the LENSES project

LEarning and action alliances for NexuS EnvironmentS in an uncertain future

LENSES

WP6

D6.1 Socio-economic indicators and framework for Nexus-relevant NBS

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Project Website

This project is part of the PRIMA programme supported by the European Union.
GA n° [2041] [LENSES] [Call 2020 Section 1 Nexus IA]

Project no.	2041
Project acronym:	LENSES
Project title:	Learning and action alliances for NEXUS environments in an uncertain future
Call:	PRIMA call Section 1 – Nexus 2020, Topic 1.4.1-2020 (IA).
Start date of project:	01.05.2021
Duration:	36 months
Deliverable title:	D6.1–Socio-economic indicators and framework for nexus-relevant NBS
Due date of deliverable:	November 2022
Project Coordinator:	Stefano Fabiani, Council for Agricultural Research and Economics (CREA)

Organisation name of lead contractor for this deliverable: University of Padova (UNIPD)

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Contributions from	
Internal Reviewer 1	
Internal Reviewer 2	

Dissemination level		
PU	**Public**	**PU**
CO	**Confidential, restricted under conditions set out in Model Grant Agreement**	
CI	**Classified, information as referred to in Commission Decision 2001/844/EC**	

History

Version	Date	Reason	Revised by
01	25/11/22	Internal review	Linda Barci, Juan Diego Restrepo (Etifor)
02	25/11/22	Internal review	Christina Papadaskalopoulou (DRAXIS)

Executive summary

The use of water resources has become an important and relevant issue and it is increasingly clear that water management must be addressed with an integrative perspective, interlinking the objectives and needs of multiple sectors. This is at the basis of the water-energy-food-ecosystem (WEFE) nexus approach. The WEFE nexus approach considers the WEFE elements as interdependent and aims to maximise synergies while reducing trade-offs and conflicts that may occur among them.

A plethora of emergent solutions are increasingly being considered within the WEFE nexus management. They fall under the umbrella term of Nature-Based Solutions (NBS). NBS are based on and inspired by nature. They are designed to address societal and environmental challenges and are capable to provide social, economic, and environmental benefits.
The aim of this deliverable is to develop and provide indicators to assess the socio-economic benefits associated with NBS implementation to face WEFE nexus-related challenges vis-à-vis associated costs.

Guidelines have been developed to support decision makers that will select NBS to face WEFE-related challenges. In particular, the guidelines are designed to support evaluating NBS capacity to provide benefits – in terms of ecosystem services - while also considering their implementation and management costs. An illustrative example of the guidelines' implementation is presented.

This document has been developed within the framework of the EU PRIMA Lenses project (LEarning and action alliances for NexuS EnvironmentS in an uncertain future). The project aims to support and operationalise the nexus paradigm contributing to improve water allocation, enhance food security while preserving ecosystems and aiding climate change adaptation. More specifically, the report has been developed under Work Package 6: "Environmental and natural resource economics approaches for nexus business cases" and task 6.1: "Socio-economic analysis of NBS".

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Acronyms used along the text

BAU	Business As Usual
B/C	Benefits costs ratio
EbA	Ecosystem-based approaches
EC	European Commission
ES	Ecosystem service
CBA	Cost-Benefit Analysis
IRR	Internal Rate of Return
NBS	Nature-Based Solutions
NPV	Net Present Value
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
WEFE	water-energy-food-ecosystem

1. INTRODUCTION

The management of water resources has become a critically pivotal issue in the past decades due to challenges posed by ongoing global changes such as climate change and the increasing social pressure on water resources due to the growing population, urbanisation, globalisation, and economic growth (Zhang *et al.*, 2019). It is widely acknowledged that water management needs to integrate the needs of different sectors looking at water as a primary resource. For instance, water is essential for food production via irrigation, but it is also an important resource for energy production that, on the other hand, also serves farming operations. At the same time, it is fundamental to keep water use within the boundaries of ecological sustainability, to ensure water availability for the survival of the ecosystems as well as benefits to downstream users. Given the complexity of this nexus, competitive uses pose challenges and, if not properly managed, may also lead to conflicts.

For the above-reported reasons, a holistic and interdependent approach to water resource management is needed (Pahl-Wostl, 2007). This is also the rational through which the water-energy-food-ecosystem (WEFE) nexus conceptualisation has been launched in 2011 during the Bonn 2011 Nexus Conference (Hoff, 2011). Since then, the WEFE nexus concept has expanded in literature and its components are commonly recognised as interdependent, thus requiring coordinated management strategies and actions (Albrecht *et al.*, 2018). The nexus thinking approach, considering how water, food, energy, and environment interact and are interlinked, aims to maximise the synergies among them and to reduce the trade-offs and the conflicts that can occur, ultimately internalising social and environmental externalities associated to water resource use (Kurian, 2017). In doing so, it aims to integrate the different management practices enhancing water, energy, food security and environmental conservation (Scott *et al.*, 2016).

In this context, ecosystem and ecosystem-based approaches (EbA) have been pointed as relevant solutions to face WEFE nexus challenges. EbA may include sustainable management, restoration, or conservation of ecosystems considering their multiple co-benefits. Although multiple definitions have been coined for ecosystem-based approaches (e.g., CBD, 2010; EC, 2014; UNDRR, 2015; Seddon *et al.*, 2020), their common understanding is linked to the capability of nature to make ecosystems more resilient. Furthermore, these approaches are seen as solutions to help address the societal challenges linked to the Sustainable Development Goals (SDG) (EEA, 2021). Among the different concepts and terms used with reference to ecosystem-based approaches, Nature-Based Solutions (NBS) have been defined by the European Commission (EC) as "*living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to simultaneously provide economic, social, and environmental benefits*" (EC, 2015).

Within the NBS conceptualisation, society is not seen as a passive beneficiary of the nature's benefits, rather people are considered active players whose actions, addressed to protect and manage ecosystems, support, and improve the provision of environmental benefits (Cohen-Shacham *et al.*, 2016). In the last years, NBS found a privileged place within the EC strategies to reduce disaster risks and support adaptation to climate changes, on the one side, and to deliver multiple benefits, from the other (EEA, 2021). Indeed, the ecosystem approach implied by the NBS recognises that healthy and well managed ecosystems provide a range of goods and services that are beneficial to humans, and, at the same time, reduce ecosystems vulnerability. Services provided by ecosystems and NBS, ensuring benefits to humans are referred to as ecosystem services (ES) (MEA, 2005).

The social and economic benefits are inherent to the concept of ES (see TEEB, 2010; Maes *et al.*, 2012) and they are relevant also within the WEFE nexus understanding. In addition to the understanding of the interlinkage among physical resources that was the initial scope of the nexus thinking (Webber, 2016), a development of the research in this field pointed out as relevant the incorporation of the social, economic, environmental, and political dimensions into the nexus analysis (Lawford *et al.*, 2013). Indeed, the management of water, energy, food, and environmental resources affect the socio-economic benefits they are capable to provide (Scott *et al.*, 2015) and vice versa.

The aim of this deliverable is to "*develop criteria to allow the pilots to assess the socio-economic benefits, costs, and risks associated with specific nexus-relevant NBS and integrated solutions*" (LENSES, 2021). To achieve this, an ES-based approach has been adopted by developing ES-based indicators to evaluate socio-economic benefits of NBS. In fact, the term ES, encapsulates the interdependency between ecological and socio-economic systems. The logic behind this concept is that people can experience different benefits from the ecosystems, attributing to their different physical functions different values, and that the flows of ES are not independent from each other, but they are interconnected in different ways, either positive (synergies) or negative (trade-offs). (Martín-López *et al.*, 2014).

ES assessment will provide information about the social benefits, co-benefits and trade-offs associated to NBS in facing WEFE nexus-related challenges and their economic value. Indeed, ES supply results from a combination of natural and social conditions and its valuation requires to consider human dimensions in terms of choices and appreciation (Spangenberg *et al.*, 2014).

In Section 2 the ES approach adopted is deepened in presenting the guidelines to assess socio-economic costs and benefits of NBS. Through the assessment of ES and the implementation of the Cost-Benefit Analysis (CBA), that delivers investment profitability, efficiency and risk indicators, the guidelines will support decision-makers in selecting a set of NBS capable to face the WEFE nexus-related challenges, comparing alternative solutions from a socio-economic perspective. Section 3 describes an illustrative example of the guidelines' application.

In this deliverable we do not describe in detail the theoretical foundations of the existing ES framework or indicators to evaluate their supply, demand, and economic value as these have already been addressed by a large body of literature. We advise to refer to the report developed within the framework of H2020 REXUS project (see: Righetti *et al.*, 2022).

2. GUIDELINES TO EVALUATE NBS SOCIO-ECONOMIC BENEFITS AND COSTS

This chapter presents the guidelines to support decision-makers while assessing the socio-economic benefits and costs of NBS. This is ultimately aimed to the identification of the set of NBS that can best address the specific WEFE nexus-related challenges within a certain area. In Figure 1 the different phases of the guidelines have been synthesised and they will be deepened in sub-sessions 2.1 and 2.2. After an analysis of the WEFE nexus-related challenges faced in the area under analysis, challenges are linked with the ES. This allows to identify some NBS capable to support the provision of those ES. Having identified ES will allow to evaluate their supply and economic value (benefits) under the current scenario and after the implementation of the NBS. Computing also the costs of NBS implementation and maintenance allows to implement a CBA to compare different NBS and understand which could be the most financially sustainable.

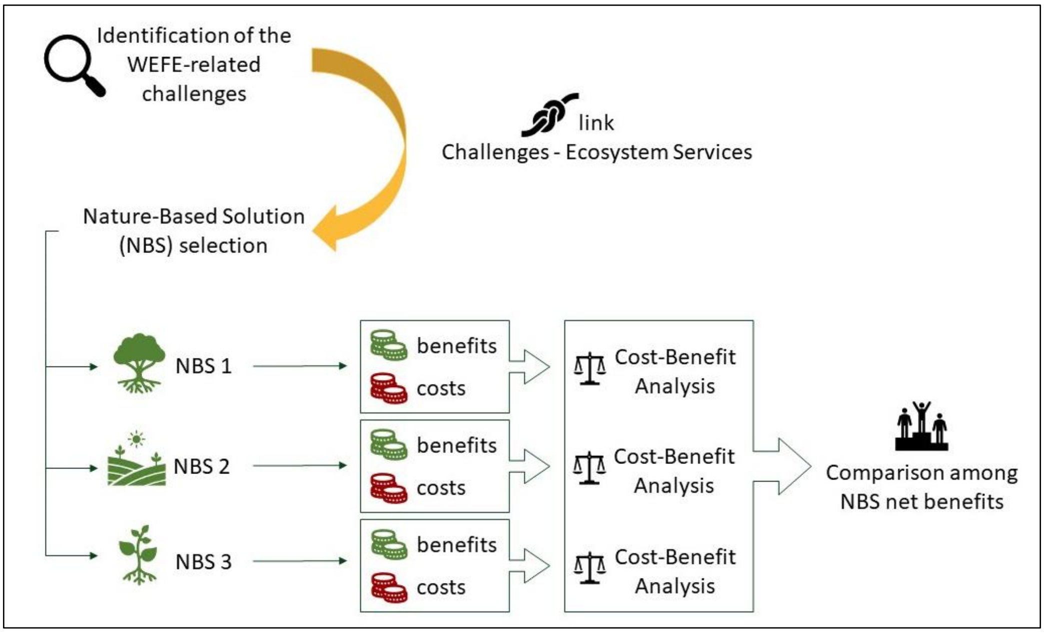

Figure 1. Guidelines to assess socio-economic benefits and costs of NBS

2.1 Linking WEFE nexus-related challenges and ecosystem services

As a first step, it is important to point out which are the WEFE nexus-related challenges that the area under consideration is facing. An overview of the challenges allows to consider those NBS that could be capable to face them. Indeed, to facilitate NBS selection, the WEFE nexus-related challenges are linked to those ES whose provision or enhancement could support to meet them.

To this aim, it is fundamental to involve stakeholders to gather all the possible challenges and conflicts that could occur or that are already in place for the competitive use of water and the other resources in the targeted area (e.g., Haie, 2015; Howarth and Monasterolo, 2016; de Strasser *et al.*, 2016; Wolfe *et al.*, 2016). The identification of all the possible challenges will allow to gain a better understanding of the complexity of the system being analysed and at the same time it is a prerequisite for the identification of strategies and actions/solutions to cope with them. The link between the challenges and the ES allows to highlight challenge connections with the biological domain, thus supporting the identification of the NBS that are more suitable to the challenges.

Some questions that can help to identify the link between WEFE nexus challenges and ES are:
- Which ES can support addressing the challenges under consideration?
- Does a higher provision of a certain ES decrease the severity of the challenges faced?

For the aim of this deliverable, a list of ES has been developed (Table 1) building on the existing international ES classification systems (MEA, 2005; TEEB, 2010; Díaz, 2018 (IPBES); Haines-Young and Potschin, 2018 (CICES). The list of selected ES has been developed according to the components of the WEFE nexus (i.e., W=water; En=energy; F=food; E=ecosystem) and considering the possible challenges (C=challenge) that decision-makers can face in dealing with WEFE nexus management. As for challenges, reference has been made to those identified by the LENSES pilots.

Table 1*: Ecosystem services considered in relation to WEFE nexus-related challenges*

Ecosystem Service	Description	WEFE nexus components*
Water provision	Surface and groundwater used, for instance, for drinking, irrigation, cooling, energy purposes	W
Food provision	Food products derived from plants, animals, other living organisms. Either cultivated or wild. Used for nutritional purposes (for humans or cattle)	F
Energy provision	Biological material used as energy sources. They can be cultivated or wild plants, animals (also for mechanical exploitation), surface or ground water, or mineral substances	En
Materials Resources	Fibers and other materials but also ornamental materials	C
Genetic Resources	Gene and genetics information present in all biota (e.g. seeds, spores, and other materials)	C
Regulation of water flows	Capability of ecosystems to regulate run-off, flooding, and aquifer recharge	W
Climate regulation	Capability of ecosystems to regulate climate locally and globally (e.g. chemical composition of atmosphere, vegetation influence on rainfall, albedo, evapotranspiration)	E
Water purification	Capability of ecosystems to filter out and decompose toxic organic and anthropogenic substances	W
Moderation of extreme events (flood protection)	Capability of ecosystems to moderate and regulate natural hazards	E
Erosion prevention	Capability of ecosystems to prevent and moderate soil erosion	E
Biological control	Capability of ecosystems to regulate the spread and the impacts of humans, crops, and livestock pests and disease	E
Lifecycle maintenance	Capability of ecosystems to preserve the optimum status of the ecosystem itself, guaranteeing the biogeochemical cycles, and the quality of the habitats preserving biodiversity	E
Opportunities for recreation and tourism	Characteristic of ecosystems that allow people to spent leisure time enabling activities to enjoy them (non-material benefits people obtain from the ecosystem)	C

* W = water; En = energy; F = food; E = ecosystem; C = challenge

Linking ES to relevant WEFE nexus-related challenges, however, may not be enough to identify specific and effective solutions. Indeed, addressing some challenges, might require strategies that go beyond ES. Therefore, besides “ES-related strategies”, namely those strategies that envisage the implementation of solutions that are addressed to implement or enhance the identified ES, “non-ES strategies” might also be necessary. Non-ES strategies consist of policy, governance, management, consumption choice or organisational approaches (e.g. associations, communities, energy district) that could contribute to WEFE nexus management. The inclusion of “non-ES strategies” is of paramount importance to identify a full range of actions and dimensions that need to be considered in facing pilots’ challenges. The identification of “ES-related strategies” and/or “non-ES strategies” has been performed for all the pilots of the LENSES project. The results are illustrated in Table 4-10, in Section 3.1.

Within the LENSES project, links with ES concept have been already considered by Deliverable 5.2 (Nikolaidis and Lilli, 2022), where, to help the process of NBS selection, ES have been linked with the NBS capable to provide them. ES adopted for the aims of Deliverable 5.2 however are slightly different from those considered by this report (Table 2).

Table 2: ES used for Deliverable 5.2 and for Deliverable 6.1

Ecosystem Services in Nikolaidis and Lilli (2022)	Ecosystem Services in the current deliverable
Water	Water provision
Food, crops, wild foods, and spices	Food provision
Energy	Energy provision
-	Materials Resources
-	Genetic Resources
-	Regulation of water flows
Carbon sequestration and climate regulation	Climate regulation
Water purification	Water purification
Flood protection	Moderation of extreme events (flood protection)
Erosion prevention	Erosion prevention
Pest and disease control	Biological control
Maintaining populations and habitats	Lifecycle maintenance
Soil formation and composting	
Recreation	Opportunities for recreation and tourism

Aligning ES-related terms and concepts used in the two deliverables is necessary to allow linking challenges to the relevant NBS. The full process adopted to bridge challenges and NBS via ES is outlined in Figure 2.

Figure 2. Pathway from challenges to Nature-based solutions

At first, the link between challenges and ES was established along with the link between NBS and the ES they provide and support. By using ES as a common element, it is possible to identify which NBS may be suitable to face the challenges of the area under analysis.

The selection and definition of ES is also meaningful for the assessment of NBS benefits because these are defined in terms of economic value of ES using selected indicators. The following section (Section 2.2) deepens this aspect and further explores the socio-economic dimensions of NBS to facilitate their selection.

2.2 Socio-economic indicators to assess NBS benefits and costs

A methodology to support decision makers in assessing different NBS from a social and economic perspective is proposed starting from Ghafourian *et al.* (2021) who reviewed different methodologies to economically assess NBS, concluding that Cost-Benefit Analysis (CBA) is the most widely adopted one. CBA allows to economically and socially assess NBS (Dicks *et al.*, 2020). It also permits to have a more comprehensive picture of NBS because it considers both benefits and costs of the solutions implemented as well as their trade-offs. Through CBA it is possible to identify if a project is more financially sustainable, in relation to other alternatives. The outcomes of a CBA, jointly with the technical effectiveness implementation module developed in the Deliverable 5.3 (Chatzitheodorou and Ntzioni, 2022), can thus support the decision-making process in NBS selection.

To implement a CBA, it is necessary to estimate the costs and the benefits associated to an NBS. Before deepening cost and benefit assessment (sub-section 2.2.2 and 2.2.3) the rationale behind the use of ES as benefit proxy is described.

2.2.1 ES and benefits from NBS

ES and their economic value have been used as means to valuate NBS benefits. In fact, they have a preferential role in interlinking ecosystems structures and processes to human wellbeing (Martín-López *et al.*, 2014) and a vast body of literature has been already produced in defining indicators for their assessment (e.g. Brenner *et al.*, 2010; Raudsepp-Hearne, *et al.*,2010; Baral *et al.*,2014). ES evaluation can be done through different methods depending on the scope and aim of the assessment.

For this deliverable we decided to focus on ES supply and economic value to translate NBS benefits into economic terms. Since there are multiple methods for assessing ES provision, demand, and value, this report capitalizes the extensive literature review performed in Righetti *et al.* (2022) and adopts the list of indicators proposed by the same authors.

In addition to these indicators, different models and software for ES assessment can be used, including for spatially defined assessments of the ES. Among these models and software, InVEST is one of the most largely used. It is an open-source suite of models for the mapping and valuing of a broad range of ES, thus resulting a valuable tool to support decision-makers[1]. InVEST has been used to test the implementation of the guidelines reported in Section 3.

2.2.2 Benefits assessment

To assess the benefits provided by NBS, these guidelines rely on the economic valuation of ES. To translate the capability of NBS to increase or enhance ES into monetary terms it is necessary to:

1. quantify the ES provided by the NBS in biophysical terms (ES provision)
2. translate the ES provision in ES economic value (ES economic value)
3. sum-up the ES economic values of the different ES assessed to compute the total amount of benefits.

ES provision refers to the benefits the ecosystems provide to humans through the combination of natural processes and social conditions (Spangenbers *et al.*, 2014). It is based on the biophysical properties of the ecosystems. To select the indicators to assess ES, the review done by Egoh *et al.* (2012) has been used as a starting point and integrated with other studies (e.g., TEEB, 2010). The indicators were associated to each ES and then the most appropriate, easy to use, and least costly indicators have been selected. The full list of indicators is described in the Annex 3 in Righetti *et al.* (2022).

ES economic value expresses the monetary value of ES and embeds people preferences through them. The assessment of the ES economic value ideally aims to the identification of the so called total economic value (TEV) that incorporates both use and non-use ES values (Thorsen *et al.*, 2014). The assessment of the economic value of ES relies on multiple methods. Some of them directly or indirectly rely on existing market values (i.e. prices) to estimate ES (e.g. Acharya *et al.*, 2020; Westling *et al.*, 2020; Ruijs *et al.*, 2017). Some others refer to the creation of a demand curve for those values for which there is not an explicit market. These methods estimate the ES value in terms of stated or revealed consumers' preferences. Indicators considered in this deliverable rely only on methodologies based on the market values. This approach was selected because the guidelines have been thought to be user friendly and intuitive, to allow their use by a broad spectrum of decision makers. Demand-curve methods tend to be more costly and time consuming, and they usually require expert support.

Table 3 presents the list of indicators selected to assess the ES associated to the WEFE nexus challenges.

Table 3: Indicators selection for ES supply and ES value assessment

Ecosystem Service	Provision indicators	Economic value indicators
Water provision	Fresh and/or process water availability per water use (m^3/ha per year)	Market price per sector: water (€/m^3 per year)
Food provision	Average production yield (kg/ha)	Market price per crops (€/kg per year)
Energy provision	Converted energy (kWh/m^3 per year) Produced electricity (kWh/m^3 per year)	Market price: energy (€/kWh per year)
Materials Resources	Natural resources extracted (kg/ha per year)	Market price: natural resources (€/kg per year)

[1] https://naturalcapitalproject.stanford.edu/software/InVEST

Ecosystem Service	Provision indicators	Economic value indicators
Genetic Resources	Number of crop varieties and livestock breed species living in a region/surface	Restoration costs (€/ha per year)
Regulation of water flows	Water storage capacity per land use (m^3/ha per year) Groundwater recharge rate (m^3/ha per year)	Replacement costs: (€/m^3 of construction material)
Climate regulation	Carbon sequestration rate per land use (tons CO2/ha per year)	Market price: carbon credit (€/ton CO2)
Water purification	kg of pollutant retained from soil per soil type	Replacement costs (€/ton of pollutant removed)
Moderation of extreme events (flood protection)	Water storage capacity per land use (m3/ha per year) groundwater recharge rate (mm/ha per year)	Replacement costs (€/m^3 of construction material)
Erosion prevention	Amount of soil retained, or sediment captured (m^3/ha per year)	Replacement costs (€/ton of soil retained)
Biological control	Populations of pest control agents (n/ha)	Replacement costs (€/l of pesticides)
Lifecycle maintenance	Native vegetation or high nature value farmland; Biodiversity index; Structural changes in habitats and other ecosystem characteristics	Restoration costs (€/ha of habitat restored)
Opportunities for recreation and tourism	Number of facilities (e.g., hotels, restaurants, hiking paths, parking lots; n/ha) Results from questionnaires on nature and leisure preferences (wildlife-viewing, hiking, fishing, sports)	Visitors' total expenditure (€)

2.2.3 Costs assessment

NBS costs can be divided into different categories, i.e. capital costs, operational costs, opportunity costs (Dicks *et al.*, 2020) and transition costs (Gray *et al.* 2019):

Capital costs are the initial costs to implement the NBS. They identify the expenses for the labour, materials and machineries that are needed for developing the NBS. They also include the financial costs incurred when an initial investment support is required.

Operational costs refer to the monitoring and the management of the NBS to ensure its implementation over time. They include the maintenance and monitoring costs of the NBS.

Opportunity costs are the costs of excluding or limiting the previous activities in place by implementing a different solution. Opportunity costs represent the forgone value of implementing a NBS and reflect the landowners' willingness to giving up with the current situation in favour of the NBS.

Transition costs are the costs associated to time, resources, and efforts to initiate, negotiate, enforce the NBS, thus making the context ready for their implementation (e.g., stakeholder involvement, permissions request, workers training, knowledge sharing, etc.).

2.2.4 Cost-Benefit Analysis implementation

Once benefits and costs have been estimated, it is possible to compare them and calculate the net benefits generated by each NBS. This assessment, combined with the technical effectiveness of NBS (Nikolaidis and Lilli, 2022), represents a valuable input to inform the selection of the most appropriate solutions.

CBA allows to calculate a number of indicators to assess the financial sustainability of the investment in terms of profitability and exposure to risks. Profitability indicators include the net present value (NPV), the internal rate of return (IRR) and the benefit/cost ratio (B/C), while the risk exposure indicator used for this report is the payback period (PB). These indicators have been identified based on Masiero *et al.* (2019). All of them are described below by referring mainly to the same source.

The **NPV** of a given project is the present value of the net cashflow associated with it, i.e., it is calculated as the difference between total discounted benefits and costs (Dicks *et al.*, 2020). Absolute profitability is attained if a project's NPV is greater than zero. Relative profitability is achieved when a project's NPV is higher than the alternative (such as another project, or business as usual - BAU). In general terms, therefore, it is desirable that the NPV is positive and as high as possible. This implies that, in comparing the NPV of alternative projects, the higher of the NPVs should be preferred. NPV provides information on the absolute net value generated by a given project. Its focus is on maximizing the project's value, but it is not informative on its efficiency. Thus, NPV should never be used as a stand-alone profitability indicator.

The formula to evaluate the NPV is the following:

$$\boldsymbol{NPV = \sum_{t=1}^{n} \frac{(B_t - K_t)}{(1+r)^t}}$$

where B_t and K_t represent the benefits and the costs respectively at the time t, n is the considered time span; r is the discount rate.

The **IRR** is the rate at which the discounted costs equal the discounted benefits (i.e., NPV becomes null, or zero). As such, the IRR is a measure of the rate of profitability expected from a project. The IRR of a given project can be compared with the IRR associated with alternative projects: the project with the highest IRR would be ranked highest. The IRR can also be compared with a baseline or standard rate, for example the interest rate paid on ordinary investments, the interest rate for a commercial loan, or the rate paid for safe investments like state bonds.

The **B/C** is the ratio between discounted benefits and costs. Like the IRR, the B/C focuses on efficiency rather than on maximizing a project's profitability (which instead the aim of the NPV). A B/C greater than 1 means that the discounted benefits exceed the discounted costs. In comparing project options, the one with the highest B/C should be preferred. Note that the project option with the highest B/C will also have the highest NPV. The B/C allows the ranking of project options, which is especially helpful when there are budgetary constraints.

The **PB** is the time taken to recover the original investment thus measuring the exposure risk for investors (i.e., how long they will have to wait until a project's benefits meet the costs). In other terms the PB is the time (e.g., number of years) needed for the cumulated discounted benefits to equalize or overcome the cumulated discounted costs. A shorter PB period is desirable because it implies lower risk; thus, project options with the shortest PB periods should be preferred.

3. APPLICATION TO PILOTS

In this section an example of the application of the guidelines to the pilots of the PRIMA LENSES project is reported.

In the first sub-section (Sub-section 3.1), the link between the pilots' challenges and the "ES" and "non-ES" strategies was done for all the pilots.

In sub-section 3.2 the CBA and the assessment of NBS benefits and costs have been implemented only for one pilot with an illustrative purpose. The implementation of the methodology on pilot areas developed by the different project's work packages will be delivered by the work package 8: "Pilot implementation".

3.1 Linking pilots' challenges with the associated ES

The identification of challenges has been done starting from the project's baseline description (LENSES Deliverable 8.1., Henao *et al.*, 2022). For each pilot, single challenges identified have been analysed and possible links with ES have been proposed. For those challenges or those aspects within the challenges that had not a direct link with an ES, or where relevant, a "non-ES strategy" has been associated. As mentioned in 2.1, "non-ES strategies" include policy, governance, management practices that could be necessary to support pilots in facing the challenges.

The outcomes of this analysis have been shared with the pilots for validation. Pilots were asked to confirm, integrate, or modify the challenges identified as well as the proposed links between the challenges and the "ES" and "non-ES" strategies. The results of the validation exercise by the pilots are shown in Tables 4-10 below.

Table 4: Challenges and strategies of Pinios River Basin (Greece, GR)

Challenges	Type of strategy	ES strategy	Non-ES strategies
There is an uneven spatiotemporal distribution and over-exploitation of groundwater resources *(Pinios Hydrologic Observatory).*	ES	Water provision Regulation of water flows	-
There is a lack of coordinated action to water management that leads to increased water use inefficiency *(both areas).*	Non-ES	-	Management
Limited application of environmentally friendly agroecological practices (such as cover crops, mulching, conservation tillage and mulching), reduction of agricultural inputs, safe implementation of agricultural processes (such as sprays), and promotion of recycling economy principles in terms of managing agricultural residues (waste) *(both areas).*	Not ES	-	Management
The area is sensitive to water droughts since a significant part of crop water needs are satisfied through the capillary rise. However, the extent of the significant contribution of capillary rise to crop water needs fulfilment is not well perceived by farmers *(Pinios River Delta).*	ES Not ES	Water provision Regulation of water flows	Management
Some areas are irrigated with water of low quality because of high salinity; a fact that affects many crops including kiwi-fruit which is a very dynamic crop for the area (*Pinios River Delta).*	ES	Water provision Water purification	-
There are competitive water uses, mainly touristic along the coastline and between municipalities *(Pinios River Delta).*	Not ES	-	Consumption Choice Management
	ES	Water provision	Management

Balancing water quantity, quality, and demands is a big challenge. So is balancing management of the phreatic to the deeper aquifer in conjunction to surface runoff along the River Pinios and the relatively high - but decreasing - yield springs at the upstream edge of the PRD. All of the above are critically important for all the productive sectors, and mainly for the agricultural sector in the context of climate change (e.g. drought periods) *(both areas).*	Not ES	Climate regulation Regulation of water flows Water purification Climate regulation	Consumption Choice
Water is collected directly from the springs to irrigate mainly the chestnuts fields found in the predominantly mountainous part of the pilot. Potentially this fact reduces the water available for the wildlife. *Pinios Hydrologic Observatory).*	ES Not ES	Lifecycle maintenance Water provision Regulation of water flows Food provision	Management
Management of produced agricultural residues from professional activities and on a seasonal basis from households and touristic units *(both areas)*	Not ES	-	Management
Irrigation from the river is made irrationally, and therefore the environmental flow might not be maintained *(both areas).*	Not ES	-	Management Policy
The *Pinios River Delta* constitutes a significant ecosystem (NATURA2000) stressed by anthropogenic activities, such as agriculture and tourism.	Not ES	-	Policy
Regarding food, the ultimate challenge is to maintain the agricultural production for both watersheds. In particular, in the case of the *Pinios Hydrologic Observatory*, the local economy must maintain and improve the fruit production (apples, cherries, chestnuts) which includes exports to several countries inside and outside the EU. As for the PRD, the plain area is highly productive, and its productivity has to be secured to support the local economy. At the same time, production costs must be optimized to keep agriculture viable and competitive *(both areas).*	ES Not ES	Food provision	Management Policy
Shift to financially viable agriculture and sustainable touristic development through a coordinated, substantiated and long-term business plan *(both areas).*	Not ES	-	Management
In the last years, food-producing crops, such as corn, have been substituted by energy crops (mainly sunflower) *(Pinios River Delta).*	Not ES	-	Policy
Wide application of pesticides affecting soil organic matter content. *(Pinios Hydrologic Observatory).*	Not ES	-	Management
Limited maintenance of irrigation networks/canals; need for closed channels construction; need for mechanization of agricultural sector with modern equipment *(both areas).*	Not ES	-	Management
Limited organization of farmers in cooperative schemes *(both areas).*	Not ES	-	Organisational approaches
Demand for riparian habitats and forests conservation *(Pinios River Delta).*	ES Not ES	Lifecycle maintenance	Policy
Limited capacity of surface water reservoirs *(Pinios Hydrologic Observatory).*	ES	Regulation of water flows	Organisational approaches

Table 5: Challenges and strategies of Doñana National Park (Spain, ES)

Nexus Challenges	Type of strategy	ES strategy	Non-ES strategies
The use of fertilizers and pesticides in intensive agriculture significantly impacts water quality in some water bodies.	ES non-ES	Water purification	Policy Management
Irrigation is a large water user in the area. Overexploitation (irrigation over the allocated volume) limits the environmental flow of surface water to the Doñana wetlands (groundwater discharges into the marshlands (e.g. through the Rocina stream) have largely decreased).	ES non-ES	Water provision Regulation of water flows Lifecycle maintenance	Management Consumption choice
As a consequence of this over-exploitation (agriculture + also summer tourism in Matalascaña area), many temporal lagoons and wetlands near the marshlands, which are very dependent on groundwater contribution, are facing serious deterioration in the last years.	ES	Lifecycle maintenance Water provision Regulation of water flows	-

Enforcement of the water uses annual plans / illegal use of water	non-ES	-	Management
In addition to groundwater overexploitation, resource-intensive process of berry cultivation has created several other problems: e.g. deforestation, habitat fragmentation.	ES non-ES	Lifecycle maintenance	Management
Guadiamar river is disconnected from the marshlands (increase of agricultural lands + dikes after Aznalcollar mining spill).	ES non-ES	Water provision Regulation of water flows Lifecycle maintenance	Restoration
Doñana is broadly considered a very threatened area by climate change. Several recent studies and scientific publications warn of the big climatic threats for Doñana, e.g., rainfall reduction, sea-level rise, changes in climatic conditions affecting endangered species.	ES non-ES	Lifecycle maintenance	Management
Sustainable high-value agricultural activity in a context of water scarcity exacerbated by climate change.	ES non-ES	Water provision Regulation of water flows Food provision	Management
Doñana is widely considered a hotspot in biodiversity and one of the most important wetlands across Europe. Droughts and reduced rainfall together with increased competition for freshwater resources are changing flooding patterns and reducing wetland extension.	ES	Lifecycle maintenance Genetic Resources	-
Changes in salinity distribution in the wetland.	ES	Lifecycle maintenance Genetic Resources	-
Invasive alien species.	ES non-ES	Lifecycle maintenance Genetic Resources	Management

Table 6: Challenges and strategies of Galilee, Hula Valley (Israel, IL)

Challenges	**Type of strategy**	**ES strategy**	**Non-ES strategies**
The discharge of the Jordan River - the primary water source of the Sea of Galilee that flows through the Hula Valley, is expected to decrease by up to 22% in the 21st Century. It is a dramatic trend for the region in terms of water availability and water scarcity.	ES non-ES	Water provision Regulation of water flows Climate regulation	Policy
From 2012 to 2018, the precipitation amount in the Galilee was lower than the long-term average for this region. This figure reflects a local decrease in the replenishment of water resources.	ES	Water provision Regulation of water flows Climate regulation	-
Water pricing is a political and societal issue which will bear the desalination costs.	non-ES	-	Policy
Agriculture in the Hula Valley was always dependent on the effective use and control of water resources.	ES	Water provision Food provision	-
The Galilee is the "fruit barn" of Israel and fruits are also exported to Europe, and therefore the effect on the crops is important.	ES	Food provision	-
Water uses for irrigation.	ES	Water provision Regulation of water flows	-
Disease control.	ES	Biological control	-
Uses of fertilizers, pesticides, and herbicides.	ES	Water purification	-
The agricultural and the food chain dimensions play a significant role in conferring stability, resilience, and adaptability to farming systems.	ES	Food provision	-

Table 7: Challenges and strategies of Koiliaris Critical Zone Observatory (Greece, GR)

Challenges	**Type of strategy**	**ES strategy**	**Non-ES strategies**
There is lack of one managing authority of water resources.	non-ES	-	Governance
There is high fluctuation of the spring flow between winter and summer – prone to drought periods – cannot rely on groundwater wells from upgradient.	ES	Water provision Regulation of water flows	-
Mixing of spring water with high Cl concentrations – conflict between DOC and farmers.	ES non-ES	Water purification	Management
Lack of infrastructure – small reservoir with quality water.	ES non-ES	Water provision Regulation of water flows	Policy

		Water purification	
During drought periods it is difficult to satisfy irrigation requirements in part of the pilot area.	ES	Water provision	Management
	non-ES	Regulation of water flows	Management
Irrigation with water of low quality because of high salinity.	ES	Water purification	-
Competitive water uses between irrigation, tourism, and local drinking water use – areas with insufficient water supply.	ES	Water provision	Management
	non-ES	Regulation of water flows	
Significant erosion due to land use practices (tilling) even in areas with high slope.	ES non-ES	Erosion prevention	Management
Urbanization impacts on the springs – villages without sewage system are built on the springs.	non-ES	-	Policy
Intensive agriculture with significant fertilization, pesticide and herbicide applications.	ES	Water purification	Management
	non-ES	Food provisioning	
Abandoned terraces – contribution to erosion and soil degradation.	ES	Erosion prevention	Policy
	non-ES	Lifecycle maintenance	
Small farm lots– no economy of scale.	non-ES	-	Policy
No profit for citrus and low for olive oil.	non-ES	-	Management
Avocado is a dynamic new crop with good price.	non-ES	-	Management
Farmers do not have formal training.	non-ES	-	Management
Unsustainable agricultural practices – tilling.	non-ES	-	Policy Management
Farmers get information from agronomists who sell fertilizers and other farmers at the coffee shops.	non-ES	-	Management
Climate mitigation and adaptation.	ES	Climate regulation	-
Water management - Reduction of flood risk.	ES	Moderation of extreme events (flood protection) Regulation of water flows	-
Participatory planning and governance.	non-ES	-	Governance Policy
Public health and well-being.	ES	Opportunities for recreation and tourism	-
Potential of economic opportunities and green jobs.	non-ES	-	Policy

Table 8: Challenges and strategies of Gediz Basin and Delta (Turkey, TR)

Challenges	Type of strategy	ES strategy	Non-ES strategies
Difficulties in reaching quality water due to administrative deficiencies in water distribution.	ES	Water purification	-
Agricultural areas generally consist of irrigated arable lands however the problem is that excessive irrigation in summer causes salinity in the soil caused by lack of planning.	ES non-ES	Water purification	Management
Fluctuation in water reserve and water scarcity due to drought.	ES	Water provision Regulation of water flows	-
Since the Menemen plain located at the outlet of Gediz, the water pollution load is high.	ES	Water purification	-
Urgent planning is needed for sustainable agriculture and food security in the plain.	ES non-ES	Food provisioning	Policy
Drought, which has been frequently encountered in recent years due to climate change, negatively affects agricultural production in the pilot region.	ES	Water provision Regulation of water flows Food provisioning Climate regulation	-
There is a periodic water shortage due to drought, which affects the agricultural production decisions of producers.	ES	Water provision Regulation of water flows	-
This situation leads to unconscious and excessive use of water, so that producers in the outlet parts of the irrigation network cannot access sufficient irrigation water. Producers who cannot reach the irrigation water they need, have to obtain water from the drainage channels by pumping.	ES	Water provision	Choice consumption
	non-ES	Regulation of water flows	Management

Agricultural sustainability is under threat as a result of agricultural land decrease and shrinkage day by day due to the increasing population, industrialization and non-agricultural use, increasing agricultural input costs, changes in demographic structure, restriction of natural resources and decline in soil fertility.	non-ES	-	Policy
Biodiversity within the basin decreases over the years.	ES	Genetic Resources	Policy
	non-ES	Lifecycle maintenance	
Climatic fluctuations and environmental effects seriously disrupt the balance in the ecosystem.	ES	Climate regulation	Policy
	non-ES	Lifecycle maintenance	

Table 9: Challenges and strategies of Tarquinia Plain (Italy, IT)

Challenges	Type of strategy	ES strategy	Non-ES strategies
The main challenges of this area are strictly connected with the quantity and the quality of water in agricultural areas.	ES	Water provision	-
		Regulation of water flows	
		Water purification	
A high amount of water is requested during the summer period. Water distribution is complex due to structural and management problems of the Water Use Association. This problem is also connected with the high energy costs of water pumping on irrigation networks. Moreover, a competitive use of water is present, for different activities (agriculture, tourism, civil use).	ES	Water provision	Management
			Policy
	non-ES	Regulation of water flows	Choice consumption
The quality of ground water is not very good due to the pollution of Nitrates derived from fertilizer.	ES	Water purification	Policy
	non-ES		Management
In the area, there are soil degradation problems also due to very intensive agriculture.	ES	Erosion prevention	Management
	non-ES	Lifecycle maintenance	
Pressures on the water resources quality – i.e. Marta River and the groundwater body – due mainly to summer tourism pressure and slightly also due to the unsustainable use of chemical products in agriculture.	ES	Water purification	Management
	non-ES		
The main challenge is to protect and restore the landscape from the rapid transformation due to the agricultural use of the territory (more in the past). Protecting the landscape could have positive impacts on the local biodiversity, and specifically on the wild birds' population.	ES	Genetic Resources	Policy
	non-ES	Lifecycle maintenance	Management
There is a significant process of contraction of agricultural enterprises. The agricultural producers of Tarquinia have long been committed to surviving in the global competition of markets. They are often excluded due to their small and fragmented size compared to the large operators in the sector.	non-ES	-	Policy
			Organisational approaches
The socio-political European condition and the increase of energy, fertilizers, and water prizes are leading to a decrease of agricultural products' value.	non-ES	-	Organisational approaches

Table 10: Challenges and strategies of Middle Jordan Valley, Dair Alla (Jordan, JO)

Challenges	Type of strategy	ES strategy	Non-ES strategies
High fluctuation of water quality and quantity effluent for different seasons (e.g., Winter and Summer) due to competitive on water resources different sectors with agricultural sector.	ES	Water provision	Management
	non-ES	Water purification	Policy
		Regulation of water flows	
Irrigation water salinity used range from 2 to 3 dS/m.	ES	Water purification	-
Ground water quality in Jordan Valley is saline, so farmers cannot rely on it for irrigation before desalinization.	ES	Water purification	-
During drought periods it is difficult to satisfy irrigation requirements.	ES	Water provision	-
		Regulation of water flows	
Significant soil degradation and deterioration soil productivity due to salinity build up and intensive agriculture. As well as over fertilization, pesticide and herbicide applications.	ES	Water purification	Management
	non-ES	Lifecycle maintenance	
		Erosion prevention	

The Unique ecosystem of Jordan Valley that is below sea level (range from -200 to -400 meter) gave it privilege as an agricultural environment to produce vegetables, fruits and forages out of season.	ES	Food provisioning	-
The potential decreasing precipitation and high temperatures in Jordan because of climate change could worsen the existing problems.	ES	Climate regulation	-
The adoption of intercrop rotation technique by the farmer and produce forages and or silage.	non-ES	-	Policy & Management
			Management
Intercrop silage palatability and acceptance by the Animal which will affect technique adoption by the farmer.	non-ES	-	Management

Challenges and links with ES and non-ES strategies were revised according to the feedback provided by the pilots. In the case of Koiliaris pilot (Crete, Greece) the final set of challenges and strategies was used as a starting point for the socio-economic assessment via a CBA.

3.2 Socio-economic assessment in Koiliaris pilot

To provide an example of the socio-economic analysis of NBS, the case of the Koiliaris pilot has been taken into consideration. The selection of this pilot was made because an explorative and participatory process to identify a possible NBS and a possible area in which to implement, has been already performed (Lilli *et al.*, 2020). Given the illustrative aim of this exercise, a limited set of ES has been identified for the assessment. Although justified by the nature of the assessment, as well as by some limitations in accessing data needed for a full ES assessment, this choice has some practical implications. Focusing on a sub-set of ES, indeed, allows grasping just a part of the total benefits associated to a certain NBS finally resulting in an underestimation of the NBS total value.

3.2.1 Description of the selected case study

The Koiliaris River watershed is located in the north-western part of the Crete Island (Greece). It extends for 132 km^2 and the altitude ranges from 0 to 2,120 m above the sea level. The mainland uses are intensively grazed shrublands and pastures, olive, citrus groves, vines, vegetables, and mixed forest (0.6 %). The length of the drainage network is 44.8 km, consisting of the intermittent tributary of Keramianos (13.8 km), two ephemeral streams providing surface runoff feeding the Anavreti tributary (total length is 27.2 km), the karstic springs of Stylos (permanent flow) and the karstic spring of Anavreti (intermittent flow), which merge with the rest of the streams to form the main segment of the Koiliaris River. These springs are fed by an extended area of karst which is located outside the basin boundaries and occupies an estimated 80 km^2 (Henao *et al.*, 2022).

According to the baseline description the main challenges that the Koiliaris River watershed is facing derive mainly from the following (Henao *et al.*, 2022):

1. The Keramianos tributary loses most of its water in the two faults that crosscut the gorge and generate flash floods when the precipitation in the sub-basin exceeds 120 mm (Nerantzaki *et al.*, 2015).

2. The watershed represents severely degraded soils due to many centuries of heavy agricultural impacts, including grazing.

A more in-depth analysis of the challenges can be found in table 7. The ES that have been associated with the challenges, and confirmed via stakeholders' consultation, are food provision, water provision, regulation of water flow, water purification, climate regulation, moderation of extreme events (flood protection), erosion prevention, lifecycle maintenance, and opportunities for recreation and tourism.

As for the identification of the NBS to address these challenges, reference has been made to Lilli *et al.* (2020) who indicated the restoration of the riparian forest as the most effective NBS for the area. The restored riparian forest will cover 20m-wide buffer stripes on each riverbank for a total of 200,000 m^2. Joint discussion and brainstorming with pilot leaders, however, brought to a recalibration of the size of the area in which NBS is planned to be implemented, thus resulting in a final total area of 335,450 m^2. The NBS will incorporate a walking path to improve the recreational and tourism potential of the area. The area in which the NBS has been planned is shown in Figure 3.

Figure 3: Koiliaris watershed and the area aimed to the riparian forest restoration (light green)

3.2.2 Cost-benefit analysis

According to sub-section 2.2.1, NBS-associated benefits have been assessed in terms of the economic value of the selected ES provided or enhanced by the NBS itself. ES were assessed according to the "with and without" principle (Gregersen and Contreras, 1995), i.e., as a difference between values accounted under the NBS scenario and the baseline conditions. In this way it is possible to highlight changes brought in by NBS implementation in terms of ES generation compared to the BAU conditions.

As already commented, for the assessment only a sub-set of ES have been considered. These include:

- Moderation of extreme events, to identify the potential of the NBS to reduce flood impacts
- Climate regulation.

The selection of these two ES is due to some limitations/constraints in accessing data that would allow calculating additional ES.

The outcomes of the analysis are reported below for each of the two ES assessed. For each ES, the ES provision has been initially valuated by quantifying the ES supply in biophysical terms under both the BAU and NBS scenarios. As for the latter, literature-based average data related to a mature forest have been used. The net ES provision (i.e., NBS-BAU) has been then calculated and ultimately converted into monetary terms to detect the change in ES value generated by the NBS implementation. By summing all net monetary values for the ES taken into consideration, the total net benefits associated to the NBS have been calculated.

To implement the analysis, InVEST [2] models have been used. The visualization and further elaborations of the InVEST model outcomes have been performed trough QGis 3.22 with a file resolution of 5x5m.

3.2.2.1 Benefit analysis

ES: Moderation of extreme events

Moderation of extreme events has been analysed using the InVEST 3.9.1 through the Flood risk mitigation model. The inputs needed by the InVEST model are:

- *area of interest*: a vector file describing the area under analysis in which to show the results. For our analysis the shapefile of the area covered by the NBS (Figure1) has been used.

- *rainfall depth*: in mm, for the design storm of interest. For the analysis a rainfall depth of 120mm has been considered according to Nerantzaki *et al.* (2015), who reported this to be the amount of rainfall capable to generate floods.

- *Land Use/Land Cover:* a raster file with information of Land Use and Land Cover (LULC, CLC2018). The current Land Use and Land Cover map has been used to generate the Land Use and Land Cover map for the NBS scenario by turning baseline values into broadleaved forest (Lilli *et al.*, 2020) to simulate the NBS implementation.

- *Soil Hydrologic Group*: a map describing the soil hydrologic groups. Reference has been made to the Global Hydrologic Soil Groups (HYSOGs250m) by Ross *et al.* (2018).

- *Biophysical Table*: csv file reporting the Curve Number for each LULC according to USDA (1986).

Table 11 reports the result of the retained runoff volume (m^3), the runoff retention index (i.e., the runoff retention volume relative to the total precipitation volume), and the runoff value (mm) for

[2] Natural Capital Project InVEST 3.9.1. Available online: https://naturalcapitalproject.stanford.edu/software/InVEST (accessed on 18 November 2022)

the hypothetical area interested by the NBS, with reference to the current land use and the land use change after NBS implementation.

Table 11: Moderation of extreme events assessment under current land use and hypothesizing NBS (riparian forest restoration) implementation

	A. Baseline (no NBS)	B. Broadleaved forest (NBS scenario)	B-A
retained runoff volume (m^3)	17,931.96	20,620.84	**2,688.88**
runoff retention index	5,977.32	6,873.61	896.29
runoff value (mm)	871,641.81	764,086.41	-107,555.4

The value of the runoff retention in m^3 indicates the capability of each pixel to store runoff. The difference between the retained runoff volume of the current land use and the NBS implementation of a broadleaved forest, indicates the expected change in the runoff retention capacity. It indicates the improvement on the provision of the moderation of extreme events ES by the NBS that results to be equal to about 2,690 m^3, corresponding to a 13% improvement compared to the baseline.

The economic value of the moderation of extreme events ES has been calculated through the replacement cost method, using a lamination basin as a substitute good aimed to retain the same amount of water stored by the NBS. In the absence of more specific data for the local context, a unit cost of 400€/m^3 has been used as proxy (Masiero *et al.*, 2022). The value of moderation of extreme events provided by the NBS therefore results to be equal to **1,075,554.07€**.

ES: Climate regulation

For the assessment of climate regulation, the InVEST "Carbon storage and sequestration" model has been used. The input needed by the InVEST model are:

- *Current Land Use/Land Cover*: raster file with information of Land Use and Land Cover (LULC, CLC2018). As in the previous case, the current Land Use and Land Cover map has been used to generate the Land Use and Land Cover map for the NBS scenario by turning baseline values into broadleaved forest (Lilli *et al.*, 2020) to simulate the implementation of the NBS.

- *Carbon Pools*: a .csv file with the value of the carbon pool per each LULC (t/ha), considering the carbon stored in the aboveground biomass, belowground biomass, carbon soil, and carbon in the dead matter. Values for the different carbon pools have been elaborated based on Asksoy *et al.* (2012); Ilarioni *et al.* (2013); Pluske *et al.* (2015); Scandellari *et al.* (2016); and Kilpeläinen and Peltola (2022).

The increase in carbon storage in the broadleaved forests (NBS scenario) when compared to the current land use (baseline or BAU scenario) is equal to 5,819.71 tons of carbon. This corresponds to a 60% increase of the carbon storage capacity when passing from the current to the NBS future land use.

InVEST returns a value of carbon stocked in the vegetation in tons per pixel, therefore, to determine the corresponding weight of carbon dioxide we multiplied the weight of carbon by 3.67. This conversion is necessary to evaluate the total benefit generated by the NBS based on the average price of a carbon credits sold in the market. The price used for carbon is 7.70€ per tCO_2eq ($7.90

tCO_2eq) based on Ecosystem Marketplace (2022). The total economic value for the ES has then been calculated by multiplying the net CO_2 storage generated by the NBS by the price per ton of CO_2. This finally corresponds to **164,459.32€** (Table 12).

Table 12. Summary of climate regulation economic value calculation.

tons of carbon	tons of CO_2	price per tCO_2eq	total value
5,819.71	21,358.35	7.70€	164,459.32€

Total benefits associated to targeted ES

The total benefits associated to targeted ES provided by the selected NBS correspond to the sum of values for each ES - i.e. moderation of extreme events and climate regulation – that result equal to **1,240,013.38€**.

3.2.2.2 Cost Analysis

Costs associated to the NBS implementation have been retrieved from Lilli *et al.* (2020). Since in the paper the costs are presented in an aggregate form, without any distinction between the different cost types, authors have been contacted and requested about more detailed information. Based on the information received and by considering a total NBS area of 335,450 m^2, a total cost of **1,082,808.50€** has been estimated for the NBS implementation. Besides implementation and unforeseen costs, maintenance costs should also be taken into account when performing the CBA. For more information, please see 3.2.2.3 below.

3.2.2.3 CBA Implementation

When implementing the CBA, we considered implementation costs and their distribution over time based on Carvajal and Janmaat (2016). As a consequence, implementation costs have been distributed unevenly within the first two years of the project, 75% and 25% respectively, to take into account additional implementation costs that might occur after year zero (e.g., to address seedling mortality after planting). Maintenance costs have been assumed to be equal to 5% of the total costs. Benefits have been introduced from the fifth year, assuming the NBS will start delivering benefits when the forest reaches a minimum growth stage.
A discount rate equal to 3.5% has been considered (Dicks *et al.*, 2020). The time horizon has been set to 20 years.

Table 13 presents the results of the CBA.

Table 13: Outcomes of the Cost-Benefit Analysis

NPV (€)	B/C	IRR	PB
11,364,940.45	7.67	40.49%	5

From Table 12 it is possible to notice that the NPV is positive and indicates a net profitability of the investment equal to about **11.4 million €.**

Consistently with the NPV being positive, also the B/C is positive, confirming that the riparian forests implementation is expected to deliver a positive net present value to the implementers: for any single Euro invested, the investment pays back **7.67€.**

It is important to remember that this B/C has some limitations, as it does not incorporate all co-benefits, in terms of ES, that a riparian forest could provide. This highlights the importance to assess the full range of benefits and the co-benefits of a NBS to ensure a complete set of information that allow a better and more precise decision making behind its implementation. It can be assumed, indeed, that given the fixed cost estimated, adding the value of the other ES provided by the NBS, i.e., water provision, water purification, erosion prevention, lifecycle maintenance, opportunities for recreation and tourism (Lilli *et al.*, 2020), would have a higher positive impact in the economic return for every 1€ invested.

The IRR is the discount rate that would turn the NPV equal to zero, i.e. the return rate at which the project just breaks even. For the riparian forest the IRR is equal to **40.49%.**

Finally, the PB results to be equal to **5 years**, i.e. in 5 years the money invested in the NBS would be fully covered and paid back.

4. DISCUSSION AND CONCLUSIONS

This deliverable reports indicators and methodologies to assess the socio-economic benefits and costs of NBS to support the WEFE Nexus management. Guidelines have been proposed to support decision-makers when assessing and identifying strategies and solutions that are more efficient in providing benefits and responding to the challenges faced.

In the last section of the deliverable (section 3), an example of a socio-economic assessment for a selected NBS to be implemented within one of the pilots has been illustrated. Since the assessment exercise has a merely illustrative scope to show the feasibility and utility of the guidelines, some limitations arose, mainly linked to the CBA.

Data availability has been one of the main bottlenecks for the assessment, ultimately affecting the selection of the ES to assess. It is advisable to include as many ES as possible within the assessment in order to have a more complete overview of the benefits generated by the NBS. At the same time, a precautionary approach might suggest considering a buffer of ES values as a form or risk management, i.e., to take into consideration any possible adverse event - either natural or man-induced - that might affect the amount and value of ES generated by the NBS.

Additionally, a better idea of benefit distribution over time is advisable since this allows to have a better picture of NBS-associated impacts. For instance, in the case of the riparian forest assessed for the Koiliaris area, the capacity of the established forest to sequester carbon dioxide regulation will change over time, based on the forest growth stage. This requires a more in depth understanding and knowledge of the NBS dynamics including, where needed, primary data collection or expert-based inputs. Similarly, a better understanding of different costs as well as their distribution over time would result beneficial for a more precise assessment.

CBA can represent a useful tool to support decision making and to guide the selection of NBS, however it is not a stand-alone instrument. In order to explore NBS feasibility, technical aspects about NBS developing and functioning have to be deepened, together with the governance and policy factors that might enable NBS. The estimation of ES value is just a preliminary step towards making this value real. An appropriate mix of policy tools and governance mechanisms are needed for this. Enabling policies for NBS establishment are addressed by task 6.2 of the LENSES project - more info are available in Righetti *et al.*, in press – while the development of business models to successfully implement NBS is covered by task 6.3.

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