits such as carbon sequestration or recreation and fishing opportunities.

[35] Kopsieker L., Gerritsen E., Stainforth T., Lucic A., Costa Domingo G., Naumann S., Röschel L. and Davis Mc., 2021. Nature-based Solutions and their socio-economic benefits for Europe's recovery: Enhancing the uptake of Nature-based Solutions across EU policies. Policy briefing by the Institute for European Environmental Policy (IEEP) and the Ecologic Institute.
[36] Nature-Based Solutions initiative, 2020. Policy Brief: How cost-effective are Nature-based Solutions to climate change adaptation?
[37] Kahan J.M., Rouxel N., Deniaud Y., Tourment R., Poulain D., Ledoux P., Groupe de Travail du Ministère de l'Ecologie, du Développement durable, des Transports et du Logement, 2015. Référentiel technique digues maritimes et fluviales.
[38] Bassi A.M., Bechauf R., Casier L., Cutler E., International Institute for Sustainable Development and United Nations Industrial Development Organization, 2021. How can Investment in Nature Close the Infrastructure Gap?
[39] Ibid.

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In coastal contexts, a range of natural hazards can be treated with NbS, along with multiple co-benefits that may be translated into ecosystem services. In fact, by translating the additional benefits of NbS, it is possible to demonstrate that the costs of coping against hazards without NbS are higher than the economic benefits of NbS[40]. Therefore, this quantification plays a major role in enhancing NbS investment by providing a decision support framework. An overview of the links between hazards, NbS and benefits is proposed in the table below.

Table 1 : Examples of additional benefits and ecosystem services provided by NbS in a coastal context, Adapted from Adaptation Gap report, UNEP, 2020 (Chap 6)

Natural hazard	Nature-based Solution	Additional benefits	Ecosystem Services provided
Sea level rise Storm surges Coastal erosion	▪ Mangrove protection and restoration to anchor sediments and dissipate wave energy ▪ Management and restoration of coastal marshes and/or dunes to dissipate wave energy and/or complement engineered protection ▪ Coral reef management, restoration to attenuate wave energy	▪ Improved fish stocks ▪ Biodiversity conservation ▪ Carbon sequestration and storage ▪ Sediment accretion ▪ Tourism and recreation and associated employment	▪ **Provisioning services**: Fish production ▪ **Regulating services**: Global climate regulation, Coastal erosion regulation, Storm surge protection, Flood protection ▪ **Cultural services**: tourism and recreation enhancement ▪ **Support services**: biodiversity enhancement and sheltering

Eventually, NbS contribute to an enhancement of **Natural Capital**, therefore increasing the value of nature's benefits. For example, it was shown that for every euro invested in Marine Protected Areas (MPAs) would generate a return of at least three euros.[41] Natura 2000 sites are valued between €200-300 billion/year and could support 500,000 additional jobs. It was argued that NbS provided a cost-effective long-term solution for hydrological risks and land degradation.[42] In particular, in those same studies, NbS in coastal defense projects using old style engineered structures have proven to be expensive and require continuous maintenance, while NbS are low-cost in construction and maintenance. Moreover, those coastal engineered structures may feel safer when they are intended for flood protection, for instance. However, they only provide this particular benefit and do not yield the multiple benefits that NbS tend to.[43] The table below provides examples of those multiple benefits.

[40] IPCC, Working Group III, 2022. Mitigation of Climate Change.

[41] Brander L. et al., 2015. The benefits to people of expanding Marine Protected Areas.
[42] Keesstra S. et al., 2018. The superior effect of Nature-based Solutions in land management for enhancing ecosystem services. Science of The Total Environment. Volumes 610–611. Pages 997-1009. ISSN 0048-9697 https://doi.org/10.1016/j.scitotenv.2017.08.077
[43] Ibid.

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Table 2: Multiple benefits of NbS for climate change mitigation (UNEP, WCMC, 2021)

		Environmental benefits				Socioeconomic benefits		
		(often feed into adaptation benefits, including through improved resilience of natural, seminatural and modified ecosystems)						
	Biodiversity and ecosystem services	Biodiversity conservation	Climate stability	Soil Health	Water quality	Reduced risks of extreme events	Food and/or energy provision	Cultural services and health security
Nature-based solutions for climate change mitigation	Avoided Forest Conversion	+++	+++	+++	+++	+++	+++	+++
	Reforestation	++/+++	+++	++	++/+++	++	++/+++	+++
	Improved Plantations	+ / + +	+++	+	+	++	+++	+
	Natural Forest Management	+ / + +	++	+ / + +	+	++	++	
	Conservation Agriculture (cover crops)	+	++	++	++		+++	
	Trees in Croplands	++	++	++	+ / + +	++	+++	
	Avoided Peatland Impacts	+++	+++	+++	+++	+++	+++	+++
	Peatland Restoration	+++	+ / + + / + + +	++	+++	+++	+ / + + / + + +	++
	Avoided Coastal Impacts	+++	+++	+++	+++	+++	+++	+++
	Coastal Restoration	+ / + + / + + +	+++	+ / + + / + + +	+ / + + / + + +	+++	+++	+++

In addition, from a technical point of view, NbS often require less management operations and therefore **less management costs**, while those costs can be more significant in the investment phase.[44] Some studies also point out that NbS could reduce or avoid damages associated with coastline hazards (e.g. storm surges, erosion, and marine submersion)[45,46,47]. The avoidance of threats linked to the avoided coastline risks therefore represent tangible and accountable avoided costs. For instance, Nature based Infrastructures (which are a type of NbS — such as sand dunes, wetlands, and forests) added value is 28% greater than grey infrastructure.[48] They also enable a healthier environment, job creation and opportunities for growth in other economic sectors such as tourism and agriculture.

[44] Seddon N., Chausson A., 2020. Understanding the value and limits of Nature-based Solutions to climate change and other global challenges.
[45] Binet T., Diazabakana A., Durou N., 2015. Estimation des bénéfices de la protection des sites du Conservatoire du Littoral : état des lieux et perspectives à l'horizon 2050 - Etude de cas du sud-est du Bassin d'Arcachon.
[46] Giry F., Binet T., Keurmeur N., 2015. Benefits of the French overseas' Mangroves Protection by the Conservatoire du littoral: an Economic Valuation Towards 2040, https://doi.org/10.4000/etudescaribeennes.10485
[47] Binet T., 2015. Estimation des bénéfices de la protection des sites du Conservatoire du Littoral : état des lieux et perspectives à l'horizon 2050 - Etude de cas littoral des Maures et Vallée de l'Argens.
[48] Bassi A.M., Bechauf R., Casier L., Cutler E., International Institute for Sustainable Development and United Nations Industrial Development Organization, 2021. How can Investment in Nature Close the Infrastructure Gap?

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In a nutshell, NbS are centered on ecological engineering or supported by the natural functioning of ecosystems. This is how those solutions have proven to be more cost-effective than conventional civil engineering,[49] in the sense that their benefits outweigh the costs of implementation and maintenance when they answer to issues about disaster risk reduction along coasts, for example.[50,51,52]. To demonstrate the actual economic benefits of those solutions, assessing them in monetary terms is crucial to obtain tangible proof that it is worth shifting financial strategies.

I.2.c. NbS sustain jobs that are not relocatable

In addition to the economic benefits of NbS, jobs that are linked to their implementation in ecological engineering are not relocatable. Ecological engineering mobilizes physical and human resources that exist in the same territory as the one where the NbS is being implemented. Activities benefiting from current expenses are not relocatable, as they are essentially composed of non-market services. These include biodiversity protection expenses, such as NbS. On the other hand, activities benefiting from capital expenditure are more relocatable, such as production activities. This is particularly the case with conventional infrastructure construction, for example.[53]

More specifically, NbS could enhance or provide additional jobs for the local area. The socioeconomic impacts of a project aiming at renaturing coastal floors and restocking fish species was assessed in a recent study, for example.[54] The CasCioMar ecological engineering project was funded by CDC Biodiversité and led by the company Ecocean.[55] Not only does the NbS have socioeconomic impacts on the Mediterranean area, but also more generally on the local coastal fishing sector as it enhances the fish stock. In total, for €1 million invested in the project, 20 to 22.2 full time jobs are created in addition to a turnover of €2.9-3.2 million and added value of €1.3-1.5 million, which represents great socioeconomic value on a local scale.

Finally, NbS can represent transversal opportunities for businesses or individuals as those actions are often multifunctional. They can be applied to a diverse range of functionalities and frameworks (e.g. urban planning, infrastructures, coastline management, agriculture, and people health) when replacing gray solutions. For instance, restoring salinas enables the recreation of saltpans, a reduction in flooding, and the capture of carbon, which will ultimately represent direct benefits for the salt sectors, tourism operators, and coastal city planning commissions. In this way, those NbS can be co-financed by different stakeholders and reduce costs for each sector participating in their investment and management. This is one of the many reasons why stakeholder's engagement in the project conception is a key factor of success for NbS.

[49] CDC Biodiversité, Mission Économie de la Biodiversité Et Vertigo Lab,2019. Évaluation socioéconomique des solutions fondées sur la nature.
[50] Morris R.L., Konlechner T.M., Ghisalberti M., Swearer S.E., 2018. From grey to green: efficacy of eco-engineering solutions for nature-based coastal defence. https://doi:10.1111/gcb.14063
[51] Reguero B.G., Beck M.W., Bresch D.N., Calil J., Meliane I., 2018. Comparing the cost effectiveness of nature-based and coastal adaptation: a case study from the Gulf Coast of the United States. https://doi:10.1371/journal.pone.0192132
[52] Sutton-Grier A.E., Wowk K., Bamford H., 2015. Future of our coasts: the potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. https://doi:10.1016/j.envsci.2015.04.006
[53] Delannoy E., 2016. La biodiversité, une opportunité pour le développement économique et la création d'emplois.
[54] CDC Biodiversité, Mission Économie de la Biodiversité Et Vertigo Lab,2019. Évaluation socioéconomique des solutions fondées sur la nature.
[55] CDC Biodiversité, Ecocéan, 2018. CasCioMar 2050. Premier projet de restauration.

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I.2.d. NbS represent a high economic value potential

From an economic perspective, the opportunity of NbS in the long term is ascertained by a great number of scientific experts.[56] According to them, **$US 133 billion are currently invested in NbS**, of which 86% is public investment. To fulfill international targets for climate, land degradation and biodiversity loss, investment needs to triple by 2030 and increase to $**US 536 billion** per year by 2050.[57] **A common framework to provide the role of NbS in the increase of ecosystem services and their opportunity of socioeconomic return is - to our knowledge - still lacking**. Scientists, conservation practitioners, politicians, decision-makers, and all stakeholders taking part in NbS knowledge production have stressed the urgency of addressing this issue.

NbS can support the addressing of key global challenges for ecosystems and society. Combining conventional solutions that are already implemented with innovative NbS can also provide resilience for societies.

In particular, in Mediterranean coastal wetlands, NbS can contribute to tackling multiple major challenges e.g., coastal protection to prevent flooding and erosion, fisheries resources and salt supply maintenance. These services have an economic value that can be assessed through a number of methodologies. In the US, the cost of erosion is estimated at $US 500 million per year.[58] In Europe, the risks are also major in terms of coastal hazards. For example, in the wake of Cyclone Xynthia (2010), the costs of damages was estimated at €2.5 billion, with the real estate sector in France estimating costs linked to storm surges in the region of €3.2 to €4.2 billion between 2015 and 2040, which is 3 to 4 times more than in the last 25 years.[59] Human activities and planning decisions seriously affect those risks. Nevertheless, climate change issues contribute to coastal erosion, rising sea levels, and storm surges.

[56] Bassi A.M., Bechauf R., Casier L., Cutler E., International Institute for Sustainable Development and United Nations Industrial Development Organization, 2021. How can Investment in Nature Close the Infrastructure Gap?
[57] United Nations Environment Programme, 2022. The State of Finance for Nature in the G20. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/37919/NatureG20.pdf?sequence=3&isAllowed=y
[58] US Climate Resilience Toolkit, 2021. Available at: https://toolkit.climate.gov/topics/coastal-flood-risk/coastal-erosion
[59] Observatoire de l'immobilier durable, Taloen Bat-ADAPT, 2015. Fiche Aléa – Submersions Marines.

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Box 5: An example of an NbS economic interest assessment: a restoration project

The costs and benefits expected from a salinas restoration project in Camargue for Tour du Valat, in France and compared it to those estimated in the construction of a dike.[60] This showed that NbS are not always more costly that conventional infrastructure and that they deliver a wider range of ecosystem services.
The management actions considered are the following:

- **Conventional solution**: to fight coastal erosion and flooding, a possible solution is to build a large concrete dike on the shoreline. This enables the protection of inland activities and natural areas from significant extraordinary events, while requiring extensive management to render the dike functional in the case of damage.
- **NbS**: to fight coastal erosion and flooding, an NbS can serve firstly to restore the natural salinas directly on the shoreline. This restoration enables the storage of good amounts of carbon and supporting habitats for species, while simultaneously supporting human activities (e.g. tourism, research, fishing, salt production). It also enhances natural sponge and buffer effects that reduce the intensity of extraordinary events while protecting inland and economic activities. However, in response to the intensity of such events, the construction of a smaller inland dike could be considered as an NbS, as it is a hybrid solution combining natural and traditional infrastructure. This combination enables a reduction in the use of materials that have an impact on the environment through the design of adaptable solutions.

Table 1 : Cost-Benefit elements for NbS and conventional solutions to fight climate change effects in a coastal context

	Type	Conventional solution: Dyke construction	NbS	
			Salinas restoration	Internal dike adaptation
Costs	Investment	€20-41 Million (€M)	€1.5 M	€7-13 M
	Maintenance	€800,000 /year	NA	€80-140 M/year
Benefits	Regulation Services	Erosion and coastal flood protection	▪ Erosion and coastal flood protection ▪ Nutrient and water cycle regulation ▪ Global climate regulation ▪ Biodiversity support for coastal species and habitats	
	Cultural Services	No	▪ Ecotourism ▪ Traditional activities (fishing) ▪ Environment awareness-rising ▪ Research contribution	

As of today, NbS assessment and the demonstration of its interests in monetary terms remain limited, which also limits the mainstreaming of these solutions. Raising awareness about the importance of natural systems and biodiversity maintenance for business and human sustainability is a key aspect to ensure responsiveness to the major societal and planetary challenges humanity is faced with. It should be noted that there are numerous European initiatives funded by the European Union taking up this issue, such as ThinkNature, Oppla, Eklipse, We Value Nature, MAIA, BiodivERsA, Nature4Cities, Connecting Nature, Reconect, VARCITIES, REGREEN etc.[61] The EU Biodiversity Strategy for 2030 aims at systematizing the uptake of such NbS by

[60] Tour du Valat, 2018. La restauration des anciens salins de Camargue : une solution fondée sur la nature pour s'adapter à l'élévation du niveau marin. Available at : https://tourduvalat.org/dossier-newsletter/ la-restauration-des-anciens-salins-de-camargue-une-solution-fondee-sur-la-naturepour-sadapter-a-lelevation-du-niveau-marin/
[61] Nature4Cities Website, 2021. Available at: https://www.nature4cities.eu/h2020-nbs-projects

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showcasing their socioeconomic benefits. As an example, the European LIFE "ARTISAN" project, which supports the mitigation and adaptation Nature-based Solutions in France, is currently collecting feedback concerning the socioeconomic impacts of Nature-based Solutions.[62]

Box 6: LIFE ARTISAN project, France

Life ARTISAN project to increase territorial resilience regarding climate change by encouraging Adaptation Nature-based Solutions

The French Biodiversity bureau (OFB), the Ministry for the Ecological Transtition, the Ministry for Territorial Cohesion and the European Union signed a financing convention to set up the integrated Life ARTSAN project. The project is scheduled to run from 2020 to 2027 and participates in the National Adaptation Plan for Climate Change and Biodiversity Plan.

One of the key area of this project is to develop indicators and tools to monitor and evaluate the success and performance of NbS on the territory. For this purpose, the project has deployed 10 pilot sites in the national territory and established regional animation teams to implement identified solutions. Thematic tasks forces are working in parallel on the questions of NbS finance, inclusion of science/society interfaces and adaptation Nature-based Solutions specificities according to the ecosystem of interest (urban, rural, coastal, mountain, overseas territories). All issues or results are regularly showcased on the OFB website.

I.2.e. NbS represent interesting finance opportunities for investors

NbS are opportunities for **innovative financing and revenue models**. For instance, the carbon market appears to provide a growing opportunity for NbS, as it diversifies the revenue sources of solutions while tackling climate, biodiversity, and restoration targets. Another emerging and innovative revenue model is based on insurance. Taking the RISCO project[63] as an example, the revenue stream of the mangrove conservation and restoration is based on their inclusion into insurance products as risk reduction value. Indeed, mangroves provide coastal protection against erosion or submersion for people, as well that they lessen the flood damage to coastal properties and assets. Another revenue model is to monetize the climate mitigation value through carbon credits. As so, monetizing the ecosystem services might generate new business model. The design of those models can be thought out at the project conception stage to maximize the profitability of the investment in the project as well as the ecosystem services. *For example*, restoring sand dunes by replanting local endemic vegetation to limit erosion and stabilize the coast can be associated with the creation of an educational nature trail to teach and sensitize residential visitors and tourists concerning the local fauna and flora. In the long term, this can enhance conservation efforts and encourage greater respect from the visitors on a site.

[62] OFB, 2022. Enquête sur les freins et leviers à la mise en œuvre des SfN. Available at : https://ofb.gouv.fr/le-projet-life-integre-artisan/actualites-life-artisan/lancement-dune-enquete-sur-les-freins-et

[63] Restoration Insurance Service Company (RISCO) is a project proponed by Conservation International and supported by the Climate Finance Lab. For more information, please refer to: https://www.climatefinancelab.org/project/coastal-risk-reduction/

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Furthermore, the goal of a **Nature Positive economy**, strongly linked to the implementation of NbS, is used by a growing number of institutions:

- *Leaders' Pledge 4 Nature* claims, through their campaign "The Race is On",[64] to secure a nature-positive world, in support of climate action and the Sustainable Development Goals. Launched in advance of the United Nations Summit on Biodiversity (2020), it aims directly at NbS, providing newly mobilized financial resources, along with the commitment of the signatories to a set of ten actions over the next decade.[65]
- The *G7 2030 Nature Compact* in 2021 declared a commitment to investing in nature and driving a nature positive economy (pillar 2).[66] Furtheremore, G7 Leaders have committed to increasing financial contributions for NbS through 2025.
- The *UNEP Finance Initiative* has published a "Nature-Positive Finance Guidance", aiming to mobilize financial institutions to ensure a nature positive world. It emphasizes not only that nature loss is putting our economies at risk but also that a **nature-based transition could generate $US 10 trillion in business opportunity and create 295 million jobs by 2030.**[67]

The multiplicity of these pledges tends to show an opening up of new investment opportunities is currently underway.

To conclude Section 2, NbS provide numerous benefits compared to conventional infrastructures, and represent an interesting opportunity to provide answers to tomorrow's challenges, that can be synthetized in the table below.

Table 4: Synthetic comparison of NbS and conventional infrastructures attributes (Vertigo Lab)

	Nature-based Solutions	Conventional infrastructures
Intervention context	Sustainable solutions to tackle climatic and ecological stakes	Punctual solutions to treat risks and hazards faced by humanity
Design	Self-adapting to changing environments and to local contexts if designed purposedly	Very little adaptable to changing environmental conditions
Ecosystem approach	A unique NbS can answer a multiplicity of SDGs	A conventional infrastructure usually tackles a unique SDG
	ES provision in quality, diversity	No ES provision or centered on few specific ES delivery
Temporal aspects	Long lifetime	Must be replaced to maintain its performance
Socio-economic aspects	Cost-effective on the long term	Cost-effective on the long term
	Generates more jobs	Generates less jobs
	Great added value in GDP	Lesser added value in GDP
Financing models	Opportunities for innovative financing models	Classic little sustainable financing schemes

[64] The Race is On, Leaders' pledge for nature, 2022. Available at: https://www.leaderspledgefornature.org/theraceison/
[65] Nature-based initiative, 2022. Leaders' Pledge for Nature. Available at: https://www.naturebasedsolutionsinitiative.org/news/leaders-pledge-for-nature/
[66] G7 2030 Nature Compact, Cornwall, 2021. Available at: https://www.consilium.europa.eu/media/50363/g7-2030-nature-compact-pdf-120kb-4-pages-1.pdf
[67] Financial Sector Guide for the Convention on Biological Diversity, 2021. Key Actions for Nature. Available at: https://www.cbd.int/doc/c/8e24/f151/326b69024f014a8fb9684a8d/cbd-financial-sector-guide-f-en.pdf

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Section 3: Why are NbS not already broadly implemented?

I.3.a. NbS are still emerging solutions and are unevenly implemented on the planet

As NbS are becoming a core subject of interest for policy decision-makers, conservation practitioners, coastal planning managers and even businesses, while subjects related to NbS are more and more frequent in research studies. An overview of literature using the key words "nature based solution" illustrates this growing interest:

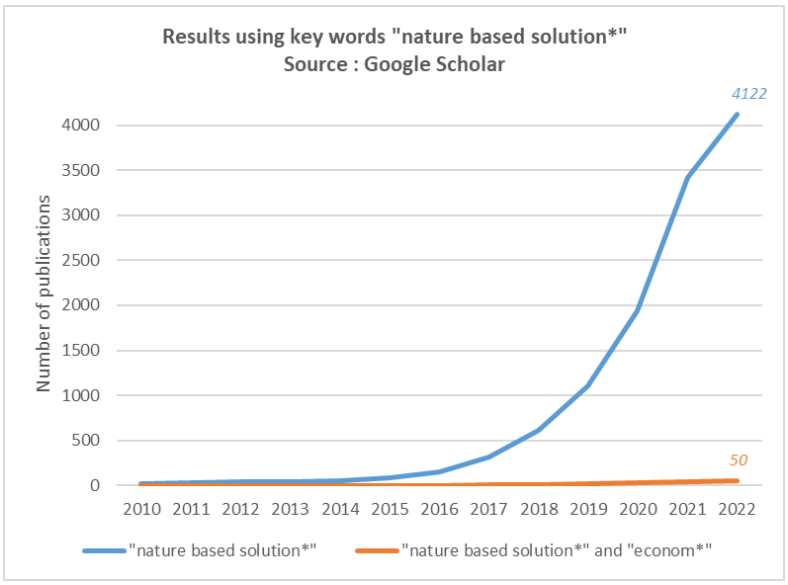

Figure 6: Bibliometric analysis of "Nature Based Solutions" and "Nature based Solution Econom*" on Google Scholar (Vertigo Lab)

From research carried out on Google Scholar, it appears that there has been an exponential growth in content about NbS in the literature since 2010, as shown in the graph above. The tendencies are similar when searching the same key words on Springer. If the search is limited to papers where the key word "econom*"[68] appears, the number of publications listed drops significantly. This highlights how research on the economics of NbS is still emerging, despite the growing interest observed on NbS as a whole. There is an existing stake to implement more research on the economics of NbS in order to fill this gap.

However, the implementation of NbS remains unequally distributed **geographically**, but also regarding the **type of ecosystems** they concern, the **hazards** they tackle and the **ecosystem services** they deliver. A meta-analysis of the studies on NbS enabled to identify the outstanding characteristics[69] of such studies:

- **Geographic distribution**: NbS are mostly studied in North America and Europe. Asia and Oceania remain relatively poor in terms of studies, although they are particularly exposed to natural disasters. This reflects the well-funded research available in the countries of the Global North, while similar research on a similar level remains limited in the Global South.

[68] The star * allows the search to accept the papers with words such as economic, economy, economics, etc.
[69] Sudmeier-Rieux, K., Arce-Mojica, T., Boehmer, H.J. et al., 2021. Scientific evidence for ecosystem-based disaster risk reduction. https://doi.org/10.1038/s41893-021-00732-4

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- **Type of ecosystem:** NbS are well-studied in urban areas (35% of the studies). Coastal ecosystems are ranked second (19% of the studies). Rivers and wetlands follow on in the ranking (9% of the NbS studies).
- **Hazards:** NbS are relatively well-studied with regard to coastal and fluvial flooding issues (36% of studies relate to their contribution tackling risk). The contribution of NbS to hazards concerning coastal wetlands such as coastal erosion, tsunamis; rising sea levels or other coastal hazards remain very sparsely studied.
- **Ecosystem services:** NbS studies often focus on regulating services (65% of studies), which are very important in coastal wetlands. The functionality of such ecosystems is not limited to such services, so further research could support their possible implementation.

In particular, the international community is aligned to the fact that there is an urge to develop best practices, indicators, models, guidelines and design standards to contribute to and enhance the development of NbS in the Mediterranean. Due to high population density, water scarcity, climate change effects (rising sea levels, coastal erosion), NbS can address key challenges and provide an opportunity to support the provision of co-benefits to local stakeholders. Their uptake in the region is still limited to policies and planning, while experiments on the ground have demonstrated that this limited uptake is rooted in knowledge gaps. There is therefore a need to study in more depth issues such as: the specific conditions enabling or limiting NbS in Mediterranean conditions; the means of augmenting NbS in territorial planning; possibilities of adapting current gray infrastructure to host NbS; the costs & benefits of green spaces, coastal ecosystems, dune-beach systems and seagrass. A specific strategy for Mediterranean countries could contribute to a successful adaptation to the effects of climate change.

I.3.b. NbS need more funding for its scaling up

One of the most considerable challenges of NbS is the absence of a centralized, comparable data base quantifying the impacts and benefits of NbS. In particular, the lack of information on the implications of NbS translated into monetary figures remains a major gap.[70] This strongly limits the popularity of restoration finance, and more generally of NbS for businesses and governments. Especially because NbS require up-front investments for setup and implementation (e.g., for stakeholder interaction and organization, training, technical equipment and baseline data collection). Access to capital is often difficult both for small scale endeavors (performance risks) and large-scale approaches (large capital volume needed). [71] A recent tracking of current investments in such solutions demonstrated that the current level of financial injections is inadequate to address the investment gap directed to biodiversity and climate management in national and regional plans.[72] As a result, about $US 300 billion of funding is lacking annually and needs to be injected into innovative strategies. This amount will be directed to further mobilize

[70] Kopsieker L., Gerritsen E., Stainforth T., Lucic A., Costa Domingo G., Naumann S., Röschel L. and Davis Mc., 2021. Nature-based Solutions and their socio-economic benefits for Europe's recovery: Enhancing the uptake of Nature-based Solutions across EU policies. Policy briefing by the Institute for European Environmental Policy (IEEP) and the Ecologic Institute.
[71] Foundation Future of the Carbon Market (Stiftung Zukunft des Kohlenstoffmarktes), 2021. Nature-based Solutions in Carbon Markets.
[72] Class I.A., Crédit Suisse Group AG and McKinsey Center for Business and Environment, 2016. Conservation finance from niche to mainstream.

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public and private finance for biodiversity and climate change. [73] Yet at present, UNEP estimates that only $US 120 to 130 billion per year flows into NbS, with public funds making up 86% and private finance 14%.[74]

The "Little Book on Investing in Nature"[75] highlights that harmful subsidies to biodiversity are still way higher than current global positive biodiversity finance: according to the report, there were negative flows of $US 1,020 billion in 2019 (including fossil fuels subsidies, agriculture production subsidies, fishery production subsidies and forestry production subsidies) while the positive flows were estimated at only $US 143 billion (including biodiversity offsets, governmental budgets and taxation, natural infrastructure, green financial products, NbS and carbon markets – estimated at $US 27 billion–, official development assistance, sustainable supply chains and philanthropy and conservation NGOs). Yet, global annual biodiversity conservation funding requires $US 176 to 230 billion for dedicated biodiversity conservation needs, and $US 546 to 737 billion for mainstream biodiversity conservation. It is to be noted that NbS can be entered in both categories: NbS are multi-purpose as they can be deployed in coastal ecosystems, sustainable croplands and rangelands, the urban environment or sustainable forestry.

As illustrated by the two estimations of shortfalls from the UNEP ($US 300 billion funding lack annually) in the "Little Book on Investing in Nature" ($US 176 to 230 billion funding lack annually), several estimates of funding needs for biodiversity have been made in the literature in recent decades. These estimates can differ noticeably. In 2021, the Convention on Biological Diversity (CBD) reported[76] that they could indeed vary from low estimates of $US 103 and 178 billion, to upper estimates of $US 599 to 823 billion. These differences could mainly be due to (i) genuine methodological differences, given the wide range of scopes (see below); (ii) different (narrower or broader) concepts of relevant types of costs, in particular financial cost and opportunity cost, the latter driving total costs substantially upward; and (iii) different (narrower or broader) concepts of what constitutes biodiversity-relevant expenditures or investments.[77] Therefore, despite those differences in investment needs, one can interpret that they echo the adaptability of NbS, making those solutions difficult to standardize when responding to natural challenges.

I.3.c. The need for a framework is impeded by the variability of NbS characteristics

Even though the positioning of stakeholders regarding NbS implementation is becoming more strategic in nature, cost-benefit analyses on those solutions are limited.[78] Such analyses often remain context-specific and do not factor in opportunity costs, and usually provide qualitative as opposed to quantitative data. More concretely, this makes it more difficult to apply the results of a cost-benefit analysis to variable time and space scales. In this way, NbS benefits are little accounted

[73] Seddon N., Smith A., 2021. Getting the message right on Nature-based Solutions to climate change.
[74] United Nations Environment Programme, 2022. The State of Finance for Nature in the G20. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/37919/NatureG20.pdf?sequence=3&isAllowed=y
[75] Tobin-de la Puente, J. Mitchell, A.W., 2021. The Little Book of Investing in Nature, Global Canopy: Oxford. Available at: https://www.afd.fr/sites/afd/files/2021-01-09-15-39/the-little-book-of-investing-in-nature.pdf
[76] CBD, 2021. Estimation of Resources Needed for Implementing the Post-2020 Global Biodiversity Framework. Second Report of the Panel of Experts on Resource Mobilization: Final Report. Available at: https://www.cbd.int/doc/c/c6de/9e79/d88a4c9b29b0318fd9492e7b/sbi-03-05-add2-rev1-en.pdf
[77] Ibid
[78] UICN, 2015. Ecosystem Based Adaptation : Knowledge Gaps in Making an Economic Case for Investing in Nature-Based Solutions for Climate Change.

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for, and often underestimated, especially in the long term, as those are difficult to assess. Natural solutions are complex to monetize, and there is a high degree of uncertainty about the non-market values those imply.[79,80]

As NbS are multifunctional, they affect both local and global communities, meaning their effectiveness and benefits are not always directly tangible in the short term by the stakeholders concerned (usually, a short-term vision adopted within political cycles).[81] Furthermore, trade-offs implied by NbS are rarely taken into consideration or differentiated between the affected communities.[82] This is linked to the fact that these communities have a different dependency relationship with natural resources, and that the future of those resources may affect more significantly one community over another which is less dependent on the resource for their survival. The NbS Standard aims at highlighting this aspect, and to favor the implementation of NbS which take into consideration side effects and trade-offs. For this, NbS integrate the anticipation of such effects and adopt an adapted management strategy to mitigate possible undesirable outcomes.

Finally, the complexity of natural processes and their contribution to hazard reduction makes NbS more difficult to appraise for investors. Natural processes are particularly variable depending on local and contextual parameters, and NbS may offer a variety of levels of protection in this regard (e.g., the intensity and frequency of the storm surges, plants and physical barriers in place to counter the damages incurred). Therefore, the capacity of the natural ecosystem to absorb the natural hazard is variable and is subject to a high degree of uncertainty. This feature is a basic assumption but must be considered at the early planning stages of NbS. Today, modelling advances [83] enable NbS planning to resemble forecasting as opposed to simply represent prospective visions, reducing uncertainty and improving stakeholders' willingness to engage in NbS.

I.3.d. The absence of regulatory and juridical framework limits NbS implementation

An additional hurdle limiting NbS operational systematization is the **limited regulatory and juridical framework** regarding the governance of their implementation.[84] In the specific context of coastal areas, water and environmental authorities, NGOs or local governmental institutions may be the competent authorities responsible for the management of the natural area. Often, those authorities function with a traditional vision of operating in silos, with goals and regulatory

[79] Mukherjee N., Sutherland W.J., Dicks L., Hugé J., Koedam N., Dahdouh-Guebas F., 2014. Ecosystem service valuations of mangrove ecosystems to inform decision making and future valuation exercises. https://doi:10.1371/journal.pone.0107706
[80] Czembrowski P., Kronenberg J., Czepkiewicz M., 2016. Integrating non-monetary and monetary valuation methods—Soft GIS and hedonic pricing. https://doi:10.1016/j.ecolecon.2016.07.004
[81] Seddon N., Chausson A., 2020. Understanding the value and limits of Nature-based Solutions to climate change and other global challenges.
[82] Reddy S.M. et al., 2016. Evaluating the role of coastal habitats and sea-level rise in hurricane risk mitigation: an ecological economic assessment method and application to a business decision. https://doi:10.1002/ieam.1678
[83] Moller I., 2019. Applying uncertain science to naturebased coastal protection: lessons from shallow wetland-dominated shores. https://doi:10.3389/fenvs.2019.00049
[84] Wickenberg B., McCormick K., Alkan Olsson J., 2021. Advancing the implementation of nature-based solutions in cities: A review of frameworks. https://doi.org/10.1016/j.envsci.2021.08.016

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frameworks that can diverge.[85] Sometimes, policies from a same institution can even contradict each other, and this lack of coherence can represent a real barrier for NbS implementation. On the other hand, NbS affect a diversity of ecosystem processes, and are **cross-sectorial**.[86] Taking the Mediterranean coastal contexts as an example, they can be interrelated with agriculture, tourism, salt production and land use planning, for instance. More than being cross-sectorial, NbS also appeal to a diversity of disciplines. Those solutions imply going beyond the boundaries between scientific disciplines as well as scientific and policy spheres.[87] As of today, awareness has been increased among managing organizations, while the traditional vision in silos is becoming more and more outdated. Even though stakeholders' operations are evolving towards more concertation and taking a diversity of interests and constraints into consideration, some political barriers remain.

Therefore, there exists strong elements limiting the consistency of policies in favour of NbS. This lack has clearly been identified by countries and the European Union wants to harmonize a clear framework and legislation. In particular, the EU biodiversity strategy for 2030 represents a key activity as part of the European Green Deal aiming at putting biodiversity on the path to recovery by 2030 for people, the climate, and the planet. This aim intends to create a common strategy to build our societies' resilience to future threats including the impacts of climate change, fires, food insecurity, or diseases outbreaks of disease.[88] As part of this common goal, EU policies will become more biodiversity-friendly, focusing on sustainable use of ecosystems and supporting the recovery in a post-pandemic world. The latest Horizon Europe 2021-2024 program supports this common goal with the strategic orientation "Protecting and restoring ecosystems and biodiversity and managing sustainably natural resources on land and at sea and achieving climate neutrality and adaptation", opening a direct management fund on Biodiversity and Ecosystem Services to develop knowledge and on "the economics of Nature-based Solutions: cost-benefit analysis, market development and funding".[89] In this call, the assumption is made that "**valuing and restoring biodiversity and ecosystem services** is necessary to develop tools to guide decisions, inform and implement policies on the environment, water, health, climate, disaster risk reduction, agriculture, forests and other land use types, protected areas management, the sustainable bioeconomy, the blue economy, maritime and cross-sectoral spatial planning, and responsible business practices". This demonstrates the will to engage with the issue of NbS at a higher level.

Ultimately, NbS often run into strong discrepancies between their **long-term effects and planning**[90] *versus* the short-term vision conditioned by the few years of political mandate terms[91]. For the implementation of such solutions, it is a considerable hindrance in the sense that most often decision-makers are motivated by short-term political concerns and tend to favor solutions

[85] Ferret A., Laurans Y., IDDRI, 2020. Mise en œuvre des solutions fondées sur la nature (SFN) : une revue de littérature.
[86] European Commission, 2020. Nature-based Solutions for flood mitigation and coastal resilience.
[87] Hanson H.I., Wickenberg B., Olsson J.A., 2020. Working on the boundaries—How do science use and interpret the Nature-based Solution concept?
[88] European Commission, 2021. EU Biodiversity strategy for 2030. Available at: https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en
[89] EU Horizon Europe call, 2021. Assess and predict integrated impacts of cumulative direct and indirect stressors on coastal and marine biodiversity ecosystems and their services. Available at: https://www.euro-access.eu/calls/assess_and_predict_integrated_impacts_of_cumulative_direct_and_indirect_stressors_on_coastal_and_marine_biodiversity_ecosystems_and_their_services
[90] Kabisch N., Frantzeskaki N., Pauleit S. et al., 2016. Nature-based Solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action.
[91] Hériard-Dubreuil G., Dewoghélaëre J., 2014. Biodiversité et long terme : un défi pour la gouvernance.

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proven to have a visible impact during the term of their mandate. It is thus of major importance to either adopt an NbS-positive regulatory framework or attempt to change political perspectives.

I.3.e. To implement NbS, more technical knowledge and training needs to be shared

From a technical point of view, ecological engineering companies implementing NbS are relatively small-scale on the ground. This claim is particularly true with regard to projects tackling coastal hazards (e.g., marine submersion, erosion and coastal flood) through the construction of coastal defense infrastructures.[92]. The training offer for NbS implementation remains very limited compared to conventional civil engineering. Finally, knowledge gaps are still limiting the implementation of NbS in general, as the construction sector is not currently promoting methods for an optimal selection of NbS or hybrid actions combining NbS and conventional infrastructure which could limit the impact of infrastructure on nature. In addition, design support tools to encourage willing stakeholders to implement NbS are still lacking on the ground.[93]

More generally, the subject of NbS has been studied and engaged with in depth in urban contexts, where the level of robust evidence and agreement between stakeholders is satisfying. On the other hand, NbS studies frequently focus on coastal ecosystems, but there is still a lack of quantified data to be robust, and thus shared and reused by the interested stakeholders.[94]

Box 7: Key actors seize the opportunity to develop knowledge on NbS

Many European and global projects aim at operationalizing NbS. They represent an opportunity to increase their uptake. Those are inventoried and analyzed in a dedicated chapter of the European Commission Nature-Based Solutions – State of the Art in EU-funded projects. Their effectiveness and contribution to flood and coastal challenges are particularly emphasized. The diversity of funded projects highlights the importance of these solutions, as well as the necessity to develop knowledge to be able to assess the interest of NbS before implementation, but also to monitor their performance and evaluate their success. Indeed, the iterative learning and adaptative planning management strategy is a key principle of the IUCN Standard. This supposes that the key lessons are drawn from the NbS throughout the project so as to continuously improve it.

I.3.f. Technical and economic tools have been developed to assess NbS and need to be adopted

The EU Commission has suggested filling the gaps in NbS knowledge with **technical** and **economic** tools. They offer a relevant set of indicators for monitoring and assessing NbS, as well as a first range of costs for NbS implementation. This assessment material could represent a basis for

[92] Narayan S., Reguero B. G., Van Wesenbeeck B., Burkes-Copes K. A., Coastal Structures and Solutions to Coastal Disasters Joint Conference, 2015. Bridging the Gap between Engineering and Ecology: Towards a Common Framework for Conventional and Nature-Based Coastal Defenses.
[93] European Commission, 2020. Nature-based Solutions for flood mitigation and coastal resilience.
[94] Sudmeier-Rieux, K., Arce-Mojica, T., Boehmer, H.J. et al., 2021. Scientific evidence for ecosystem-based disaster risk reduction. https://doi.org/10.1038/s41893-021-00732-4

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enhancing the economic and environmental opportunity assessment of those solutions. The material is presented in the boxes below.

Indicators represent interesting tools as those may help actors to obtain tangible elements to assess their NbS, as well as to know which parameters to look at to make sure that the NbS is effective, successful and that it yields the expected benefits. This is an important component to take into consideration for any project holder aiming at implementing an NbS as it enables them to monitor the NbS consequences of their project on sustainability criteria. Furthermore, such indicators could be part of the elements to examine with regard to monitoring plans in supporting the consideration of the project as an NbS as per the IUCN Global Standard. An adaptation of these indicators and cost propositions for coastal areas is provided in Part II of this publication (Section II.4).

Furthermore, larger frameworks can provide knowledge about the **economic** implications of NbS (e.g., costs of implementation) by giving mean costs of NbS actions and linking them to their effectiveness in ecological terms (ecological or mechanical functions provision). Such considerations of effectiveness and their relationship with costs are crucial for project holders to be confident in the success of their projects and to plan the means they may deploy for NbS accordingly.

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Box 8: Economic tools – Typology of Costs and effectiveness of Nature-based Solutions in coastal ecosystems Adapted from Wild T., Bulkeley H. et al., 2020.[95]

The following table is an example of typology of these costs and effectiveness levels for coastal wetlands.

Table 5: Example of Typology of Costs and effectiveness levels

Nature-based-Solution	Effectiveness		Cost	Source
	Runoff volume reduction	Peak flow reduction		
Small scale NbS				
Porous Pavement	~30–65%	~10% - 30%	~$US 252/m²	Shafique et al. (2018), Damodaram et al., 2010
Green Roofs	up to 70%	up to 96%	~$US 564/m²	Carpenter & Kaluvakolanu, (2011)
Rain Gardens	up to 100%	~48.5%	~$US 501/m²	Ishimatsu et al. (2017), Goncalves et al. (2018)
Vegetated Swales	up to 9.60%	~23.56%	~$US 371/m²	Luan et al. (2017), Huang et al. (2014)
Rainwater Harvesting	~57.8-78.7%	~8%-10%	~$US 865/m³	Khastagir & Jayasuriya (2010), Damodaram et al. (2010)
Detention Ponds	up to 55.7%	up to 46%	~$US 60/m²	Liew et al. (2012), Damodaram et al. (2010), Goncalves et al. (2018)
Bioretention	up to 90%	up to 41.65%	~$US 534/m²	Luan et al. (2017), Huang et al. (2014), Khan et al. (2013)
Infiltration Trench	up to 55.9%	up to 53.5%	~$US 74/m²	Huang et al. (2014), Goncalves et al. (2018)
Large scale NbS				
Coral Reefs	~70-91%	~34 – 3200%	No data	Ferrario et al. (2014) ; Narayan et al. (2016); Debele et al. (2019)
Salt Marshes	~72-92%	~5 – 425%	No data	Ferrario et al. (2014) ; Narayan et al. (2016); Debele et al. (2019)
Mangroves	~31-53%	~32 – 260%	No data	Ferrario et al. (2014) ; Narayan et al. (2016); Debele et al. (2019)
Seagrass	~36-58%	~258-949%	No data	Ferrario et al. (2014) ; Narayan et al. (2016); Debele et al. (2019)
De-culverting (river restoration)	Not assessed	Not assessed	~$US 16.92 million	Chou (2016); see also Wild et al. (2019)
Floodplain lowering	Not assessed	Not assessed	~$US 136.7 million	Klijn et al. (2013)
Dike relocation/floodplain lowering	Not assessed	Not assessed	~$US 342.60 million	Klijn et al. (2013)
Floodwater storage	Not assessed	Not assessed	~$US 386.20 million	Klijn et al. (2013)

[95] European Commission, 2020. Nature-based Solutions State of the Art in EU-funded Projects

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Conclusions

Nature-based Solutions are sustainable ways to tackle global societal, climatic, and environmental challenges. In the way they address multiple stakes, those solutions also provide multiple socioeconomic and environmental benefits [96] and represent a great opportunity to unleash innovative financial mechanisms, to move towards a sustainable, desirable future.

This publication illustrates that the concept of NbS is currently a growing subject of interest, as an increasing number of research, company strategies, conservation and management action projects focus on their uptake. Our research shows that the gap between their implementation potential and the need for systematization remains wide and has to be filled to guarantee a sustainable future on the planet.

For this purpose, we have identified several levers that should be activated. Enhancing investment stands as a key lever to unlock the implementation of NbS. This could be activated by the definition of a dedicated regulatory and juridical framework to align processes when deciding for the uptake of NbS. In addition, technical knowledge on NbS is still limited to specific contexts and should be developed in order to be more easily replicated. Finally, technical and economic tools to assess NbS success and establish best practices are starting to emerge, but are still too limited to be up to speed and answer widely to current and future challenges tackled by NbS.

To lift identified barriers, Part II proposes a handbook that simplifies the methodology to assess NbS, with an aim to design the assessment to bring it into alignment with stakeholders' needs and context. Associated with this publication, a Policy brief completes the document to support the key messages of NbS opportunities in pitches to decision-makers and to make sure that the assessment results obtained with the handbook stand as arguments in their future decision-making processes.

[96] United Nations Environment Programme and International Union for Conservation of Nature, 2021. Nature-based Solutions for climate change mitigation.

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Discussion

The results presented in this publication reveal certain weaknesses that should be discussed. It is indeed assumed that the obstacles and levers presently identified are not new to NbS specialists and gather already identified research conclusions. That being said, this study highlights important and recurrent ideas that still need to be addressed.

Additionally, we note that in reality, the concept of NbS itself is still not widely accepted nor assimilated by economic actors on the ground, which prevent its implementation. This report also highlights economic arguments as key levers to further enhance NbS investment, which can be considered as a strategic bias and may be questionable. Although NbS are not systematically positive as from an economic perspective and still need evidence in that sense, we as operational environmental economists strongly believe the economic argument strongly backs up efforts to argue in favor of better knowledge of NbS and their implementation with decision-makers.

Finally, available investment budgets are not realistically raised for impactful biodiversity projects. Indeed, most biodiversity projects are usually only of general interest and do not provide the economic value investors are looking for. Hybrid solutions and innovative mechanisms can be found in the NbS concept in order to enhance impact investing.

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Glossary

Ecosystem Services	The Millennium Ecosystem Assessment (MEA) defined Ecosystem Services as “the benefits people derive from ecosystems”. It can be considered as outputs, flows, conditions or processes of natural systems that directly or indirectly benefit humans from a social, economic and environmental point of view.
Multifunctionality	Multifunctionality (or multiple benefits) corresponds to the capacity of actions or to provide a solution to a variety of challenges.
Natural Capital	“The stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people (adapted from Atkinson and Pearce 1995; Jansson et al. 1994)”- Natural Capital Protocol, 2022 Society uses and exploits Natural Capital, which provides numerous benefits (goods and services). This Natural Capital plays a primary role in the existence and maintenance of human lives, which justifies the pertinence of assessing its value in monetary terms, just like another capital type (financial, human). Natural Capital is a useful concept to link natural assets and economic features, and could enable the integration of nature into accounting systems to influence decisions.
Nature-based Solutions	Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. - IUCN Global Standard, 2016
Nature-based Adaptation Solutions	NbS which focus on tackling the adaptation and mitigation challenge.
Nature-based Infrastructure	Engineered systems where natural features are combined with more hard or structural engineering approaches to create a hybrid system. NbI are specific solutions that are part of more general concept of NbS.

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