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from
Nexus Thinking to
Nexus Doing

REXUS

MANAGING RESILIENT NEXUS SYSTEMS THROUGH PARTICIPATORY SYSTEMS DYNAMICS MODELLING

Roadmap to navigate among Nature-based Solutions for addressing Nexus challenges

INCORPORATING NATURE-BASED APPROACHES INTO NEXUS SOLUTIONS

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Executive summary

This report presents a roadmap to assist a variety of decision-makers at different levels to identify potential Nature-based Solutions (NBS) to be implemented under the perspective of the Water-Energy-Food (WEF) Nexus. The roadmap is primarily aimed at a diversity of practitioners in a decision-making position (e.g., environmental authorities, public administration, governmental agencies) who want to address environmental challenges within their jurisdiction and achieve climate resilience targets by incorporating nature-based approaches.

The document has two main objectives. The first is to guide the user through the vast landscape of existing catalogues and tools in the process of selecting an NBS to address challenges in the context of the WEF Nexus. The user is provided with a roadmap that summarizes the most relevant considerations to make this decision and a list of NBS suitable for addressing different WEF Nexus challenges. The second objective is to illustrate to the user the potential role of NBS in helping improve the provision of multiple ecosystem services (i.e., the biophysical system) and addressing some of the socio-political challenges that hamper the adoption of a Nexus approach.

This document was developed as part of the EU Horizon 2020 Rexus project (Managing Resilient Nexus Systems through Participatory Systems Dynamics Modelling), a three-year international collaboration between universities, research centres and the private sector. The project is part of several Horizon 2020 Research and Innovation projects designed to promote the advancement of WEF Nexus understanding.

In particular, this work belongs to Work Package 5, "Incorporating nature-based approaches into Nexus Solutions", task 5.2; Identifying the potential role of Ecosystem based Adaptation (EbA) and NBS within the WEF Nexus approach.

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Abbreviations and acronyms

CICES: Common International Classification of Ecosystem Services

DRR: Disaster Risk Reduction

EbA: Ecosystem-based Adaptation

EC: European Commission

ES: Ecosystem Service(s)

EU: European Union

FAO: Food and Agriculture Organization of the United Nations

GI: Green Infrastructure

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IUCN: International Union for Conservation of Nature

MEA: Millennium Ecosystem Assessment

NCP: Nature's contribution to people

NBS: Nature-Based Solution(s)

NWRM: Natural Water Retention Measures

SDG: Sustainable Development Goals

TEEB: The Economics of Ecosystems and Biodiversity

WEF Nexus: Water-Energy-Food Nexus

1. Introduction

Water, energy, and food security are central to the development agendas around the world, as well as being fundamental factors for the progress of society and enhanced quality of life (United Nations, 2018). These three domains are also highly interrelated. Of the current use that society makes of freshwater resources, about 71 % is used for food production, 16% is utilised for energy generation, and just 14% is employed in other uses (United Nations, 2018; Simpson & Jewitt, 2019). Moreover, around 30% of total global energy production is used by the food production and supply chain (FAO, 2011). Similarly, the provision of water to cities and houses is highly dependent on the availability of energy used for its extraction, transport, and distribution.

The close interaction of the three domains has given rise to the development of the Water-Energy-Food (WEF) Nexus, an approach to illustrate and manage the interrelationships and dependencies between the water, the energy, and the food security agendas. In a society that will progressively demand more resources under climate change scenarios and persisting socio-economic challenges, the scarcity of natural resources and competition for water and land make management of trade-offs and the joint use of these resources increasingly important (Naranjo & Willaarts, 2020; UNECE, 2018).

The WEF Nexus approach has been studied mainly from a theoretical perspective, focused on illustrating the multiple ways its domains are interrelated and quantifying the trade-offs from sectoral decisions where changes in the provision of one of the resources affect availability for the other two (Allan et al., 2015; Karabulut et al., 2016; Simpson & Jewitt, 2019). It could be considered that the approach is still in a 'Nexus thinking' phase, with considerable room for the practical implementation of actions. In other words, the applied examples of 'Nexus doing' are still limited (Simpson & Jewitt, 2019).

In parallel to the development of the WEF nexus approach, the evolution of the Nature-based Solutions (NBS) concept has been one of the main targets of environmental agendas in recent years due to the multiple - and interrelated - social and environmental problems currently faced by society and the potential of nature to help address these challenges (Castellari et al., 2021; IUCN, 2016). The idea of NBS encompasses several approaches developed by different societal sectors (e.g., academia, policy, industry), such as Ecosystem-based adaptation, Disaster risk reduction (DRR), climate change adaptation, green infrastructure (GI), among others. NBS is used as an umbrella concept that seeks to propose an alternative to the "grey solutions" traditionally used to solve such societal challenges (Somarakis et al., 2019).

One of the most relevant acknowledgments in recent years regarding the NBS is about their capacity to provide multiple benefits when implemented (Castellari et al., 2021; Chausson et al., 2020; Seddon et al., 2020). As stated in the term's definition by the International Union for Conservation of Nature (IUCN), NBS simultaneously provide human well-being and biodiversity benefits (Cohen-Shacham et al., 2019), thereby contributing to multiple goals at the same time. For example, when a strategy such as wetlands restoration is undertaken to improve the regulation of hydrological flows in an area, the action not only contributes to this objective but is also generating or strengthening other functionalities of the ecosystems that can be beneficial for human beings. Such co-benefits could include the increase in the stock of fish, the improvement of water quality through phytoremediation, or the generation of habitats with benefits in biodiversity and aesthetics, to mention a few (NWRM Project, 2013).

These "ecological functions" or "nature's contributions to people" can be understood as ecosystem services (ES) that humans perceive from ecosystems (Diaz et al., 2018; Haines-Young & Potschin, 2012; MEA, 2005).

NBS are typically more effective meeting societal needs when they are designed following a participatory approach, as this brings different actors and interests to the table. Following these multi-stakeholder processes helps to look at socio-environmental problems in a holistic way, improving on the adoption of traditional grey infrastructure approaches, which may be more cost-effective to achieve single objectives (e.g., flood reduction) and are easier to implement under the current fragmented policy landscapes (Janssen et al., 2020). Participatory methods can also help validate and weigh a series of socio-economic co-benefits of NBS beyond the environmental ones, typically not considered in the decision-making process or contested among stakeholder groups (Giordano et al., 2020).

It is precisely this “multipurpose nature” of NBS that makes them promising as potential options to help address some of the fundamental challenges of the WEF Nexus.

However, up to now little has been discussed about the role of NBS to help address socio-environmental challenges with a WEF Nexus perspective and their potential to improve multiple ecosystem services related to the provision and regulation of water, energy, and food. Even less has been discussed about the potential that NBS have, based on their design characteristics and participatory principles, to address the institutional, political, and governance challenges that a WEF Nexus approach entails. At the same time, decision support tools that offer guidance for the selection of specific NBS are scarce, particularly in cases where trade-offs among multiple benefits must be balanced. Existing tools produced to support practical NBS selection are typically tailored to a single outcome or produce advice on the multiple benefits of highly aggregated NBS groupings rather than specific NBS options (Sekulova & Anguelovski, 2017). Moreover, most of them focus on technical aspects of the NBS, without fully integrating socio-economic concerns.

Therefore, the objective of this study is to identify the potential role of NBS for addressing the challenges and opportunities for achieving a climate resilient WEF Nexus. This document seeks to assist stakeholders and decision-makers at different administrative levels and in different sectors on the considerations to examine when identifying NBS to implement in a specific context. In particular, the report presents a roadmap to be used by practitioners involved in multi-stakeholder and multi-disciplinary teams participating in the design, implementation, and evaluation of NBS with a Nexus approach, particularly during the stage of identification of the potential solutions.

The roadmap here described was developed as part of the EU Horizon 2020 Rexus project (Managing Resilient Nexus Systems through Participatory Systems Dynamics Modelling). Rexus is a three-year international collaboration, and it is part of a number of Horizon 2020 Research and Innovation projects designed to promote the advancement of WEF Nexus understanding. The goal of this project is to contribute to closing the gap between science and policy, moving from Nexus thinking to Nexus doing. In the project, this will be done in practical terms in five pilots, which have been selected as representative of the dynamics and challenges described by the Nexus. The five pilot cases cover a wide range of climatic, environmental, socio-economic, and socio-technical conditions as well as diverse governance structures to put the REXUS approach to the test and build a broader evidence base about the opportunities it offers and its limitations.

The rest of the document is structured as follows: Chapter 2 provides the theoretical background for the study, expanding on the concepts of WEF Nexus, Nature-based solutions and their different approaches, and the notion of ecosystem services and its several existing classifications and frameworks.

Chapter 3 illustrates the methodology for the current work. It describes the series of steps and reflections made to select the base literature, define the final list of NBS for addressing the WEF Nexus challenges, and propose the roadmap to guide decision-makers in the NBS identification process.

Chapter 4 presents the roadmap for identifying NBS with a WEF Nexus approach. It provides a simple, three-dimensional diagram that seeks to illustrate the primary considerations to examine when identifying an NBS and shows the main contributions that NBS offer to face challenges with a Nexus perspective. Conclusions and next steps are presented in chapter 5.

The document ends with an annex that contains the complete list of the selected NBS, with a brief description for each one, the geographic scales of implementation, the degree of intervention, and the contribution each NBS may have towards a selected list of ecosystem services.

2. Background

This section presents the concepts that constitute the study's theoretical background and provides the basis for developing the roadmap to select NBS solutions with a Nexus approach. The starting point is the definition of the Water-Energy-Food Nexus, its main elements, and the interactions between the Nexus domains. Subsequently, it presents the concept of Nature-based Solutions, describing the approaches it encompasses and introducing the recently developed NBS Global Standard. Finally, the chapter presents the ecosystem services approach and its different classifications and definitions as a theoretical element to illustrate the relationships between the NBS and the WEF Nexus.

2.1 The WEF Nexus approach

The Water-Energy-Food Nexus has emerged as a useful concept to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic, and environmental goals. According to the Food and Agriculture Organization of the United Nations (FAO), the WEF Nexus approach sheds light on the fact that water security, energy security and food security are deeply intertwined (FAO, 2014). This implies that actions in any particular area often can have effects in one or both the other areas (Figure 1).

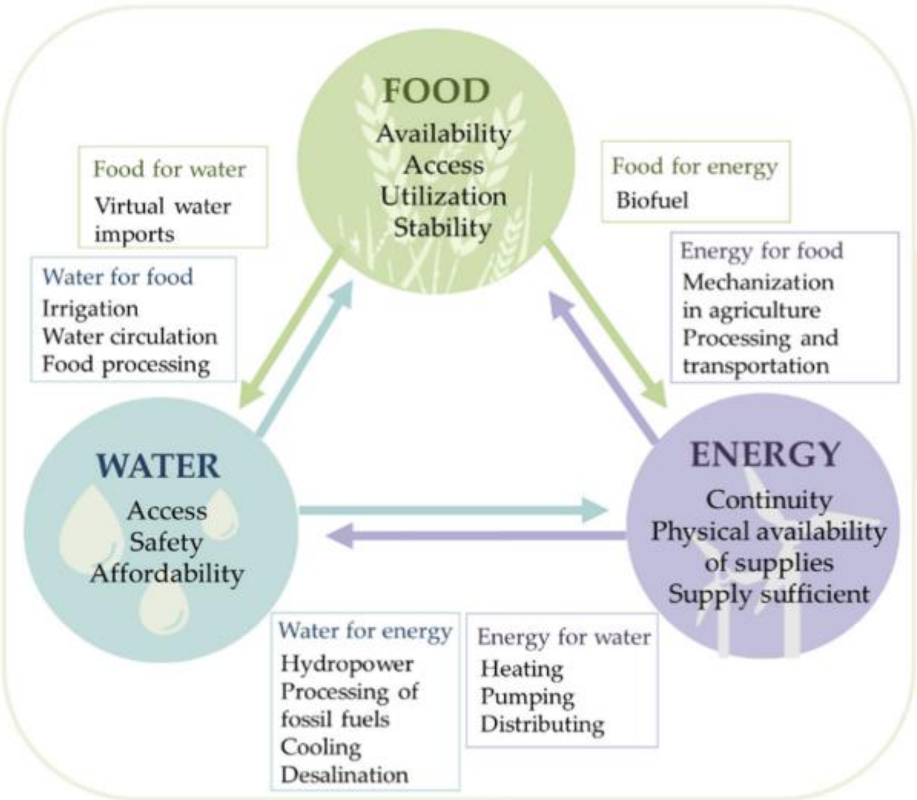


Figure 1. The Water-Energy-Food Nexus framework. Source: (Fernández-Ríos et al., 2021)

This approach provides a new way of thinking that is not limited to just the water, energy and food agendas independently, but it treats them as domains of a broader system: The WEF Nexus. In doing so, the approach highlights the interdependencies and overlaps among these domains that underpin their security, as well as existing trade-offs (Terrapon-Pfaff et al., 2018).

Water

Water forms a natural connection with other domains within the Nexus. Along with soil and nutrients, water is an underlying resource to produce food, and is also critical for energy. One of the most direct links between water and food domains is the growing expansion of irrigated agriculture, which poses several challenges related to water quality and abstraction, limiting the resource availability for competing uses (Naranjo & Willaarts, 2020). The increased use of water for agriculture creates an initial trade-off within the Nexus with other potential water uses (e.g., ecological flows, drinking and sanitation, energy production). Besides being used intensively during food production, water plays an essential role throughout the food supply chain in phases such as food processing.

With regards to the relationship between water and energy, it is estimated that 90% of global power generation is water intensive (WWAP, 2014). This fact could be referred to as the dependence of the energy domain on water, which is not only used to generate electricity directly but is also essential to cool hydropower plants themselves, nuclear power plants, and other energy production sources (Naranjo & Willaarts, 2020;). Other examples of the "water for energy" flow include the demand for water in the hydrocarbon and mining sectors. All in all, these processes have impacts on systems beyond the energy production (e.g., impacts on aquatic ecosystems, impacts on the climate) due to effects such as pollution and carbon dioxide emissions. At the same time, changes in these external systems (e.g., climate) also affect the relation between water use and energy production (Fernández-Ríos et al., 2021). For example, increasingly warm summers could hamper energy production if water for cooling processes is not sufficiently available due to droughts/heat waves.

Energy

The growing demand for energy to guarantee reliable drinking water and sanitation service is one of the main interactions between the water and energy domains (Naranjo & Willaarts, 2020). Energy is required during the process of pumping surface and subsurface water, and it is used to distribute water to different reception points (e.g., cities, agriculture, industries). The "Energy for water" flow also plays a fundamental role for heating processes in temperate latitudes, as in cases where techniques such as aquathermy are used by taking heat from the water in summer, storing it in the ground, and taking it out during winter to heat houses (Zuuk, 2021).

Regarding the relationship between energy and food production, it is estimated that around 30% of the total global energy production is used by the food production and supply chain, most of which is used for housing livestock, harvesting crops, and pumping water for irrigation (FAO, 2011). Some of the most notorious relationships are the mechanization processes in agriculture that are energy-intensive and the processes of transporting food (Fernández-Ríos et al., 2021). Energy, typically from fossil sources (e.g., petroleum) is also used to produce agricultural inputs, including chemicals fertilizers that tend to be increasingly utilised when farming activities intensify (Fabiani et al., (2020).

Food

Agriculture is the main activity in terms of consumptive use of water (i.e., the water removed from available supplies without return to a water resource system). About 70% of freshwater resources are used for food production, of which only 50% return to the basin to be available for other uses. These estimations imply that agriculture has a consumptive use of 92%, compared to only 5% from industry and 3% for the drinking water sector (Allan et al., 2015). Furthermore, agri-food systems expansion in general is one of the principal drivers of water depletion and other effects such as land degradation and biodiversity loss (FAO, 2021).

Regarding the "food for energy" flow, the primary relationship between these two domains refers to the production of biofuels (FAO, 2021). Biofuels represent an alternative to fossil fuels production and have the potential to reduce some undesirable aspects of the latter, including greenhouse gas (GHG) pollutant emissions. On the other hand, the biofuel production poses major concerns related to changes in land-use patterns, water depletion and pollution, and increased food cost (US EPA, 2013).

The WEF Nexus thinking has as one of its objectives to highlight the social and political dynamics by which decisions in one domain might impact the other, thus calling for an interrelationship in the way decisions are made to define coherent agendas and more efficient results (Simpson & Jewitt, 2019). The approach aims to overcome the political, institutional, and governance barriers that cause decisions to continue to be made from institutional silos and not with a comprehensive approach to resources and territory (UNECE, 2018). The attention brought by the concept of the water-energy-food Nexus can help reduce trade-offs and boost synergies between its domains, resulting in greater policy coherence, better resource-use efficiency and conservation of healthy ecosystems. Moreover, the WEF nexus approach could play an essential role for assessing livelihoods with the aim of creating communities more resilient to external shocks such as climate change (Mabhaudhi et al., 2019)

When thinking from a Nexus perspective, it is crucial to look for solutions that aim at multiple objectives that benefit the biophysical system (e.g., that enhance biodiversity) and help overcome some of the challenges of the socio-political system, such as institutional fragmentation, lack of cooperation, conflicting policies, and others.

2.2 Nature-based Solutions to help address the Nexus challenges

In the past few years, the term Nature-based Solution has been used to refer to various strategies and approaches that place "nature" as a central element to help solve societal challenges such as Climate Change, Water, and Food Security, and others (Castellari et al., 2021; IUCN, 2016). In this way, several approaches originating from different sectors (e.g., academia, industry, policy) and initially considered as different from each other, started to be regarded as NBS. The term has now become an umbrella concept encompassing such approaches (Somarakis et al., 2019).

On March 2nd, 2022, The Fifth Session of the United Nations Environment Assembly[1] (UNEA-5) formally adopted the definition of NBS as "*actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits*".

[1] IUCN "Landmark UN Environment Assembly adopts key decisions and restores hope on multilateralism".

This definition, which largely based on the one provided by IUCN (IUCN, 2016), places ecosystems as a central element in providing well-being to humanity, and biodiversity benefits but leaves room for interpretation of what is meant by “natural”. Moreover, it does not offer a clear route on how to address such societal challenges.

Despite these efforts by the international community, in practice there is not a univocal definition for NBS, and the concept is still largely contested by different sectors of society. Some of the current questions on the debate relate to the need to clarify the concept of NBS in relation to existing similar approaches, to clarify its added value, or the need for relabelling ongoing processes, to avoid misunderstanding or duplication issues (Nesshöver et al., 2017).

In this sense, the NBS definition has made it possible to group a broad spectrum of actions that, although at first glance seem complementary or even synonymous with each other, are different in terms of the main objectives they pursue, the starting points, and the strategies they use to achieve it (Somarakis et al., 2019). Some of these examples include integrated landscape management strategies for climate change adaptation, green infrastructure options to ensure the provision of certain essential services or ecosystem-based approaches to natural disaster risk reduction (Castellari et al., 2021; Somarakis et al., 2019).

The main terms that fall within the concept of NBS are (Castellari et al., 2021, p. 26):

- Ecosystem approach and ecosystem-based approaches
- Green and blue infrastructure
- Ecosystem-based adaptation
- Ecosystem-based disaster risk reduction
- Natural water retention measures (NWRM)
- Sustainable management and ecosystem-based management

Due to the diversity of approaches that the concept encompasses, NBS have been classified in multiple ways. One of the most used classifications is based on the degree of intervention NBS generate in ecosystems (Figure 2). This classification proposed by Eggermont et al. (2015) categorizes NBS into three types:

- Type 1 that includes the NBS to better use the natural and protected ecosystems
- Type 2 that groups the NBS for sustainability and multifunctionality of managed ecosystems
- Type 3 that consists of the NBS aimed to design and manage new ecosystems

This classification also considers the number of stakeholders to impact and the maximization of the delivery of key services according to each type of NBS.

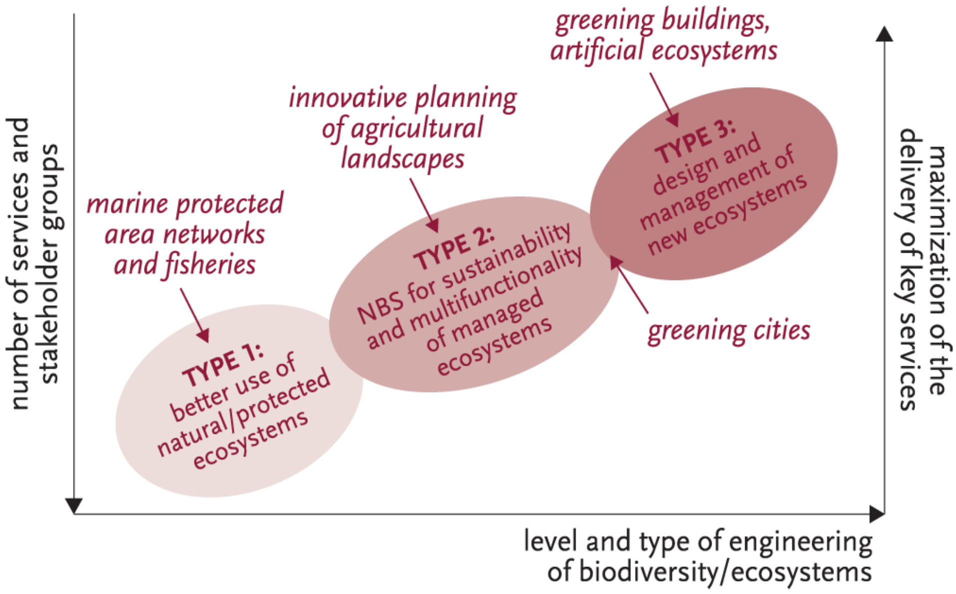


Figure 2. The types of NBS based on the degree of intervention of the ecosystem. Source: Eggermont et al, 2015

Regarding the potential of NBS to help address the WEF Nexus challenges, there are two key elements to highlight. One is the goal of NBS to contribute to solving different societal challenges and the other one is the enhancement of multiple ecosystem services provision and biodiversity benefits (IUCN, 2016). The societal challenges identified by the IUCN in 2016 were i) Climate change, ii) Food security, iii) Water security, iv) Disaster risk, v) Human health, and vi) Economic and social development, whereas vii) ecosystem degradation and biodiversity loss, was added later (IUCN, 2020). The ecosystem services enhancement implies that such societal challenges are addressed through the strengthening of the biophysical systems and the multiple benefits that society receives from them expressed in human well-being and in biodiversity benefits (Figure 3).

Figure 3. The Nature-based solutions framework. Source: IUCN, 2016

All in all, it can be said that the concept of NBS continues to evolve, and its definition is not exempt from being contested from different sides of the academy (e.g., Sowińska-Świerkosz & García, 2022). As an illustration, the term initially began to be used to give visibility to the importance that the protection and restoration of biodiversity played in the well-being of humanity. With the development of the environmental agenda and the definition of the Sustainable Development Goals (SDGs) and the European Green Deal[2], aspects that had not been initially considered were incorporated into the term. Such is their role in contributing to sustainable economic development.

In fact, the definition of NBS of the European Commission (EC) slightly varies from that of the IUCN, as it adds new elements to the concept. The EC (as cited in Castellari, 2021, p.17) recognizes NBS as "*solutions to societal challenges that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience*". This new definition includes additional aspects to the role of NBS, such as cost-effectiveness and the provision of social and economic benefits during their implementation.

One of the most important recent initiatives to create a shared understanding of what NBS are, what their goals are, and how they are implemented was the development of the IUCN Global Standard for Nature-based Solutions (IUCN, 2020). The standard defines eight criteria set to establish the fundamental characteristics to consider an action as an NBS and set the process through which an NBS must be planned and implemented (Figure 4).

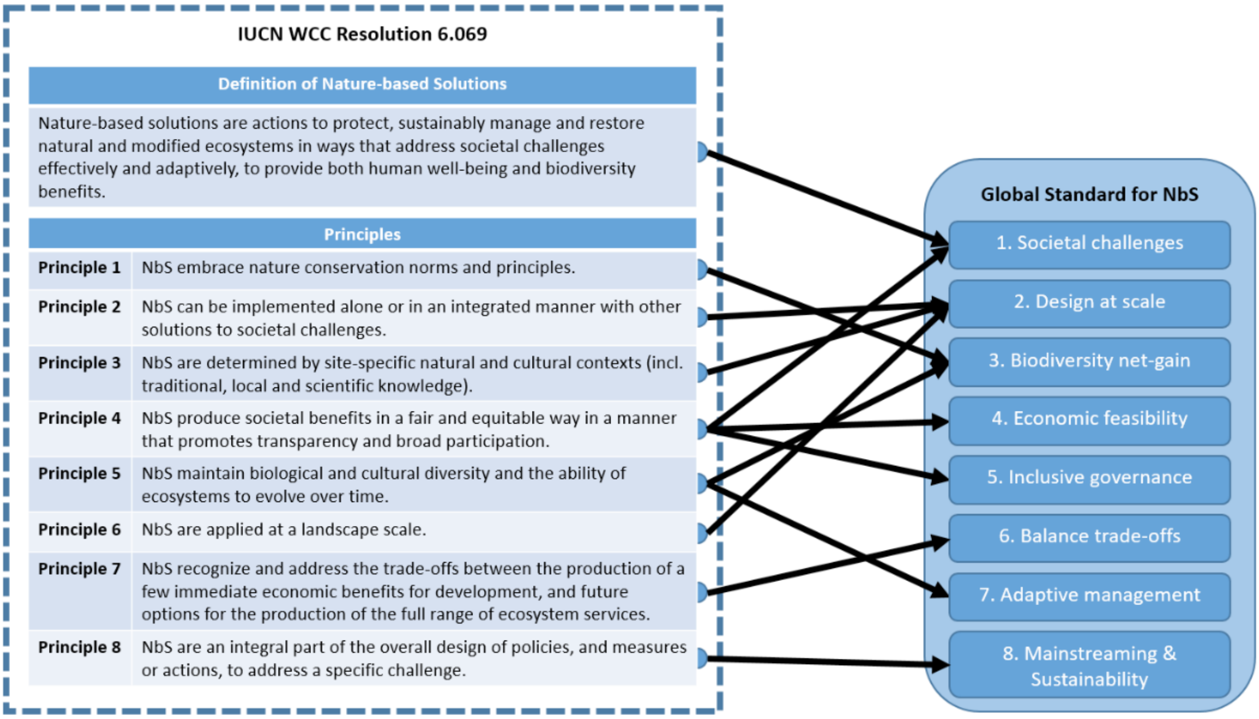


Figure 4. Principles and Criteria from the NBS Standard defined at the World Conservation Congress in 2016. Source: IUCN, 2020

[2] European Commission, "Nature-based solutions research policy".

The standard advocates for considering the entire life cycle of the NBS project, adding new characteristics to what NBS implementation should include. It brings specific guidance to the NBS design process, seeking to add aspects of participatory governance, the balance of trade-offs between their primary goal and the associated co-benefits, and inclusion of minority groups. These new additions constitute another promising aspect of NBS to contribute to the WEF Nexus approach, apart from the aforementioned multipurpose provision of ecosystem services.

2.3 Ecosystem Services and their classifications

The theoretical framework of ecosystem services, widely used in the literature on NBS, is an opportunity to connect the use of these solutions that seek to generate multiple benefits from strengthening the biophysical system with the challenges and opportunities of the WEF Nexus approach and its domains. To describe the concept of *ecosystem services* (ES) it is necessary to introduce two major concepts, namely *ecosystem* and *biodiversity*.

The ecosystem notion is not recent as its original definition dates back to the mid-1930s by Arthur Tansley. However, its most widely used definition today is the one provided by the Convention on Biological Diversity in 1992: "*An ecosystem is a dynamic complex of plant, animal and microorganism communities and the non-living environment, interacting as a functional unit*" (CBD, 1992, p. 5). Ecosystems are varied in both size and, arguably, complexity, and may be nested one within another. Understanding their functioning and interlinked processes underlying this functioning is essential, as preserving their integrity could provide social, economic and ecological stability in the long run. However, due to their complexity, they are not easily evaluated or predictable, although it is still possible to quantify the services they provide.

Biodiversity is defined as "*the variability among living organisms from all sources, inter alia, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part, this includes diversity within species, between species and of ecosystems*" (United Nations, 2002). Increased biodiversity corresponds to greater resilience and adaptation to changing conditions and, conversely, reduced fragility and vulnerability of ecosystems (Cleland, 2011). According to the *cascade model* defined by Haines-Young (2018), ecosystems and biodiversity are the foundational element for the flow of ES and benefits derived from them. Thus, ecosystem components, processes and functions constitute ecosystem services.

The Earth's ecosystems, as defined above, provide humanity with a wide range of benefits commonly known as ecosystem services. Although some references can be found in some classical authors (e.g., Plato, Theophrastus), ecosystem services have gained increasing relevance only over the last 50 years. Gómez-Baggethun et al. (2010) pointed out that the origins of this concept date to the late 1970s, when it was mostly used to increase public awareness on biodiversity conservation. Later, in the 1990s, the concept gained much more attention thanks to the proliferation of scientific contributions on the subject (Costanza & Daly, 1992) and the first attempts to estimate the economic value of ecosystem services (Costanza et al., 1997).

There are many different definitions of ES, but the most cited one is that provided by the **Millennium Ecosystem Assessment** (MA), which is considered the publication that finally defined and popularized the concept. According to this international work programme launched by the United Nations in 2001, ES are defined as "*the benefits people obtain from ecosystems*" (MA, 2005, p. 39).

Experts involved in the work agreed to categorize ES in four groups, all vital to human health and well-being:

- Supporting services: such as soil formation, photosynthesis, nutrient and water cycle. They enable the provision of all other types of ecosystem services.
- Provisioning services: they consist of all the goods and products that people obtain from ecosystems to satisfy their needs. They include food, fresh water, fuels but also more abstract products such as genetic resources.
- Regulating services: these are the benefits derived from the regulation of ecosystem processes such as water purification, pollination and the regulation of climate and air quality.
- Cultural services: these services share the common characteristic of being intangible. They include services that contribute to human spiritual well-being, such as educational, aesthetic, cultural diversity, spiritual and religious values, inspiration, recreation, and ecotourism.

Another classification is the one developed by **The Economics of Ecosystems and Biodiversity** (TEEB), a global initiative whose principal goal is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels. The TEEB study applies a similar classification approach as proposed by MEA, distinguishing 'provisioning', 'regulating' and 'cultural' services, while the fourth category is labelled 'habitat or supporting services', which cover habitats for species and maintenance of genetic diversity.

Another, more complex approach is applied by **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services** (IPBES), which is organized around the following three categories:

- **intrinsic value of nature** including individual organisms, biophysical processes and biodiversity;
- **nature's contributions to people** (NCP), which includes:
    - biosphere‘s ability to enable human endeavour (i.e. life cycles, carbon and water footprint; land cover flows etc.);
    - nature‘s ability to supply benefits (i.e. habitats for fisheries, contribution of soil biodiversity to sustenance of long-term yields);
    - nature‘s goods and services (i.e. regulating services: climate regulation, regulation of water flows, pollination, biological control etc.; provisioning services: food, timber, water, bioenergy etc.; cultural services: ecotourism, education, psychological benefits etc.);
- **good quality of life** including security and livelihoods; health and well-being; education and knowledge; good social relations; art and cultural heritage; spirituality and religions; governance and justice.

Due to a rapid proliferation of literature with sometimes inconsistent definitions and categories of ecosystem services, the **Common International Classification of Ecosystem Services** (CICES) was proposed in 2009. The classification provided by CICES, which purpose is not to replace other existing classifications but to simplify the understanding of the concept of Ecosystem Services as well as make them easier to assess, considers only three categories of ES, namely provisioning, regulating and cultural services.

The idea of a common international classification is an important one, as it was recognized that if ecosystem accounting methods were to be developed and comparisons made, then some standardization in the way we describe ES was needed.

In the CICES, the category of supporting services, which is made explicit in the MA classification, is no longer considered as a group in itself, but instead as part of the underlying structures, processes and functions that make up ecosystems. The reason for this choice is that life supporting services are essentially intermediate ES, as such not directly used by humans, but functional in ensuring the provision of other ES more directly associated with human well-being. It does not mean the supporting services are less important, but such narrowing down of the assessment scope is essential to avoid double accounting when valuing the ecosystem services – i.e., assessing the importance of a nature component more than once because it is embedded in, or underpins, a range of other service outputs.

The ES identified by CICES are framed in a five-level hierarchical structure, according to an increasing order of detail:

- Section
- Division
- Group
- Class
- Class type

The hierarchical structure allows users to go down to the most appropriate level of detail required by their application as well as combine results when making comparisons or more generalized reports.

Nevertheless, considering the complexity of the issue, one comprehensive classification system, suitable for all assessment purposes, most probably would not be possible. The choice of the appropriate classification approach depends on the objective of the study or the decision-making context. For this reason, the ES categories used for this report are the ones defined in the Rexus Deliverable 3.6 about "*Socio-economic indicators in nexus systems*", as will be explained in the methodology section.

3. Methodology of the study

This chapter presents the methodological pathway to develop the roadmap for selecting NBS with a Nexus approach (Figure 5). It first describes the methods for collecting and reviewing relevant literature. Then, it explains the process of identifying the challenges faced by the pilot areas within the Rexus project as a sample of recurring challenges in the WEF Nexus domains. It then describes the definition of the ecosystem services component of such challenges and the selection of NBS to address them. The methodology ends by describing the considerations for building the roadmap, such as the role of NBS in addressing some non-ecosystem-service-related challenges of the Nexus.

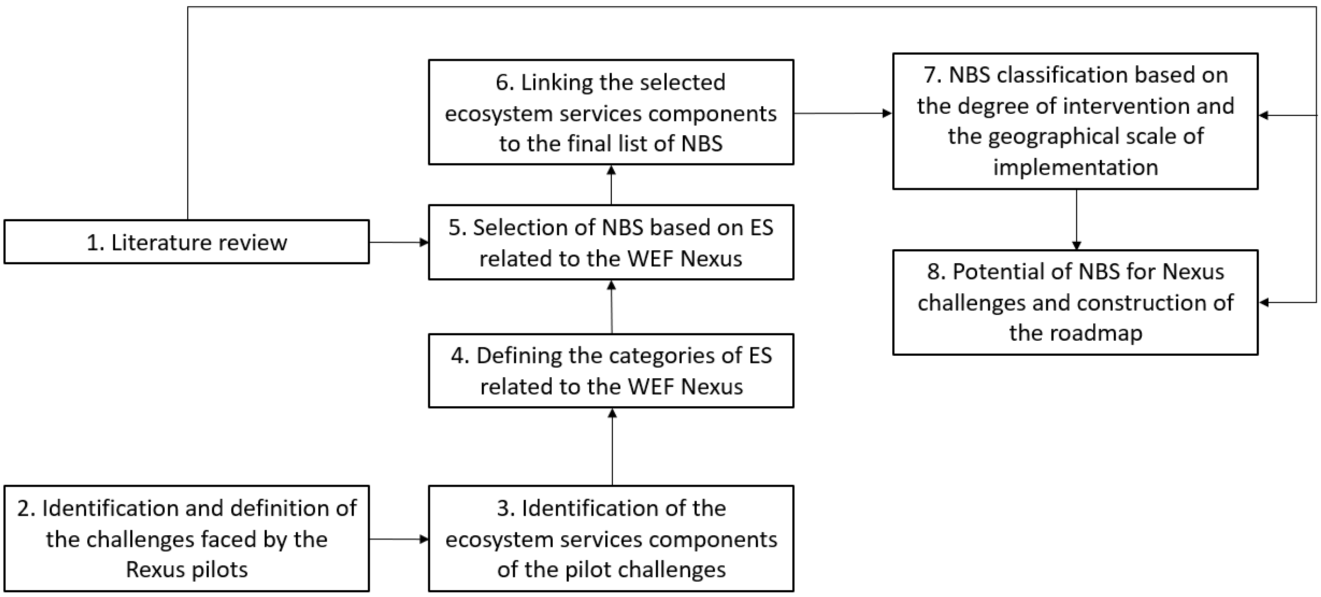


Figure 5. Methodological process for the present study. Source: Own elaboration

The methodology used to create and define this roadmap was developed as part of the EU Horizon 2020 Rexus project, taking as relevant the challenges and the Nexus-related dynamics of the five pilots used within the project. The pilot areas of the Rexus project are considered as a benchmark, though the study's output can be transferable and scalable for defining strategies applicable to other latitudes and contexts.

As previously mentioned, the five pilot areas cover a wide range of climatic, environmental, socio-economic, and socio-technical conditions as well as diverse governance structures. In the specific, four pilots will address the physical water management boundaries in the project framework (i.e., the river basin or sub-catchment scale within or across countries), namely the transboundary Lower Danube Basin (Romania/Bulgaria/Serbia section), the Isonzo-Soča transboundary basin (Italy/Slovenia), the Cauca River Basin (Colombia) and the Pinios River Basin (Greece). The fifth pilot targets mainly the political boundaries of water-to-Nexus management (i.e., the national scale in the case of Spain).

The methodological approach adopted for the aims of this report consists of a stepwise approach: each step is described below.

1. **Literature review**

As a first stage, we conducted a broad review of scientific and grey literature about solutions related to the WEF Nexus, NBS, and similar approaches. The selected body of literature would lay the ground to analyse the potential contributions of NBS to address the Nexus challenges and build the roadmap for decision-makers to navigate amongst the available information on NBS. The first step was to consult the EU initiatives for the promotion of NBS, summarized in the Think Nature handbook (Somarakis et al., 2019). The handbook grouped reports, materials, and networks (e.g., Oppla marketplace) from several European projects regarding NBS, as well as catalogues with proposed solutions.

The second step consisted of a search via Google Scholar and Google using the key words "Nature-based solutions", "Ecosystem-based adaptation", "climate change mitigation and adaptation", "WEF Nexus", and their respective extended/narrow versions to avoid excluding search results. The documents were then evaluated based on their title and abstract to determine their relevance for this study. Additionally, those documents that contained a list or a catalogue of activities were added to an NBS catalogue database. Given the fact that this exercise had a technical focus rather than an academic one, the results from Google Scholar and Google were consider enough, and no further scientific literature directories were consulted.

The documents in this database were classified in a spreadsheet according to several characteristics (author, year, type of source, targeted environment, scale, Nexus themes, challenges addressed). Once finalized, the list of catalogues was shared with the members of the Rexus consortium, and an expert validation was requested on key references that might be missing. As a result, two new sources were recommended. The final list of catalogues included 16 references, of which 14 are reports, and two are web-based tools (i.e., UNDP-Nature-based Solutions Database and OXFORD-Nature-Based Solutions evidence platform).

2. **Identification and definition of the challenges faced by the Rexus pilots**

The objective of this phase was to identify the challenges related to the Nexus faced by each pilot area. This was done by drawing on what was produced within the project in Deliverable 6.1 – Baseline Description, where a general characterization of each pilot area was provided, with a particular focus on its primary challenges related to the water, energy and food domains (Table 1). The summary includes all kinds of challenges related to the Nexus, ranging from biophysical, to socio-economic and institutional challenges.

Table 1. Challenges faced by Rexus pilot areas. Source: Rexus project

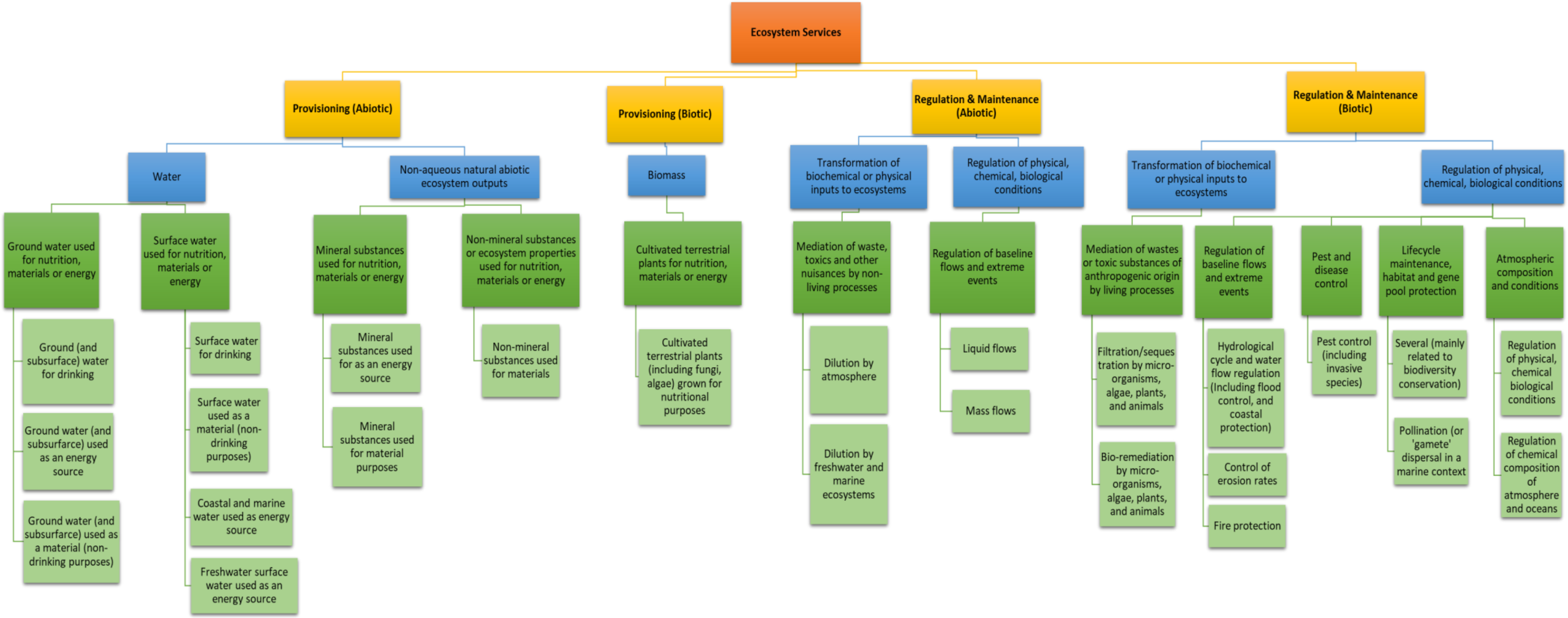
Rexus pilot areas	Challenges
Nima-Cauca River Basin	Water for irrigation (sugar cane cropping system)
	Water for livestock
	Maintain sufficient water quantity and quality
	Fertilizers and pests' control
	Preservation of natural resources in the watershed
	Maintain the environmental flow for ecosystems
	Regulation of material extraction from Nima river
	Overflow risk
	Riverbank erosion risk
	Regulation in sugar cane burning
	Water for hydropower energy production
	Reduce environmental impacts of agriculture in the watershed (explore other crop systems and agricultural management alternatives)

Rexus pilot areas	Challenges
Pinios River Basin	High-water consumption and groundwater over-abstraction for irrigation
	Satisfy the needs of all the competitive water users
	Maintain the environmental flow for ecosystems
	Deal with climate extremes (floods but mainly with droughts)
	Increasing water demand due to energy supply
	Increasing water demand due to food production
	Decreased water availability due to climate conditions
	Water infrastructure risk due to climate extremes and water abstraction
	Maintain or increase energy production through renewable resources to decrease emissions
	Reduce vulnerability of productive sectors to climate impacts (prepare/adapt to climate change impacts)
Peninsular Spain & Jucar River Basin	At political level: policies and implementation
	At scale level: transferability between regions and river basins (e.g., inter-basin water transfers)
Isonzo-Soča River Basin	Flood risk
	Water for hydropower production upstream
	Water for irrigation downstream
	Poor water management
	Poor ecological river status
	Policy fragmentation due to transboundary issues
	Increased extremes events
Lower Danube River Basin	Flood risk
	Riverbank erosion and collapse
	High-water consumption for irrigation
	Water for hydropower energy production
	Poor ecological river status
	Exploitation for navigation

3. Identification of the ecosystem services components of the pilot challenges

Once the challenges for each pilot area were defined, we proceeded by identifying the ecosystem service component that, explicitly, was most easily relatable to them. As a first step, the ES classification proposed by CICES was used in this process as it is the one with the highest level of detail and proved to be the most suitable for the accuracy required in this step. The same process was carried out for each of the challenges identified above. There was not always a one-to-one correspondence between the challenges and the ES classes. Consequently, some challenges were linked to more ES while others, less related to the biophysical component, found no association. These were categorized as non-ES related, and a separate reasoning was elaborated for them in the methodology’s step 7. The work done in this phase resulted in a final list of ES classes that can be seen in Figure 6. This we assume to be the most related to the challenges linked to the Nexus domains.

Figure 6. Classification of Ecosystem services associated with the Rexus pilots' challenges using CICES. Source: own elaboration



4. Defining the categories of ES related to the WEF Nexus

Having pinpointed the CICES class types, the corresponding ES groups as defined by other international classifications, namely TEEB, IPBES and MEA were identified. This step was conducted to align the exercise of identifying the ecosystem services component of the Rexus pilots' challenges with the bulk of literature regarding NBS and ES, which does not often use the CICES classification. In addition, we validated this exercise with original materials produced within the REXUS project on socio-economic indicators for Nexus analysis and management (Deliverable 3.6) to have a common denomination of ES categories within the project.

Based on the above exercise, the following categories were defined as the ecosystem services components related to the Nexus challenges faced by the REXUS pilot cases:

Table 2. List of Ecosystem services categories related to the WEF Nexus. Source: Rexus project

ES final categories	CICES classes
Food provision	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes
Water provision	Ground (and subsurface) water for drinking
	Ground water (and subsurface) used as a material (non-drinking purposes)
	Surface water for drinking
	Surface water used as a material (non-drinking purposes)
Energy	Coastal and marine water used as energy source
	Freshwater surface water used as an energy source
	Ground water (and subsurface) used as an energy source
	Mineral substances used for as an energy source
Water purification and waste treatment	Bio-remediation by micro-organisms, algae, plants, and animals
	Dilution by freshwater and marine ecosystems
	Filtration/sequestration by micro-organisms, algae, plants, and animals
Regulation of water flows	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)
	Liquid flows
	Mass flows
Erosion prevention	Control of erosion rates
Biological control	Pest control (including invasive species)
Climate regulation	Dilution by atmosphere
	Regulation of chemical composition of atmosphere and oceans
	Regulation of physical, chemical, biological conditions
Lifecycle maintenance	Several (mainly related to biodiversity conservation)
	Pollination (or 'gamete' dispersal in a marine context)
	Fire protection
Raw materials	Non-mineral substances used for materials
	Mineral substances used for material purposes

A detailed description for each category can be found in the REXUS Deliverable 3.6 "*Report on Socioeconomic indicators for Nexus analysis and management*"

5. Selection of NBS based on Ecosystem Services related to the WEF Nexus

Based on the analysis about the primary ES relevant for the Nexus challenges developed in steps 3 and 4, the process followed the review of solutions included in each of the NBS catalogues identified. This exercise resulted in the selection of 51 NBS that can contribute to addressing the ecosystem service-related challenges of the WEF Nexus.

6. **Linking the selected ecosystem services components to the final list of NBS**
The 51 selected NBS were then associated with the ES they influence. The ES enhancement resulting from the NBS implementation implies that the challenges are addressed through the strengthening of the biophysical systems and the multiple benefits that society receives from them. This association was made by highlighting the trade-offs that the application of each NBS has for each category of ecosystem service. For example, an NBS option such as "elimination of riverbank protection to enhance lateral connections of the river" can increase the ES of Regulation of Water Flows, Erosion Prevention, Lifecycle Maintenance. In turn, this strategy can diminish the potential of the river for Energy production.

To carry out this step, we draw knowledge from the following reference studies, from which we have also extracted some of the NBS included in the final list:

1) Nature Based Solutions Handbook by Think Nature (Somarakis et al., 2019)
2) NBS for more sustainable cities (Croci & Lucchitta, 2021)
3) Nature-based solutions in Europe: Policy, knowledge and practice (Castellari et al., 2021)
4) Selecting, designing and implementing Natural Water Retention Measures in Europe (NWRM Project, 2013)
5) Addressing climate change in cities (Iwaszuk et al., 2019)
6) Evaluating the impact of nature-based solutions. A handbook for practitioners (Dumitru & Wendling, 2021)

After this association, the process followed an expert validation by selected project partners.

7. **NBS classification based on the degree of intervention and the geographical scale of implementation**
A brief description was provided for each solution, explaining the contexts in which it is used and its main objectives. Additionally, each solution was categorized using the classification by Eggermont et al. (2015) on the degree of intervention of the ecosystem that it generates. Further, the geographic scale of implementation for each solution was specified. Both exercises were carried out based on reference documents and previous NBS classifications. Finally, for some solutions, additional sources were provided.

8. **Potential of NBS for Nexus challenges and construction of the roadmap**
The literature review results allowed us to identify specific key references to discuss and analyse the potential role of the NBS in facing the challenges of the WEF Nexus. Some of these references include work by the United Nations and its commissions for Europe (UNECE) and Latin America (ECLAC) on applying the Nexus approach in these regions, the challenges identified, and some proposed methodologies (Naranjo & Willaarts, 2020; UNECE, 2018). Other important references are part of the EU initiative to promote the adoption and mainstreaming of NBS in the region (e.g., Horizon 2020 projects such as Think Nature, Naturvation, Nature4Cities), the European Environment Agency, and the flagship IUCN work on NBS (Castellari et al., 2021; Croci & Lucchitta, 2021; Dumitru & Wendling, 2021; Ecoshape, 2020; FAO & TNC, 2021; Iseman & Miralles-Wilhelm, 2021; IUCN, 2016, 2019, 2020; Iwaszuk et al., 2019; Pbl et al., 2021; Raymond et al., 2017; Sekulova & Anguelovski, 2017; Somarakis et al., 2019).

The analysis of these documents, together with the baseline provided by the Rexus pilot areas, made it possible to identify common elements between the literature on the WEF Nexus and the NBS, where challenges in implementation were identified, but also opportunities that one approach could bring to the other. These considerations were added to the exercises on ecosystem services and the definition of scales to help build the roadmap that guides implementers in the NBS selection process with a Nexus approach.

4. Roadmap for the identification of NBS to address Nexus challenges

This section synthesizes the work of this study and presents the roadmap for selecting NBS with a Nexus approach (Figure 7). The objective of the roadmap is, on the one hand, to introduce decision-makers to some of the theoretical elements needed in the process of identifying an NBS to address WEF context-dependent challenges. This process provides guidance for pre-selecting solutions from the list of NBS. On the other hand, the roadmap aims to illustrate the potential that NBS can offer for the Nexus challenges, both from the biophysical as well as the socio-political perspective.

The roadmap comprises three main dimensions of considerations to be taken into account and provides sources that can be consulted to delve into specific topics according to the user's interest. These dimensions may appear simultaneously when identifying NBS in the WEF Nexus context and are the following:

1) Ecosystem Services components of the WEF Nexus challenges
2) Scale of application and degree of intervention of the NBS
3) Enabling factors for implementing NBS with a Nexus approach

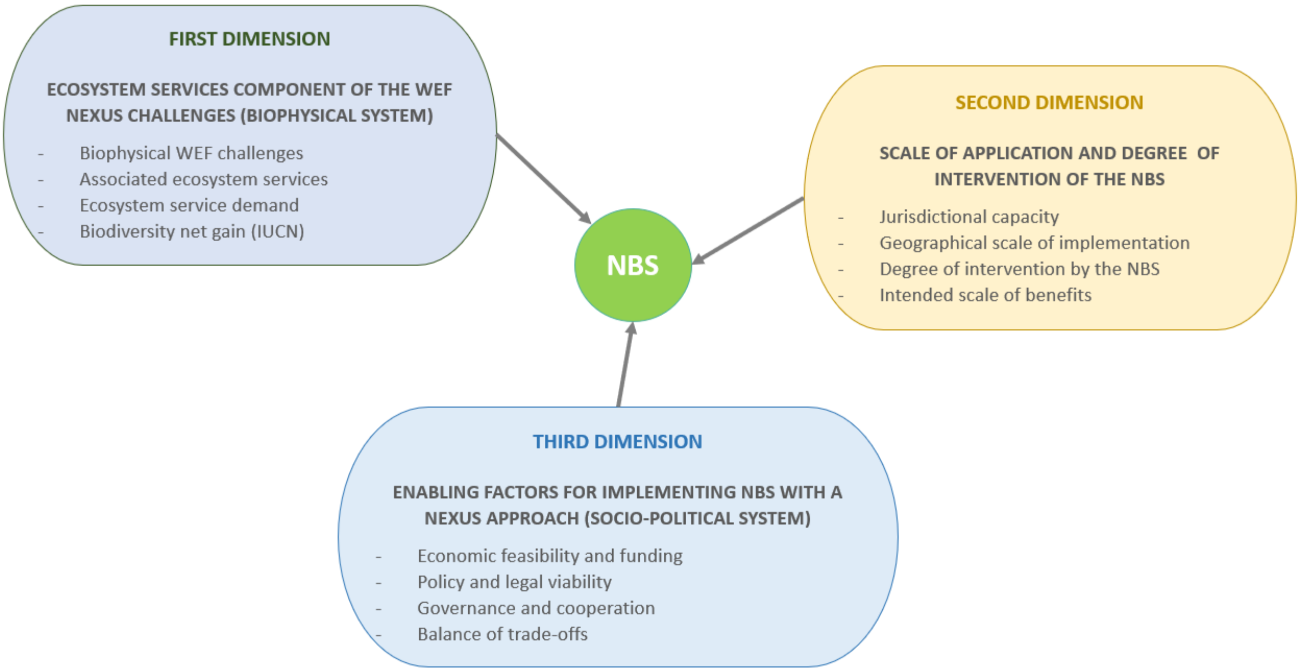


Figure 7. Roadmap for the selection of NBS to address Nexus challenges. Source: own elaboration

4.1 First dimension: Ecosystem services component of the WEF Nexus challenges

The first dimension of the roadmap seeks to guide the user on the biophysical aspects to consider when selecting an NBS with a WEF Nexus approach to identify the challenges and ecosystem services that the NBS seeks to address. These considerations also serve as a methodological order for the user. These are grouped into 1)

Biophysical WEF Nexus challenges (e.g., food security, disaster risk reduction), 2) Associated ES to the identified challenges, 3) Considerations on the ES demand, and 4) considerations about a Biodiversity net gain.

Biophysical WEF challenges: Considerations on the biophysical challenges to be solved in the area are the starting point when conducting a NBS identification process. At this stage it is crucial to define which challenges require a solution and what might be the effect of long-term and unregulated use of the resources related to the Nexus.

For this initial phase, it is suggested to have the following inputs:

- System understanding, considering how the different factors of the WEF Nexus system are interconnected and where the main challenges might root.
- Information on the challenges to be solved, including current and expected trends, on the use of natural resources related to the Nexus.
- Information on the socio-economic context of the territory and on the other domains to be assessed.

In this regard, the Ecoshape consortium proposes the Technology and system knowledge category as one of the enablers for the creation, implementation, and upscaling of NBS (Ecoshape, 2020). This enabler refers to a series of aspects to consider concerning the understanding of the physical and social system that will be intervened through the NBS.

Ecosystem services associated with the identified challenges: Once the challenges have been defined, it is important to identify the ecosystem service component that directly can be related to them.

Ecosystem service demand: When the ES associated with the challenges faced have been defined, it is important to enter the socio-political system's interface and estimate the population's needs for each of the identified ES. This exercise allows estimating the indicators of demand for ES and identifying the real needs of a population regarding the ES of/from a certain territory. This consideration can also help to shed light on the types and levels of trade-offs among ES that could be acceptable when deciding on the type of solution to implement (i.e., the acceptable type and extent of trade-offs among ES for that particular system).

Biodiversity net gain: As the last consideration of this dimension, when an NBS is selected, its implementation should result in a net gain for biodiversity values. In this regard, the *Global Standard* for Nature-based Solutions establishes that NBS provide goods and services mainly based on the health and capacity of an ecosystem. Therefore, for a solution to be considered an NBS, it cannot go against these principles and the changes suffered in the ecosystem due to the solution cannot result in biodiversity loss (IUCN, 2020). To select NBS that results in a net biodiversity gain, the standard proposes four indicators (Figure 8), referring to the need to plan NBS following an evidence-based assessment of the current state of the ecosystem and the need to establish measurable biodiversity conservation objectives thar are periodically evaluated and to evaluate unintended impacts on biodiversity.

All in all, the ecosystem service approach for identifying NBS will allow in the future to make measurements of each of the Nexus components to see net gains in the biophysical system. It will also enable the practitioners to evidence trade-offs that might have happened between such components (e.g., food production increased, but energy decreased).

Guidance:	Indicators
NbS are derived as goods and services from ecosystems, therefore strongly depend on the health of an ecosystem. Biodiversity loss and ecosystem change can have significant impacts on the functioning and integrity of the system. Therefore, NbS design and implementation must avoid undermining the integrity of the system and instead, proactively seek to enhance the functionality and connectivity of the ecosystem. Doing so can also ensure the long-term resilience and durability of the NbS.	**3.1 The NbS actions directly respond to evidence-based assessment of the current state of the ecosystem and prevailing drivers of degradation and loss** Guidance: To develop a solution using nature, one must have a well-founded understanding of the current state of the ecosystems concerned. The baseline assessment needs to be broad enough to characterise ecological state, drivers for ecosystem loss and options for net improvements, making use of both local knowledge and scientific understanding where possible.
	3.2 Clear and measurable biodiversity conservation outcomes are identified, benchmarked and periodically assessed Guidance: In order to inform the design, monitoring and assessment of an NbS, targets for enhancing key biodiversity values should be established. For each NbS, the type of target may differ; for example, the target could be the percentage of ecosystem area restored or the return of a keystone species.
	3.3 Monitoring includes periodic assessments of unintended adverse consequences on nature arising from the NbS Guidance: Ecosystems are complex with interdependent components and processes. There will always be a level of uncertainty in how they will react to specific interventions or other external changes. Therefore, NbS should be designed and monitored to minimise and mitigate unanticipated risks that might undermine the ecological foundations of the solution itself.
	3.4 Opportunities to enhance ecosystem integrity and connectivity are identified and incorporated into the NbS strategy Guidance: Utilising NbS can provide an opportunity to enhance biodiversity conservation and ecosystem management efforts in ways that other types of intervention, in isolation (such as engineering), will not be able to achieve. If solutions are to be implemented close to natural ecosystems that are managed explicitly for conservation outcomes, the NbS should be designed to enable greater ecosystem connectivity. Furthermore, they could be designed to re-introduce lost components of an existing ecosystem, for example, by deliberately choosing formerly existing species of vegetation when restoring.

Figure 8. Four Indicators for assuring that NBS result in a net gain to biodiversity. Source: IUCN, 2020

4.2 Second dimension: Scale of application and degree of intervention of the NBS

The second dimension of the roadmap brings together the considerations on the different scales that must be envisaged when thinking about selecting an NBS to address the challenges of the WEF Nexus. These scales comprise the 1) jurisdictional capacity of the decision-maker; 2) the geographical scale to which the NBS is to be applied, which may be partially influenced by the jurisdictional capacity; 3) the degree of intervention of the ecosystem that will be carried out with the implementation of the NBS, and 4) the scale of benefits at which it is desired that the ES be perceived with the NBS, both in space and time. Each consideration is explained in detail below, mentioning relevant sources useful to the decision-maker.

Jurisdictional capacity: Jurisdictional capacity considerations are the starting point when considering the geographic scale of NBS implementation and its level of intervention and effect on the biophysical system. The jurisdictional capacity includes the political and administrative authority and the financial possibility of the decision-maker to implement an action in a specific area, as well as the administrative obligations (e.g., implementing the Water Framework Directive or Natura 2000 regulation). These considerations are related to the legal feasibility and options of investing in an NBS. Regarding this, *the methodological guide for the design of actions with a WEF Nexus approach for Latin America and the Caribbean* proposes that in many cases, Nexus actions exceed a political-administrative scale, for which it is essential to define the scope of action of each of the actors involved. In most cases, an approach involving different governmental bodies at several scales would be needed (Naranjo & Willaarts, 2020).

In this regard, the Ecoshape consortium presents "Capacity Building" and “Multi-stakeholder approach” as two of the six enablers to deploy NBS, required to change attitudes and behaviours and develop skills to maximize the benefits of participation, knowledge exchange, and ownership (Ecoshape, 2020). Furthermore, criterion 2 of the *Global Standard for Nature-based Solutions* explains that the design of NBS requires a framing that acknowledges and addresses the interactions between people, the economy, and the ecosystem for the solution to be durable and sustainable (IUCN, 2020).

Geographical scale: Depending on their characteristics, the geographic scale of NBS implementation may vary. Some of these solutions involve specific actions in one place in a river basin or a city, while others require intervention at a territorial level. Regarding this consideration, the *Think Nature Handbook* for NBS proposes three geographical scales in which NBS can be implemented (Somarakis et al., 2019):

- Fine scale: understood as the scale at which specific actions are implemented, such as creating Terraces for runoff and erosion control.
- Local scale: integral actions in a biophysical unit such as a (sub-)catchment or a city (e.g., setting of a continuous cover forestry system in a managed forest).
- Regional scale: actions at levels that go beyond the boundaries of a biophysical system, such as policies and guidelines for the maintenance of forest cover in headwater areas of multiple catchments within a country or province.

Degree of intervention: In the same way as with the previous consideration, according to their characteristics, level of engineering, and degree of intervention in the ecosystem, the NBS can be classified into different types. The most used classification for these purposes is Eggermont et al. (2015) and taken up by Somarakis et al. (2019). Three main categories of NBS are identified:

- Type 1: NBS include minimal or no modification in ecosystems (e.g., protect, conserve, maintain, and enhance existing natural wetlands)
- Type 2: are sustainable management protocols and actions whose purpose is to actively improve the delivery of specific ES (e.g., agro-ecological practices and windbreaks)
- Type 3: NBS include intensive ecosystem management, ecosystem restoration and the creation of new ecosystems (e.g., quarry restoration and soil and slope revegetation)

Intended scale of benefits: Finally, the scale of benefits is directly linked to how the NBS delivers ecosystem services, since these are not delivered in the same way and differ in time and space (La Notte et al., 2019). As an example, the *Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects* uses an urban NBS (e.g., bioretention structures) as a reference and illustrates that although the capacity of vegetation on a single bioretention structure to store rainwater can be measured at the fine scale, the benefits of flood risk reduction and reduced run-off can be perceived at the local scale (Raymond et al., 2017).

4.3 Third dimension: Enabling factors for implementing NBS with a Nexus approach

NBS can provide multiple ecosystem services when compared to other alternatives such as grey infrastructure. Still, their planning and execution process can also contribute to solving some of the problems of the WEF Nexus that are not related to the biophysical system (i.e., the socio-political system). This third dimension of the roadmap refers to the enabling factors that must be considered when seeking to implement an NBS that is recognized as such (i.e., that complies with the IUCN Global Standard for NBS) and generates the full range of expected benefits.

The enabling factors were grouped into four categories: 1) economic feasibility and funding, 2) policy and legal viability, 3) governance and cooperation, and 4) trade-offs balance.

Economic feasibility and funding: Considerations about the economic feasibility are recurrent both in the literature on NBS and in that of the WEF Nexus. The report about *the role of Green Infrastructure in Water, Energy and Food Security in Latin America and the Caribbean* says that economic feasibility and project funding are some of the main challenges encountered to address Nexus solutions (Muñoz Castillo & Crisman, 2019). In this regard, criterion 4 of the *Global Standard for Nature-based Solutions* establishes that the return on investment, the efficiency and effectiveness of the intervention, and equity in the distribution of benefits and costs are critical determinants of success for an NBS (IUCN, 2020). The standard proposes four indicators to ensure that sufficient consideration is given to the economic viability of the intervention (Figure 9). Complementary to this, the *Methodology for Assessing the Water-Food-Energy-Ecosystem Nexus in Transboundary Basins* says that the Nexus solutions must have instruments aligned for their execution (UNECE, 2018).

Guidance:	**Indicators**
The return on investment, the efficiency and effectiveness of the intervention, and equity in the distribution of benefits and costs are key determinants of success for an NbS. This Criterion requires that sufficient consideration is given to the economic viability of the intervention, both at the design stage and through monitoring the implementation. For NbS to be sustainable, there must be strong consideration of the economic aspects as, most likely, long-term gains must be balanced against short-term costs, with short-term actions developed within the context of long-term (over generations) goals and plans. If the economic feasibility is not adequately addressed, NbS run the risk of being short-term projects, where, after closing, the solution and benefits provided cease to exist, potentially leaving the landscape and communities worse off than before. Innovative and evidence-based tools for the valuation of nature, along with ideas for NbS contributions to markets and jobs, encourage creative (blended) financing of NbS, thereby increasing the likelihood of their long-term success.	**4.1 The direct and indirect benefits and costs associated with the NbS, who pays and who benefits, are identified and documented** Guidance: Identification and documentation of the main benefits derived, including their direct and indirect, financial and non-financial elements are key components for assessing the economic feasibility of the intervention, over time. This information should be differentiated according to who receives the benefits and who bears the costs.
	4.2 A cost-effectiveness study is provided to support the choice of NbS including the likely impact of any relevant regulations and subsidies Guidance: Investing heavily in upfront costs without considering the longer-term economic and financial sustainability can negatively impact the intervention's viability. A cost-effectiveness study not only enables an examination of the upfront and recurring costs against the anticipated longer-term benefits of the proposed intervention(s) over time but also allows key (or hidden) assumptions to be made explicit, tested and verified.
	4.3 The effectiveness of the NbS design is justified against available alternative solutions, taking into account any associated externalities Guidance: A key attribute of an NbS is that it is capable of addressing at least one societal challenge in a manner that is both economically viable and efficient. This means that the cost-effectiveness and affordability of the solution must be tested against viable alternatives. Alternative solutions may include a different nature-based solution (for example watershed catchment management rather than floodplain management), a different combination of conventional and nature-based solutions, or substitution of the nature-based solution entirely with a more conventional approach such as engineered infrastructure.
	4.4 NbS design considers a portfolio of resourcing options such as market-based, public sector, voluntary commitments and actions to support regulatory compliance Guidance: The fact that NbS simultaneously offers multiple benefits to different stakeholders may place limits on some sources of financing, thereby undermining the interventions long-term viability. For example, private investors may not wish to bear the cost of delivering public goods or public authorities may be reluctant to cover costs for benefits that will accrue privately. This may require a resourcing package that integrates a range of financial mechanisms. Sources of investment can include public-sector grants, incentives and low interest loans, private-sector loans and equity, blended public-private partnerships as well as philanthropic and voluntary contributions or combinations of the above, reflecting an equitable distribution of both the risks and returns.

Figure 9. Four Indicators for assessing that NBS are economically viable. Source: IUCN, 2020

Furthermore, the *Ecoshape consortium* presents guidelines on how to build business cases for NBS, and name it as another enabler for developing Nature-based projects and approaches (Ecoshape, 2020). Trough materials, case studies and lessons learned, the consortium helps the user considering the elements to build and sound business case to support an NBS project cycle.

Policy and legal viability: Another series of recurring considerations when planning actions with a Nexus approach have to do with such activities' policy and legal viability. *The report about the role of Green Infrastructure in Water, Energy and Food Security in Latin America and the Caribbean* also identifies "governments and policy" as one of the main challenges to implement Nexus NBS such as green infrastructure approaches (Muñoz Castillo & Crisman, 2019). *The Methodology for Assessing the Water-Food-Energy-Ecosystem Nexus in Transboundary Basins* says that legal instruments must give rise to the implementation of the Nexus solutions, e.g., the definition of minimum environmental flows for each WEF domain (UNECE, 2018).

In line with this, the *methodological guide for the design of actions with a WEF Nexus approach for Latin America and the Caribbean* recognizes that legal instruments, policies and norms must generate an enabling environment to deploy Nexus solutions. The report proposes that one of the steps when diagnosing the viability of a solution is an analysis of the gaps in regulations, which is related to the incompatibility of policies from different Nexus domains (Naranjo & Willaarts, 2020).

Similarly, the *Ecoshape consortium* defines "Institutional embedding" as one of the six enablers for implementing NBS, stressing key aspects to consider such as *i)* Fitting Building with Nature in the existing context, norms and regulations, *ii)* Creating an enabling policy environment in which conservations laws and formal instruments are addressed and *iii)* Connecting with the international enabling developments, including the Paris Agreement, Sendai Framework, AICHI targets, CBD, Ramsar and UNCCD resolutions and SDGs (Ecoshape, 2020).

Governance and cooperation: The involvement of different institutions and stakeholders is a fundamental aspect when selecting a solution with a Nexus approach. The *Global Standard for Nature-based Solutions*, in its criterion 5, establishes that the selection of an NBS must respond to the concerns of a variety of stakeholders (IUCN, 2020). For this, it proposes five indicators to establish whether the NBS has "Good governance" from its selection process and that all stakeholders are involved in the process, especially the right holders.

Furthermore, the *Methodological Guide for the Design of Actions with a WEF Nexus approach for Latin America and the Caribbean* establishes the need to identify governance capacity and possible coordination gaps that may exist (Naranjo & Willaarts, 2020). Regarding cooperation considerations, the *Methodology for Assessing the Water-Food-Energy-Ecosystem Nexus in Transboundary Basins* considers that cooperation and, when applicable, international coordination is one of the elements that allows creating a Nexus solution. As one of the strategies to increase collaboration, they propose data and knowledge-sharing, as in the cases of development of tools to quantitatively analyse resource flows and impacts and benefits at the basin level (UNECE, 2018).

For cross-border cases, indicator 5.5 of the IUCN *Global Standard* is highly relevant, which establishes that where the scale of the NBS extends beyond jurisdictional boundaries, there should be mechanisms to enable joint decision-making of the stakeholders in the affected jurisdictions (IUCN, 2020).

Trade-off's balance: When decisions are made, trade-offs are inevitable, both in terms of domains and stakeholders, particularly if these decisions are being made from the WEF Nexus perspective (i.e., enhancing functions in one domain often implies diminishing them in another). The *Global Standard* for Nature-based Solutions states that while trade-offs cannot be avoided, they can be effectively and equitably managed. To do so, the standard proposes three indicators to balance the trade-offs when selecting an NBS, based on its primary objective and possible co-benefits. The indicators relate to the necessary agreements between stakeholders on the potential trade-offs. The stakeholders should be informed about the costs and benefits of the trade-off and its implications on the rights of access and use of land and resources (IUCN, 2020).

5 Conclusion and next steps

This document condenses the efforts of task 5.2 "Identifying the potential of EbA" of the Rexus project within work package 5 "Incorporating Nature-based approaches into Nexus solutions". The report presents a roadmap for navigating the landscape of NBS catalogues with a nexus approach and provides a list of 51 solutions that Rexus pilots and other users can select to address challenges related to the WEF Nexus.

This roadmap was developed by starting from an exercise to identify the most critical challenges reported by the five pilot areas of the Rexus project and a literature review on WEF Nexus solutions and Nature-based Solutions catalogues. The roadmap is structured in 3 dimensions that group the most important types of considerations to make when a user wants to start identifying an NBS with a Nexus approach.

The first dimension of the roadmap brings together the considerations of the *Ecosystem services component of the WEF Nexus challenges*, providing reflections and sources of interest in aspects such as identifying the Nexus challenges and their link with different ecosystem services that must be increased to help address these challenges. The second dimension includes considerations on the *scale of application and degree of intervention of the NBS*, mentioning aspects such as the jurisdictional capacity of the user, the geographical scale of implementation, and the intended degree of intervention within the landscape. The third dimension contains reflections on the *enabling factors for implementing NBS with a Nexus approach*, considering aspects such as economic feasibility and funding, policy and legal viability, governance and cooperation, and the process of balancing trade-offs. These considerations seek to provide users with initial theoretical elements to start their identification and planning process to implement an NBS with a Nexus approach.

Task 5.3, "Assembling evidence-based methodologies and framework," and 5.4, "Rexus NBS selection framework," will develop the methodological approaches to guide the user through an NBS selection framework with evaluation indicators. Hence, based on the initial theoretical elements proposed in this report, these upcoming tasks will create a framework to identify suits of NBS that could also combine with "grey infrastructure" in a practical manner. The framework will also provide indicators to assess and measure the solution's performance from technical and socio-economic aspects, to generate evidence about their positive impacts, and continue to mainstream the Nexus doing process.

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7 Annex 1: Catalogue of NBS with a Nexus approach

Ecosystem services' legend:

Food provision = FP

Water provision = WP

E = Energy

WWT = Water purification and waste treatment

RWF = Regulation of water flows

ERP = Erosion prevention

BC = Biological control

CR = Climate regulation

LM = Lifecycle maintenance

RM = Raw materials

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
1	Grazing exclosure and plantation to improve soil quality and prevent losses in food production	Setting aside pieces of degraded land to natural regeneration or forest planting to lessen soil degradation and enhance biodiversity	Type 1 – Better use of protected/ natural ecosystem	Local scale	(-)					(+)		(+)	(+)		Nature-Based Solutions evidence platform. University of Oxford https://www.naturebasedsolutionsevidence.info/evidence-tool/	
2	Limit or prevent specific uses and practices	This option consists of regulating and limiting different practices and land uses to protect given species or ecological functions in a determined area.	Type 1 – Better use of protected/ natural ecosystem	Regional scale								(+)	(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
3	Maintain and enhance natural wetlands	Existing, relatively intact ecosystems are the keystone for conserving biodiversity and securing different services provided by wetland ecosystems. Restoration is a complementary activity that, when combined with protection, can help achieve overall improvements in a greater percentage of a territory's waters bodies and their multiple functions	Type 1 – Better use of protected/ natural ecosystem	Regional scale		(+)		(+)	(+)		(+)	(+)	(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Principles of Wetland Restoration. Environmental Protection Agency. https://www.epa.gov/wetlands/principles-wetland-restoration#addressongoingcauses
4	Maintenance of forest cover in headwater areas	Forests in headwater areas have a beneficial role in water quantity and quality. Creating or maintaining forest cover in headwater catchments is widely used to increase soil infiltration capacity while providing other co-benefits such as slope stabilization. At the beginning of the tree's life span, the water yield might be reduced.	Type 1 – Better use of protected/ natural ecosystem	Regional scale		(+)		(+)	(+)	(+)		(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
5	Natural Protected Area network structure	A protected area is a clearly defined geographical space, recognised, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values	Type 1 – Better use of protected/ natural ecosystem	Regional scale	(-)	(+)			(+)	(+)	(+)	(+)	(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	https://www.iucn.org/theme/protected-areas/about
6	Protect forests from clearing, degradation, logging, fire and unsustainable levels of non-timber resource extraction	This activity comprises the range of legal, governance, and social instruments to ensure that forests are not harvested at levels higher than their increment rate, leading to forest clearance.	Type 1 – Better use of protected/ natural ecosystem	Regional scale	(-)	(+)			(+)	(+)		(+)	(+)	(+)	Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	
7	Agro-ecological practices	This term often refers to agricultural practices aiming to produce significant amounts of food, which valorise in the best way ecological processes and ecosystem services, integrating them as fundamental elements in the development of the practices (e.g., cover crops, green manure, intercropping, agroforestry, biological	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale	(+)		(+)			(+)	(+)		(+)	(+)	Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Wezel, A., Casagrande, M., Celette, F., Vian, J. F., Ferrer, A., & Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. Agronomy for sustainable

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
		control, biodiversity conservation practices).														development, 34(1), 1-20.
8	Biological soil crusts (biocrusts) to reduce soil erosion and improve water availability	Using mosses and lichens to improve soil structure, water holding capacity and runoff retention	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale		(+)			(+)	(+)			(+)		Nature-Based Solutions evidence platform. University of Oxford https://www.naturebasedsolutionsevidence.info/evidence-tool/	
9	Buffer strips for water infiltration and slowing surface flow	Establishment of strips of native vegetation (bushes or trees) at the margin of fields, arable land, roads and water courses. These buffer strips offer good conditions for effective water infiltration and slowing surface flow and reduction of the amount of suspended solids from agricultural runoff	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale		(+)		(+)	(+)	(+)		(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
10	Continuous cover forestry to reduce sediment production	Continuous cover forestry is a broad range of forest management practices, whose rationale lies in a reduction in the number or size of clear-cuts, to ensure that there is an uninterrupted tree canopy and that the soil surface in never exposed	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale		(+)			(+)	(+)		(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
11	Crop rotation to increase infiltration capacity	Growing a series of dissimilar types of crops in a same area in sequential seasons. This activity can improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants and at the same time reduce erosion and increase infiltration capacity. This could translate in a reduction of downstream flood risks while enhancing soil structure	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale	(+)	(+)	(+)		(+)	(+)				(+)	53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
12	Diverting and deflecting elements	Disruptive and diverting elements such as single rocks and tree trunks are placed in the riverbed with the primary objectives of redirecting and deflecting the current and initiate water dynamics. The elements can be placed near the riverbank or in the middle of a river, depending on the desired effect (e.g., deflecting and redirecting the current, one-sided riverbank erosion, sediment accumulation)	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale			(-)		(+)	(+)			(+)		Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	
13	Enrichment planting in degraded and regenerating forests	Introducing valuable native species to degraded forests without the elimination of the existing forest cover, including valuable individuals which already existed at that particular site, with the main objective of enhancing biodiversity and the multiple benefits of trees	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale							(+)		(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Mangueira, J. R. S., D. Holl, K., & Rodrigues, R. R. (2019). Enrichment planting to restore degraded tropical forest fragments in Brazil. Ecosystems and People, 15(1), 3-10.
14	Forest landscape restoration as a priority policy	Forest Landscape management tools such as agroforestry, silviculture, natural forest restoration and protective riparian forest for improving livelihoods and hydropower capacity	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Regional scale	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	Nature-based Solutions to address global societal challenges https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf	
15	Integrate biochar into agricultural soils	This activity consists of applying Biochar as a soil amendment due to its attractive properties (e.g., high carbon content, high pH, high stability, and high porosity). Biochar can be defined as the solid product of the thermochemical decomposition of biomass such as wood, corn husks, poultry manure at high temperatures under oxygen-limiting conditions	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale	(+)								(+)	(+)	Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Brassard, P., Godbout, S., Lévesque, V., Palacios, J. H., Raghavan, V., Ahmed, A., ... & Verma, M. (2019). Biochar for soil amendment. In Char and Carbon Materials Derived from Biomass (pp. 109-146).
16	Intercropping for increased yield in food production	The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. Among the different types of intercropping are mixed intercropping, row cropping, relay cropping, and others.	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale	(+)						(+)				53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
17	Living fascine	Bundled tree branches and twigs used for water bank protection and (strongly inclined) hillside stabilization	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale						(+)					Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	
18	Living revetment	Trees, shrubs, and grasses planted along the riverside to stabilize the riverbank, helping erosion control and slowdown water velocity	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale			(-)		(+)	(+)		(+)	(+)		Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	
19	Mounds	Higher ground (natural or manmade hills) above the water level during flood events. They can be refuge for farm animals (cows, horses) and wild animals, contributing to habitat conservation	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale	(+)				(+)				(+)		Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	
20	Mulching to conserve moisture and improve soil fertility	Mulching consists of using organic material (e.g., bark, wood chips, grape pulp, shell nuts, green waste, leftover crops, compost, manure, straw, dry grass, leaves etc.) to cover the surface of the soil. It may be applied to bare soil or around existing plants. When used correctly, this process can dramatically improve the capacity of soil to store water.	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale	(+)	(+)			(+)	(+)					53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
21	Multipurpose lake restoration	Restoring lakes consists in enhancing their structure and functioning where they have been drained in former times. Among the multiple benefits of lake restoration are flood control and water storage for irrigation, fisheries, tourism; carbon sequestration and storage; habitat provision, and others.	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale	(+)	(+)			(+)			(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
22	Planted embankment mat	Combination of mats with vegetation layers alongside rivers/channels that slow down water velocity and promote sedimentation	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale					(+)	(+)			(+)		Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	
23	Replenishing groundwater through reforestation	Increase of the forest area of a water catchment to mid-term gains in groundwater and water supply. The activities include reforestation of native species and establishment of pits and earthen dams to retain water while the trees grow.	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Local scale		(+)		(+)	(+)	(+)		(+)	(+)		Nature-Based Solutions for agricultural water management and food security http://www.fao.org/3/ca2525en/ca2525en.pdf	
24	Strip cropping along contours to stop soil erosion	This method alternates strips of closely sown crops (e.g., hay, wheat) with strips of row crops (e.g., corn, soybeans, cotton) to help stop soil erosion by creating natural dams for water.	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale					(+)	(+)					53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
25	Terraces for runoff and erosion control	Adoption of soft structures (traditional types of terraces) to limit runoff and combat soil erosion while increasing soil moisture and productivity	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale	(+)				(+)	(+)					Nature-Based Solutions for agricultural water management and food security http://www.fao.org/3/ca2525en/ca2525en.pdf	

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
26	Transferring rights for traditional land management practices	Bringing back sustainable land management practices such as traditional nomadic grazing systems, through transfer of land management rights to local communities	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Regional scale	(+)	(+)				(+)					Nature-based Solutions to address global societal challenges https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf	
27	Windbreaks	Windbreaks are linear plantings of trees and shrubs designed to provide economic and environmental benefits such as creating a more beneficial condition for soils, crops, livestock, wildlife, and people. Non-wind-related benefits of windbreaks include shade for livestock, visual screening, aesthetics, recreational opportunities, and wood and non-timber forest products.	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Fine scale	(+)	(+)			(+)	(+)		(+)	(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Windbreaks. USDA. source: https://www.fs.usda.gov/nac/practices/windbreaks.php
28	Afforestation of reservoir catchments to control soil erosion	This activity can help control erosion, improve soil structure, and therefore water availability and quality. On the other hand, it can occur than less precipitation will be available for reservoir recharge due to the potentially greater interception and evapotranspiration associated with forests. Forest in reservoir catchments should not be managed for timber production, nor fertilizers should be use, due to potential negative impacts on the reservoir water quality.	Type 3 – Design and management of new ecosystems	Local scale		(+)		(+)	(+)	(+)		(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
29	Constructed urban wetlands	Artificial wetlands engineered to naturally treat wastewater and stormwater runoff in urban areas.	Type 3 – Design and management of new ecosystems	Fine scale		(+)		(+)	(+)			(+)	(+)		Addressing climate change in cities - Catalogue of urban nature-based solutions. https://sendzimir.org.pl/wp-content/uploads/2020/02/ClimateNBS_catalogue_web.pdf	

#	NBS	Short description	Degree of intervention	Geographical scale	Ecosystem services										Catalogue	Other sources
					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
30	Dune replenishment	Dune rehabilitation practices refer to restoring dunes from an impaired to a less impaired or unimpaired state of overall function to gain the most significant coastal protection benefits. Among the different ways to stabilize the dune, there are building fences to trap the sand or plant vegetation that helps stabilize sediments.	Type 3 – Design and management of new ecosystems	Fine scale					(+)	(+)			(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Dune strengthening, rehabilitation and restoration. Source: https://coastal-management.eu/measure/dune-strengthening-rehabilitation-and-restoration
31	Elimination of riverbank protection to enhance lateral connections of the river	This activity is a prerequisite for implementing other solutions such as re-meandering and floodplain restoration, whose main objective is to enhance the lateral connections of the river.	Type 3 – Design and management of new ecosystems	Local scale			(-)		(+)	(+)			(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
32	Floodplain restoration and management	Floodplain restoration comprises a series of activities that can be applied at different scales, ranging from afforestation to the modification of the main channel. The main objective of these solutions is to reconnect the floodplain to the main waterway, to reduce and mitigate the risks of flooding. However, restoring floodplains can bring various co-benefits, such as habit restoration.	Type 3 – Design and management of new ecosystems	Regional scale		(+)			(+)			(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
33	Managed realignment to prevent coastal erosion	Creating an intertidal area to address flood risk and enhance habitat. By setting back sea defences and allowing controlled inundation, the coastline is placed backward, giving space to new intertidal area. The area is surrounded by a secondary dike that protects the inner land.	Type 3 – Design and management of new ecosystems	Local scale Regional scale					(+)	(+)		(+)	(+)		Nature-based Solutions to address global societal challenges https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf	
34	Meadows and pastures for flood storage, increased water retention in the landscape and runoff attenuation	Replacement of some areas of arable land for establishing rooted vegetation such as pastures and meadows. These areas can provide good conditions for the uptake and storage of water during temporary floods	Type 3 – Design and management of new ecosystems	Fine scale	(-)	(+)		(+)	(+)	(+)		(+)	(+)	(-)	53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	

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35	Quarry restoration	This activity refers to the practices of recovery, rehabilitation, and restoration of ecosystem services (e.g., provision of habitat, water regulation, biodiversity) of quarries after extracting minerals.	Type 3 – Design and management of new ecosystems	Fine scale					(+)			(+)	(+)	(-)	Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	King, H. (2013). Introducing an ecosystem services approach to quarry restoration.
36	Reconnection of oxbow lakes and similar features for flood control	Reconnecting an oxbow lake or ancient meander with the river is a solution to improve water retention during floods. It consists in removing terrestrial lands between both water bodies (i.e., the river and the old meander), favouring the lateral connectivity and diversification of flows.	Type 3 – Design and management of new ecosystems	Fine scale					(+)	(+)			(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
37	Regeneration of urban green belts	Process of redesigning and redeveloping aged, natural areas within and around cities that have become less effective in fulfilling their functions.	Type 3 – Design and management of new ecosystems	Local scale					(+)			(+)	(+)		Addressing climate change in cities - Catalogue of urban nature-based solutions. https://sendzimir.org.pl/wp-content/uploads/2020/02/ClimateNBS_catalogue_web.pdf	
38	Re-meandering to control the river flow and increase sedimentation	River re-meandering consists in creating a new meandering course or reconnecting cut-off meanders, therefore slowing down the river flow	Type 3 – Design and management of new ecosystems	Local scale			(-)		(+)	(+)			(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
39	Restoration and reconnection of seasonal streams for flood control and irrigation	Restoring and reconnecting seasonal streams with the river consists of favouring the river's overall functioning by restoring lateral connectivity and diversifying flows to these seasonal streams for better water retention during floods.	Type 3 – Design and management of new ecosystems	Local scale	(+)	(+)			(+)	(+)			(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
40	Restoration of abandoned aquaculture ponds	Restore micro-topography, creek networks, sediment inputs, and nutrient exchange in abandoned aquaculture ponds.	Type 3 – Design and management of new ecosystems	Fine scale		(+)		(+)					(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	

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41	Restoration of natural infiltration to Groundwater	This solution enables a lower run-off from surrounding land and enhances the condition of groundwater aquifers and water availability. The options promoting natural infiltration to groundwater include surface (e.g., soakaways) and subsurface structures (e.g., wells) to facilitate aquifer recharge.	Type 3 – Design and management of new ecosystems	Local scale		(+)			(+)	(+)					53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
42	Restoration of river natural flows to reduce flood risk	Restoring the river flow by removing all the artificial obstacles such as concrete dams, lowering the riverbanks, restoring the longitudinal profile of the river and revegetating the riparian area	Type 3 – Design and management of new ecosystems	Local scale			(-)		(+)				(+)		Nature-based Solutions to address global societal challenges https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf	
43	River bed re-naturalization	Removing some concrete or inert constructions in the riverbed and on riverbanks, then replacing them with vegetation structures, to increase the flow's travel time and restore biodiversity	Type 3 – Design and management of new ecosystems	Local scale			(-)		(+)	(+)			(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
44	River daylighting	Opening of covered/buried watercourses (rivers, drainage systems) by removing concrete layers, resulting in increased storage capacity of the channel, flood risk reduction, recreational values, habitat creation, etc.	Type 3 – Design and management of new ecosystems	Local scale					(+)				(+)		Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	
45	River space extension	These solutions comprise several activities such as the expansion of the flood plain area by excavating the lateral riverbed, dividing the discharge into branches, and widening the channel cross-section	Type 3 – Design and management of new ecosystems	Local scale	(+)				(+)	(-)			(+)		Unalab Nature-Based Solutions - Technical Handbook https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf	

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46	Soil and slope revegetation	Stabilizing exposed soils on slopes through revegetation to minimize or prevent the erosion of soil by wind or rain and sedimentation problems. Vegetation protects soil surfaces from rain generated splash erosion and can help slow runoff flows across a site of ground disturbance.	Type 3 – Design and management of new ecosystems	Local scale					(+)	(+)			(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	General description and characterization of the NBS entity. Soil and revegetation sheet. Centre de ressources pour l'adaptation au changement climatique
47	Sustainable urban drainage systems (SUDS)	Mix of green and grey infrastructure, which together support urban areas in coping with severe rainfall. They manage surface water and encourage maintenance of water quality, soil infiltration and groundwater recharge	Type 3 – Design and management of new ecosystems	Fine scale		(+)		(+)	(+)						Addressing climate change in cities - Catalogue of urban nature-based solutions. https://sendzimir.org.pl/wp-content/uploads/2020/02/ClimateNBS_catalogue_web.pdf	
48	Target ponds/wetland creation to trap sediment/pollution runoff in farmed landscape	Constructed field wetlands are an edge-of-field option for reducing the landscape's loss of sediment and nutrients and for diffuse pollution mitigation. Their design and depth can vary (i.e., shallow, or deep), but they are usually unlined ponds excavated along runoff pathways or in naturally wet hillslope hollows.	Type 3 – Design and management of new ecosystems	Fine scale				(+)	(+)		(+)		(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Ockenden, M. C., Deasy, C., Quinton, J. N., Surridge, B., & Stoate, C. (2014). Keeping agricultural soil out of rivers: evidence of sediment and nutrient accumulation within field wetlands in the UK. Journal of Environmental Management, 135, 54-62.
49	Targeted planting for "catching" precipitation	Land use change and associated deforestation at a large scale may lead to significant weather and rainfall patterns. Targeted afforestation has been implemented in some parts of the Mediterranean as a means of combating drought and desertification.	Type 3 – Design and management of new ecosystems	Fine scale Local scale Regional scale		(+)		(+)	(+)	(+)		(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	
50	Use engineered reedbeds/wetlands for tertiary treatment of effluents	Reedbed and constructed wetlands are a solution for the wastewater treatment, which recreates the removal processes developed in natural wetlands, exploiting	Type 3 – Design and management of new ecosystems	Local scale				(+)	(+)		(+)		(+)		Think Nature. Nature-based solutions handbook https://platform.think-nature.eu/	Constructed Wetlands. IRIDRA. http://www.iridra.eu/en/fitodepurazione-en.html

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					FP	WP	E	WWT	RWF	ERP	BC	CR	LM	RM		
		complex biochemical, physical, and physiological removal processes.														
51	Wetland restoration and management to improve the hydrological regime and enhance habitat quality	Wetland restoration and management can involve technical, spatially large-scale measures (e.g., the installation of ditches for rewetting), technical small- scale activities such as clearing trees and changes in land-use and agricultural actions, such as adapting cultivation practices in wetland areas	Type 3 – Design and management of new ecosystems	Regional scale		(+)		(+)	(+)		(+)	(+)	(+)		53 Natural Water Retention Measures illustrated http://nwrm.eu/measures-catalogue	