DANUBE4all Milestone 11

Multi-Method Approach for Evaluating Economic & Ecological Benefits of Nature-Based Solutions (NBS) in Danube4All

Authors: *Rodica Gorghiu* (CIVITTA), *Andreea Savin* (CIVITTA), *Ionut Bojan* (CIVITTA), *Alexandru Duicu* (CIVITTA), *Marcell Nemeth* (CIVITTA), *Corina Rosu* (CIVITTA), *Ruxandra Salvestru* (CIVITTA), *Diana Manoleli* (CIVITTA)

Document Information

Version	Date	Description		
		Responsible	Authors	Reviewed by
1	07/06/25	WP4	*Rodica Gorghiu (CIVITTA), Andreea Savin (CIVITTA), Ionut Bojan (CIVITTA) Corina Rosu (CIVITTA) Marcell Nemeth (CIVITTA) Ruxandra Salvestru (CIVITTA) Diana Manoleli (CIVITTA)*	*Martin Pusch (FVB.IGB), Helmut Habersack (BOKU)*
2	30/12/25	WP 4	*Rodica Gorghiu (CIVITTA), Andreea Savin (CIVITTA), Ionut Bojan (CIVITTA) Marcell Nemeth (CIVITTA) Corina Rosu (CIVITTA) Diana Manoleli (CIVITTA)*	*Martin Pusch (FVB.IGB), Helmut Habersack (BOKU)*
3	27/05/26	WP4	*Rodica Gorghiu (CIVITTA), Andreea Savin (CIVITTA), Alexandru Duicu (CIVITTA)*	*Martin Pusch (FVB.IGB), Helmut Habersack (BOKU)*

Authors (alphabetical)	
Name	**Organisation**
Ionut Bojan	CIVITTA
Alexandru Duicu	CIVITTA
Rodica Gorghiu	CIVITTA
Diana Manoleli	CIVITTA
Marcell Nemeth	CIVITTA
Corina Rosu	CIVITTA
Ruxandra Salvestru	CIVITTA
Andreea Savin	CIVITTA

Dissemination Level	Public
Task leader for this deliverable	Martin Pusch

Disclaimer

The content of the publication herein is the sole responsibility of the authors and does not necessarily represent the views of the European Commission or its services.

While the information contained in the documents is believed to be accurate, the authors(s) or any other participant in the DANUBE4all consortium make no warranty of any kind with regard to this material including, but not limited to the implied warranties of merchantability and fitness for a particular purpose.

Neither the DANUBE4all Consortium nor any of its members, their officers, employees or agents shall be responsible or liable in negligence or otherwise howsoever in respect of any inaccuracy or omission herein.

Without derogating from the generality of the foregoing neither the DANUBE4all Consortium nor any of its members, their officers, employees or agents shall be liable for any direct or indirect or consequential loss or damage caused by or arising from any information advice or inaccuracy or omission herein.

Acknowledgement

This document is a deliverable of DANUBE4all project. This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101093985.

To be cited as:
Gorghiu, R., Savin, A., Bojan, I., Nemeth, M., Rosu, C., Salvestru, R., Manoleli, D., 2025. Multi-Method Approach for Evaluating Economic & Ecological Benefits of Nature-Based Solutions (NBS) in Danube4All – Methodology. Danube4All Milestone 11, 30 pp. http://www.danube4allproject.eu/resources

Executive Summary

This report delivers the methodological framework and analytical structure for **Milestone 11 (M11) of the DANUBE4All project**. It establishes a generic, scalable economic impact model for assessing ecological restoration investments along the Danube River Basin, covering various national economies. The model is designed to support evidence-based decision-making for river managers and policymakers, enabling cross-country comparability, scalability beyond pilot sites, and alignment with environmental economics best practice. A key insight underpinning the model is that while restoration measures differ ecologically, their investment cost logic (CAPEX – capital investment/OPEX – operational costs) follows highly similar sectoral spending structures, making a measure-agnostic Input Output (IO) model feasible and defensible.

The methodological framework integrates:

- *Input–Output (IO) modelling* as the core quantitative instrument, answering the high-level policy question: What is the macroeconomic effect of 1 EUR invested in river restoration? IO results quantify sectoral output, Gross Value Added (GVA), and employment propagation, which represent economic activity redistribution, not welfare gains, and are therefore not additive to CBA benefits to avoid double counting.
- *Cost–Benefit Analysis (CBA)* as a selective and complementary welfare assessment, applied only where Ecosystem Services (ES) benefits can be robustly quantified and monetised using avoided damage or market-linked valuation methods (e.g., floods, nutrients, fisheries, water tariffs, carbon pricing).

The model therefore proposes (1) IO to simulate how investment expenditure and monetised ES flows propagate across national economies, without interpreting GVA as welfare benefit. CBA results are incorporated in IO only as calibrated demand shocks (e.g., increased tourism expenditure or marketable fish biomass), while non-monetizable ES remain in the benefits narrative without being forced into CBA and (2) CBA to quantify Total Economic Value (TEV) of monetizable ecosystem service improvements using standard valuation principles (market price, avoided cost, replacement cost, ETS, travel cost, hedonic pricing).

The final output is a transferable analytical structure that supports cross-country comparability, avoids welfare overestimation, excludes double counting between production effects and welfare benefits, and enables policymakers and river managers to interpret both the economic footprint and the ecological value of Danube restoration investments in a rigorous and operationally feasible framework.

Table of Contents

List of figures

List of tables

1. Introduction

The purpose of this document is to present the consolidated methodological framework and the sequence of analytical steps undertaken for Milestone 11 (M11). The milestone aims to develop a **general model for the economic evaluation of river restoration investments** along the Danube. This model will quantify the **macroeconomic effects of restoration spending** and, where feasible, assess the **monetizable ecosystem service (ES) benefits** generated by restoration actions.

Over the past year, the project team has undertaken a comprehensive methodological exploration to identify the most robust and scalable approach for evaluating the economic implications of restoration across a wide variety of ecological and socio-economic contexts in the Danube Basin. Given the heterogeneity of restoration measures, ecological functions, and data availability, the development of a general model required testing and comparing **multiple analytical pathways**, including:

- restoration measure–specific modelling structures,
- ecosystem service valuation frameworks and principles (e.g. TEV),
- Nature-based Solutions (NBS) typologies,
- life-cycle cost structures for restoration investments, and
- combinations of Input–Output (IO) modelling with Cost–Benefit Analysis (CBA).

This exploratory phase was an essential step in determining which components could be generalized and which required case-specific treatment. It ensured that the methodology remains firmly grounded in environmental economics while also aligned with the operational needs and data realities of Danube4All.

River restoration generates benefits through **two main channels**:

1. **Investment-driven economic effects** – arising from planning, construction, materials, labour, engineering and maintenance.
2. **Ecosystem service improvements** – which may include flood regulation, water purification, habitat quality, recreational value, or non-use benefits such as biodiversity conservation.

Because these two channels differ substantially in how they can be measured, the methodological framework integrates concepts from **environmental economic theory**, **ecosystem valuation**, and **macroeconomic modelling**. This dual structure reflects the fact that some restoration benefits can be monetised and modelled quantitatively, while others cannot and require quantitative or qualitative treatment.

Following the systematic review of options and the discussions held during the September 2025 methodology meeting, the analytical approach has been consolidated into a **two-component general model**:

1. **A macroeconomic Input–Output (IO) model** that estimates the economic effect of 1 EUR invested in restoration activities. This is the core analytical output of the general model. IO analysis draws on representative restoration cost structures, which—despite differences in absolute budgets—show consistent sectoral patterns across restoration measures and therefore allow for a generalisable modelling approach.
2. **A selective Cost–Benefit Analysis (CBA)**, applied only where ecosystem service benefits can be credibly monetised using established valuation methods. Many ES, particularly non-use

and regulating services, cannot be monetised reliably; these will be addressed quantitatively or qualitatively. CBA serves as a complementary component, enriching the interpretation of ecological benefits without overreaching the available data.

This methodological refinement results in a framework that is **rigorous, feasible, and replicable** across countries and restoration types, while recognising the limitations inherent in ecosystem service valuation. The exploratory work undertaken earlier—mapping restoration measures, NBS, ES, life-cycle cost structures, and valuation datasets—feeds directly into the tools, templates, and analytical logic applied in the IO and CBA components. The sections that follow describe the methodology in detail and present the preparatory results obtained to date.

2. General theoretical framework

2.1. Ecosystem services – the starting point

Nature's benefits as monetizable and exchangeable services were included in the economic school in the 1960's with the emergence of Environmental and Resource Economics, which recognized that nature's benefits can and should be monetized. Environmental Economics broadly broadened the scope of conventional Neoclassical economics, which significantly neglected the economic value of environmental benefits due to their limited analysis[1]. According to the neoclassical economic framework, ecosystem goods and services were only valued at market prices, while ecosystem services (ES) that are utilized without involving market transactions were considered positive externalities. Within the Environmental and Resource Economics school various approaches to quantify these externalities were developed. This was done with the objective of integrating them into extended cost-benefit analyses and internalizing the externalities (i.e. environmental benefits or damages not captured through market mechanisms)[2]. The field of Environmental Economics has been advancing, creating various methods to assess external environmental costs and benefits, broadening the understanding of the economic value of the environment, and recognizing different types of economic worth of ecosystem services.

However, there are a significant number of ecosystem services that are difficult to monetize or pose intrinsic value that are difficult and expensive to evaluate. Consequently, the comprehensive array of ecosystem services constitutes the Total System Value (TSV), which entails a combination of monetary values, quantitative metrics, and qualitative assessments. Owing to data constraints and the inherent difficulties in monetizing ecosystem services, the economic value of an ecosystem typically has a more limited representation in the Total System Value. In contrast, qualitative assessment is the richest source of information[3].

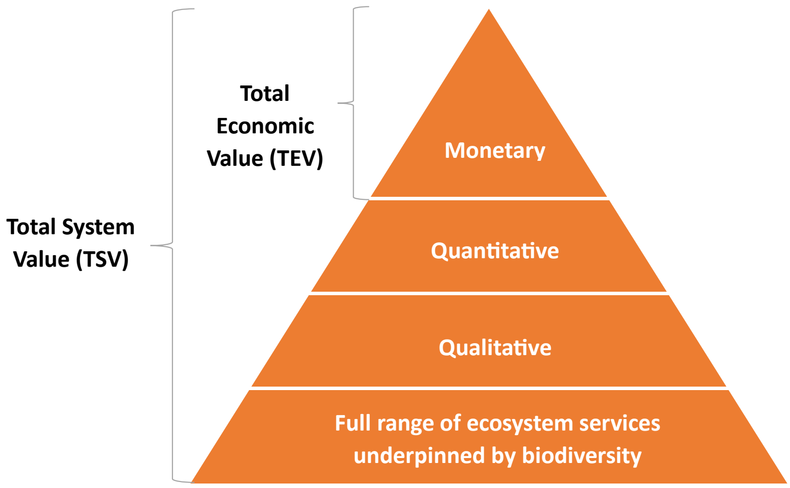
- **Total Economic Value (TEV)** is defined as "the sum of the values of all service flows that natural capital generates both now and, in the future, appropriately discounted. These service flows are valued for marginal (incremental) changes in their provision. TEV encompasses all components of

[1] Gómez-Baggethun, E., de Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Ecological Economics
[2] Luke Brander, Erik Gómez-Baggethun, Berta Martín-López, Madhu Verma (2010), Chapter 5 The economics of valuing ecosystem services and biodiversity, TEEB: The Ecological and Economic Foundations
[3] IEEP, & European Commission. (2011). Estimating the overall economic value of the benefits provided by the Natura 2000 network. Publications Office of the European Union. https://ieep.eu/wp-content/uploads/2022/12/Economic_Benefits_of_Natura_2000_Network_Synthesis_report.pdf

(dis)utility derived from ecosystem services using a common unit of account: money or any market-based unit of measurement that allows comparisons of the benefits of various goods."[4]. **TEV is the standard valuation framework in assessing the ES monetary value used for conducting a CBA analysis.**

- **Quantitative** assessment of an ecosystem service involves the measurement or estimation of the actual physical quantities or numerical values associated with that service. It aims to provide concrete, measurable data regarding the benefits derived from a particular ecosystem. For river ecosystems, quantitative assessments might involve measures such as: Cubic meters of purified water, fish biomass, flood regulation capacity, sediment retention, carbon sequestration, share of population affected by loss of food provisioning, etc.
- **Qualitative** assessment involves appraising the benefits offered by the specific ecosystem under scrutiny. This method seeks to understand the non-quantifiable aspects of these benefits, taking into account factors such as cultural, aesthetic, and experiential values. By considering the range and significance of these advantages, a qualitative assessment provides valuable insights into the broader, non-monetary dimensions of ecosystem services.

Figure 1 The benefits pyramid and Total Economic Value versus Total System



Source: Institute for European Environmental Policy, Estimating the Overall Economic Value of the Benefits provided by the Natura 2000 Network. Final Report to the European Commission, 2011

Under the TEV framework presented above, the value of the benefits is generally classified into 2 main groups: **use** and **non-use values**[5].

- **Use Values** refers to the tangible, quantifiable benefits that individuals or communities use, and which are reflected in the economic market. The use values can be divided into direct use values and indirect use values. Additionally, use values can encompass option values, also known as quasi-options:
  - **Direct use values** are directly obtained from using the ecosystem services, such as goods and services that are physically consumed, harvested, or experienced. These

[4] Luke Brander, Erik Gómez-Baggethun, Berta Martín-López, Madhu Verma (2010), Chapter 5 The economics of valuing ecosystem services and biodiversity, TEEB: The Ecological and Economic Foundations
[5] Bregje van Wesenbeeck, Sien Kok, Camilo Benitez Avila, Robyn Gwee, Ellis Penning, *Economic Rationale of NBS in Freshwater Ecosystems*, 2021

types of services mainly fall under the category of "provisioning services". Examples of direct use values include raw products such as fish and construction materials, recreational activities like fishing and tourist services that can be marketed. Direct use values can often be estimated through market transactions or by assessing the costs individuals would incur if the ecosystem service were not available;

- **Indirect use values** refer to the benefits that people receive from ecosystem processes or functions that support and maintain the conditions for various direct uses. Unlike direct use values, these benefits are not immediately consumed or experienced, but they play a crucial role in enabling the provision of direct services and are usually associated with regulating services. Indirect use values encompass ecosystem services that safeguard both natural and human systems, like mitigating floods and water purification;
- **Option value** refers to the perceived worth that individuals attach to the assurance of future access to ecosystem services for their personal benefit, even when the specific benefits are not currently well-defined or utilized. For example, conserving genetic resources could be assessed as "option values". However, it is worth mentioning that it has been debated whether option value should be included in Total Economic Value analysis. Option value can be thought of as a way of framing TEV in uncertain situations, similar to an insurance premium or the value of deferring a decision until the uncertainty is resolved. As an insurance premium, the option value can also be defined as "the added amount a risk averse person would pay for some amenity, over and above its current value in consumption, to maintain the option of having that amenity available for the future, given that the future availability of the amenity is uncertain".

- **Non-use values** pertain to the benefits derived from ecosystems that do not involve direct or indirect consumption or utilization of a specific ecosystem service. Instead, they stem from the satisfaction individuals gain from knowing that biodiversity and ecosystem services are preserved, and that others either currently have or will enjoy access to them in the future. There are two main categories of non-use values: existence values and philanthropic values which encompass altruistic values and bequest values.
  - **Existence Values** refer to the satisfaction people experience simply knowing that a particular ecosystem or species exists, regardless of any direct or future use they may have for it. For example, the appreciation of rare or endangered species solely for their existence falls under existence values;
  - **Altruist values** relate to the satisfaction individuals derive from knowing that others will have access to and benefit from a preserved ecosystem and it concerns intra-generational equity. More recent studies replace the altruist value, with **stewardship value**, which is defined as "the value placed by society on the maintenance of a healthy environment for all living organisms and not just humans"[6].
  - **Bequest values** concern the desire to pass on intact ecosystems and their associated services to future generations as a legacy, emphasizing the importance of inter-generational equity.

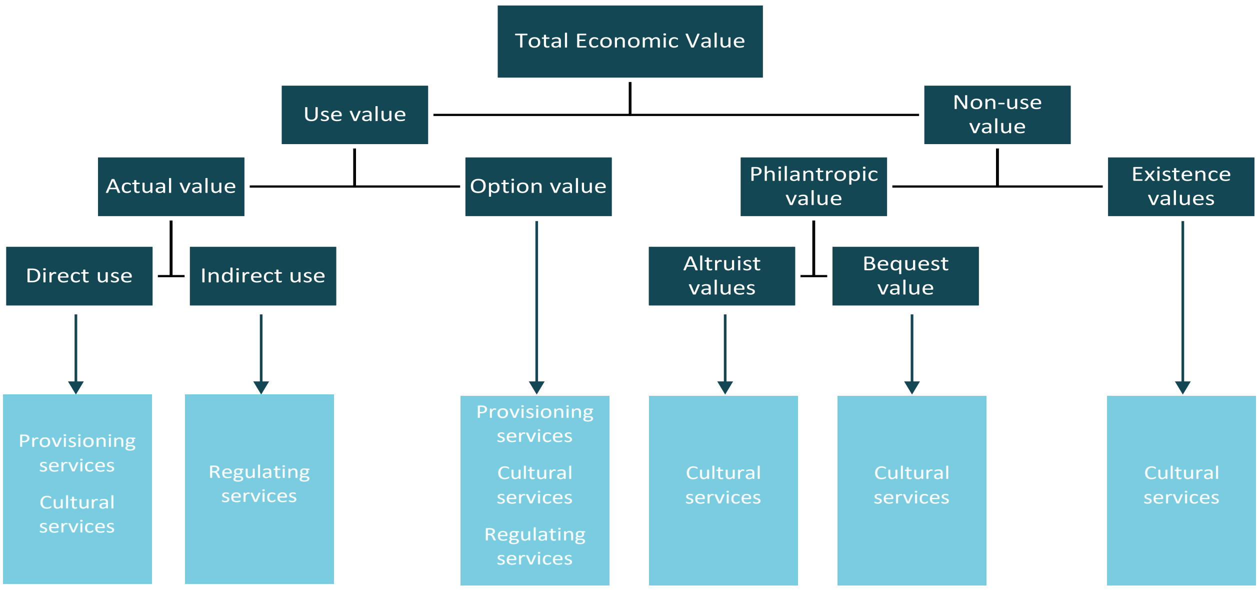
[6] ELD Initiative (2019). ELD Campus. Module: Valuation of ecosystem services

Assessing the economic value of non-use values is more challenging compared to use values, as non-use values are intangible and typically can't be monetized, such as moral, religious, or aesthetic aspects. Non-use values create experiences which are valued only in the valuer's mind[7].

The TEV is strongly tied to the ecological services they provide. When these services diminish, for instance due to pollution, it can lead to a devaluation of how people perceive environmental quality. Ultimately, this can result in reduced social benefits associated with the environment. Thus, the economic value doesn't directly measure the inherent quality of the environment, but rather mirrors people's perception of that quality[8].

Evaluating the TEV of an ecosystem hinges on identifying and comprehending all its ecosystem services. Nevertheless, it's crucial to acknowledge the inherent limitations of economic assessments, particularly when it comes to non-use value. Given the complexity of valuing ecosystem services, it requires careful selection and application of valuation methods tailored to the specific context and requirements of a given situation. While aiming for high accuracy requires using the best valuating techniques and methods, assessing the TEV is often highly time and resource consuming.

Figure 2 Value types of ecosystem services within the TEV approach



Source: Adapted from TEEB (2010) and Pascal et al. (2010)

2.2. Valuation methods for benefits

When it comes to valuing the services provided by ecosystems, various methods come into play depending on the type of benefit being assessed. The TEV framework reveals 5 main categories and subcategories of valuation approaches:

- **benefit transfer approach**

[7] TEEB (2010), The Economics of Ecosystems and Biodiversity: Chapter 5 - The economics of valuing ecosystem services and biodiversity
[8] European Commission Directorate-General for Regional and Urban policy, *Guide to Cost-Benefit Analysis of Investment Projects*, *Economic appraisal tool for Cohesion Policy 2014-2020*, 2014

- **direct valuation methods;**
- **cost-based approach[9];**
- **revealed preferences approach;**
- **stated preference approach;**

Each of the valuation approaches encompass a range of valuation methods that can be applied to reveal the economic value of an ES. Each method comes with its own set of challenges that can influence the valuation estimates. Therefore, it is recommended to use more than one method to enable comparison between the revealed results. Some results may provide valuable rough estimates, while others may be considered more experimental. Using a multiple method has higher chances of yielding reliable results, but this largely depends on the availability of data on site values. Additionally, acknowledging the existence of uncertainties in economic valuation of ecosystem services, the TEEB methodology also recommends that the results are presented as ranges[10].

Benefit transfer

Determining the value of ecosystem services would ideally require conducting comprehensive ecological and economic studies for each ecosystem under consideration. However, these studies are often costly and time-consuming, which can make them impractical in many cases. Benefit transfer provides an economical alternative for conducting economic valuations of ecosystem services, in areas where conducting a full valuation study may be impractical due to constraints such as time, resources, or data availability. It leverages existing information revealed in previous studies, making it a more cost-effective option compared to other valuation methods[11].

This transfer can be applied across various dimensions, including time, space, populations, and at times, even across different types of ecosystem goods. Notably, the benefit transfer is mostly useful in valuating recreational values, assuming a high degree of similarity between sites and recreational experiences provided. However, when applying the benefit transfer method, it is crucial to adapt the estimation to account for any variations between the reference site (for which data was measured) and the site under valuation, as overlooking significant differences between sites can lead to inaccurate estimations.

Direct valuation methods

The direct market valuation methods draw upon real-world market data, providing a reflection of actual preferences or costs for individuals. In this approach, estimating the economic value of an ecosystem service involves utilizing readily available and easily obtainable data types like prices, quantities, and costs.

- **Market price-based method**
    - Relies on actual market transactions to assign a value to ecosystem services. The value is directly obtained from the prices people are paying for these goods or services
    - Examples: increased land value, revenues from tickets paid.

---

[9] As the cost-based approach of the ecosystem value is also based on real market prices, some methodologies view it as a subcategory of the market valuation approach

[10] TEEB (2010), The Economics of Ecosystems and Biodiversity: Chapter 5 - The economics of valuing ecosystem services and biodiversity

[11] Kok S., Grondard N., Lenz M.I., Bangalore Suresh N.T., Garcia X., Llorente O., Estrada L., Acuna V., Birk S., 2025. Guidance Document – Cost-Benefit-Analysis in freshwater ecosystem restoration. EU H2020 research and innovation project MERLIN deliverable D3.4. 20-21 pp. https://project-merlin.eu/files/merlin/downloads/deliverables/MERLIN_D3.4_revised_Oct2025.pdf

Advantages	Challenges and limitations
• it accurately captures an individual's willingness to pay for both the costs and benefits associated with goods that are actively exchanged in markets, such as fish, timber or recreational and cultural services, for which people have to pay • easily available data, making it a practical and reliable approach • using observed data on actual consumer behaviour ensures that the valuation process is grounded in real-world scenario • one of the most widely accepted economic techniques, due to its reliability and credibility of the valuation process.	• may be constrained by the availability of market data • market imperfections can lead to distortions in market prices, potentially resulting in an inaccurate reflection of the economic value of goods or services to society as a whole. • Seasonal fluctuations and other factors influencing prices also require careful consideration in the analysis. • it typically does not account for the market value of other resources involved in bringing ecosystem products to market, potentially leading to an overestimation of benefits
Conclusion: should be applied with careful consideration and in combination with other methods to elicit the TEV of an ecosystem service[12]	

- **Production-based approach**
  - It is used when a marketable good is created by combining the goods or services provided by an ecosystem with other inputs. This approach is based on the fact that enhanced ecosystem services can lead to improvements in income or productivity, subsequently resulting in lowered costs, increased quantities of marketable goods due to either an increase in the number of consumers or the number of producers[13].
  - Example: improved water quality – increased fish production – increased fish farming – higher profits
  - It estimates the increase of output in the economic sectors directly impacted by the technical solution implemented

Advantages	Challenges and limitations
• relatively straightforward and has limited data requirements, which makes it accessible and easy to implement. • It often relies on readily available information, streamlining the valuation process and potentially reducing expenses associated with data collection and economic analysis. • These factors increase the cost-effectiveness of the method, and enhance the method's practicality.	• even though widely utilized in evaluating the impact environment services have on the economic activity in a region, it is constrained to valuing resources that can be directly utilized as inputs in the production of marketable goods. • requires a good understanding of the economic activity and processes, as well as the relationship between the quality or quantity of a resource and the actual outcomes achieved[14].

[12] https://www.ecosystemvaluation.org/market_price.htm
[13] TEEB (2010), The Economics of Ecosystems and Biodiversity: Chapter 5 - The economics of valuing ecosystem services and biodiversity
[14] https://www.ecosystemvaluation.org/productivity.htm#:~:text=The%20productivity%20method%2C%20also%20referred,production%20of%20commercially%20marketed%20goods.

	• the application of the method is relatively straightforward in single-use systems (one ecosystem service impacts one economic activity).
Conclusion: Should be applied with careful consideration and in combination with other methods to elicit the TEV of ecosystem services[15] Sometimes, the increased output is not apparent, such as in national parks where economic activities are limited.	

Cost-based approach

These methods assess the value of ecosystem services by estimating the costs associated with either their replacement (the ecosystem service needed to be artificially recreated) or restoration (in case of a natural disaster), as well as cost savings provided by an ES.

There are three primary methods:

- **Replacement cost** – involves determining the cost of artificial substitutes for environmental goods or services. This approach provides an estimate of the economic value of goods or services based on the costs incurred to replicate them artificially.
  - Example: instead of a built concrete wall, maybe a stone revetment would be built in order to consolidate the river banks. The method compares the cost for each option.
  - This method is helpful for approximating indirect ecosystem benefits where estimating the damage costs is impossible due to a lack of data.
  - Should be used in combination with either stated or revealed preference methods. This is essential to determine if there is a willingness to pay for the replacement cost option. Not having enough willingness to pay would indicate an overestimation of the value of the ecosystem service, making the cost of replacement simply an expense rather than an accurate representation of the ecosystem service's value[16].
  - Additionally, ensuring that the replacement solution maintains net benefits equal to or less than the original function can be challenging[17].
- **Damage cost avoided** - evaluates the benefits offered by an ecosystem by calculating the costs that would have been incurred in the absence of ecosystem services and estimates either the value based on the costs of avoiding damages due to lost services to property or the expenses incurred in preventing damages.
  - provides a tangible and measurable economic value by estimating the cost that could arise in the absence of an ecosystem service. This approach is particularly effective in cases where clear cause-and-effect relationships can be established between environmental changes and the associated economic impacts.
  - While the avoided damages costs method offers valuable insights, it also comes with some potential drawbacks. One significant challenge is accurately estimating the potential damages that would occur without preventive action, which can be complex and uncertain. Another disadvantage is that this method may not capture the full spectrum of non-use values associated with ecosystems, such as existence or bequest values, which are important

[15] https://www.ecosystemvaluation.org/market_price.htm
[16] https://www.conservation-strategy.org/
[17] TEEB (2010), The Economics of Ecosystems and Biodiversity: Chapter 5 - The economics of valuing ecosystem services and biodiversity

considerations in holistic environmental valuation. It can also be sensitive to assumptions and uncertainties in economic models, potentially leading to overestimation or underestimation of values. Implementing this method may require a comprehensive understanding of the environmental processes and systems involved, which can be resource-intensive and time-consuming.
    - Example: assume that in the absence of river bank consolidation works, erosion would lead to a decrease in land value price, loss of useful land, floods, and deterioration of infrastructure.
- **Mitigation/restoration cost** – how much would it cost to repair/reduce the damage in the absence of the solution proposed?
    - Refers to the expenses incurred by individuals or communities in taking actions to reduce or avoid the negative impacts of environmental degradation, in the absence of an ecosystem service that would do so[18].
    - In the context of a river ecosystem, mitigation costs might involve actions taken to preserve or restore the services provided by the river. For instance, this includes expenses for preventive measures in the absence of wetland services, which play an important role in flood mitigation (flood barriers) or relocation costs[19].

Revealed preferences approach

Examine individual economic decisions within existing markets related to a specific ecosystem service. This methodology asserts that economic actors (people) "reveal" their preferences through their market behaviour and the choices they make. The primary valuation methods under this approach are:

- **Hedonic pricing/wage method** - values ecosystem services by estimating their impact on the property prices and wages in the surrounding environment.
    - This approach assumes that changes in property prices reflect the value individuals place on specific characteristics, including environmental attributes, of the surrounding area.
    - For example, an increase in the provision of ecosystem services (water purification, landscape, air quality) in a specific area will directly lead to the rise in property value of the real estate, as well as an increase in wages in that area.
    - Property markets and wages are known to efficiently reflect the value of willingness to pay/willingness to accept, making them reliable indicators. Obtaining data on property sales and average wages is usually straightforward, with numerous sources readily accessible.
    - This method is only applicable to environments where ecosystem services are viewed as valuable by society, and the environmental characteristics have an impact on the proprietary prices or wages, indeed.
- **Travel cost method -** quantifies the value of an ecosystem service by calculating the individuals' willingness to pay for access to that ecosystem service.
    - This method is mainly applied in the valuation of recreational values related to biodiversity and ecosystem services, by calculating the costs individuals incur in order to access a specific recreational area/site

[18] ELD Initiative (2019). ELD Campus. Module: Valuation of ecosystem services. Available from www.eld-initiative.org
[19] TEEB (2010), The Economics of Ecosystems and Biodiversity: Chapter 5 - The economics of valuing ecosystem services and biodiversity

  - Examples: travel expenses, admission fee, on-site spending

Stated preference approach

The stated preference approach involves directly asking individuals about their willingness to pay for an environmental change and the associated services it provides, under different scenarios. This method is particularly valuable when estimating non-use values for ecosystem services, as well as use values in situations where no actual market exists to derive the economic value of the ecosystem services. There are two main valuation methods under the stated preference approach:

- **Contingent valuation method (CVM)** - entails directly asking individuals, typically through surveys, about the amount they would be willing to pay for a particular ecosystem service.
  - In certain instances, individuals may also be asked about the compensation they would accept (willingness to accept) in exchange for foregoing specific environmental benefits.
  - Under this method. Individuals explicitly state their willingness to pay, contingent on a specific hypothetical scenario and a detailed description of the ecosystem service in question.
- **Choice (or contingent) modelling method (CM)** - In a choice modelling study, participants are presented with multiple options, each defined by different characteristics.
  - Among these characteristics, a price or compensation is included.
  - Respondents are then tasked with evaluating all options by weighing the various attributes against each other.

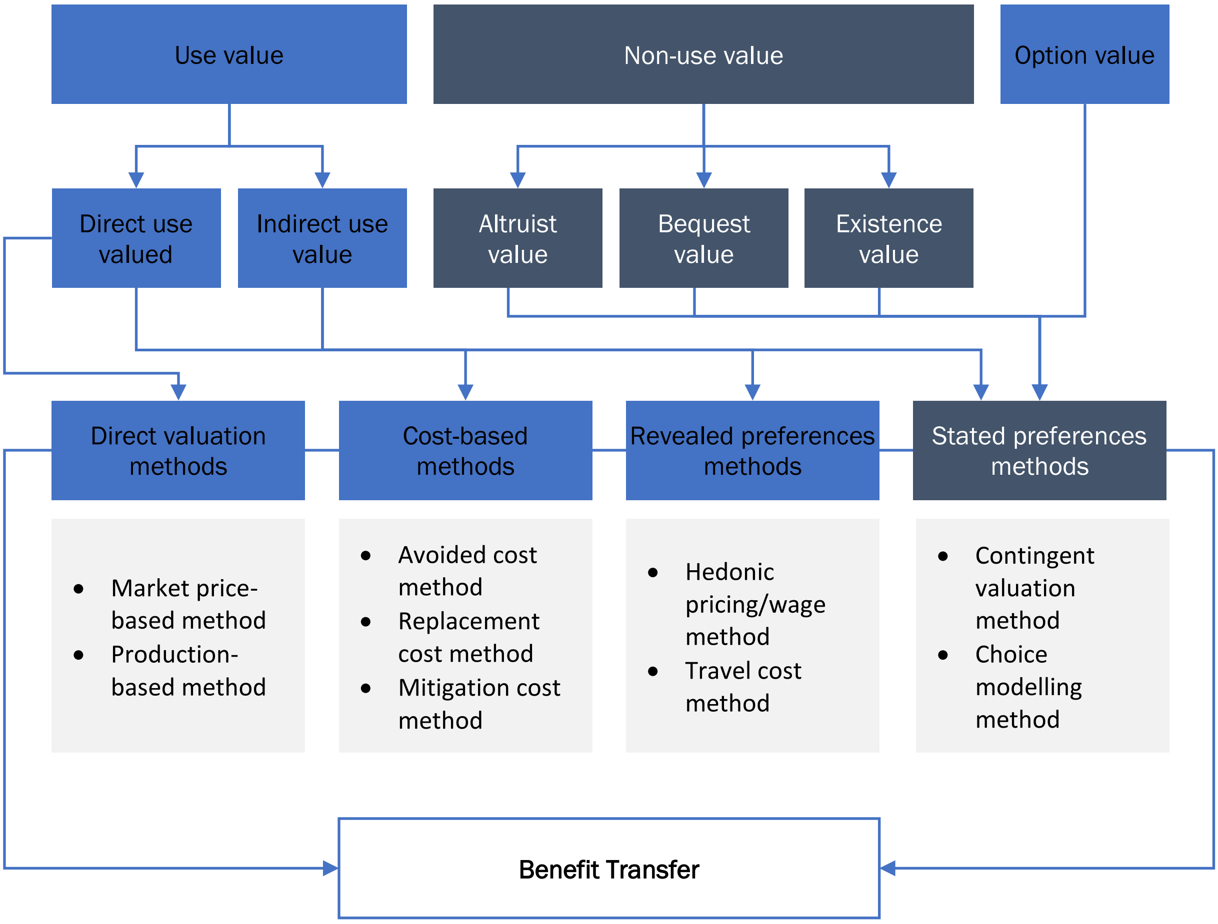
Which methods to use?

Selecting the appropriate valuation method is crucial to the economic analysis of a nature-based solution that provides ecosystem services. As noted earlier, ecosystem services provide multiple values, ranging from direct use values to non-use values, which are often intangible and difficult to quantify. As such, the following principles and steps will be applied:

- Clearly define the objectives and scope of the valuation;
- Develop a comprehensive list of ecosystem services and their value, to understand their nature and relevance to the site;
- Determine possible methods of valuation to use for each value of the ecosystem service;
- Identify the resources and data available to identify the applicable valuation method for the analysed case.

Choosing the most appropriate valuation method also depends on the costs of conducting the evaluation as well as any time constraints. Some valuation methods, and even specific techniques, can be a lot more expensive than others and can also require more time. When evaluating an ecosystem service, a “hybrid” valuation method can be used, combining multiple valuation approaches to take advantage of the strengths of each valuation method and compensate for their limitations.

Figure 3 Ecosystem services values and total economic valuation methods



Source: Author's illustration based on ELD Initiative (2019). ELD Campus. Module: Valuation of ecosystem services & Bartkowski, Bartosz & Massenberg, Julian. (2022). The economics of soils' contribution to human well-being

Regarding the types of ecosystem services, different ecosystem services require different valuation methods:

- **Provisioning services** encompass products obtained from ecosystems (e.g. fresh water, food, fibre, fuel, genetic resources, biochemical, natural medicines, and pharmaceuticals). Thus, the **market-based method** is the most appropriate for estimating their economic value[20];
- **Regulating services** provide benefits obtained from the regulation of ecosystem processes, e.g. water regulation, erosion regulation, water purification, waste regulation, climate regulation, etc.[21]. Regulating services usually do not yield products that can be traded in the market, and their value is not usually directly expressed in prices. Thus, indirect valuation methods are most suitable for these types of services. **Cost-based methods** and **stated preferences methods** are the most used valuation methods for regulating services[22];

[20] Luke Brander, Erik Gómez-Baggethun, Berta Martín-López, Madhu Verma (2010), Chapter 5 The economics of valuing ecosystem services and biodiversity, TEEB: The Ecological and Economic Foundations
[21] Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R., and Davidson N. (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels; Ramsar Secretariat, Gland.
[22] TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions, and recommendations of TEEB

- **Cultural services** when they are not directly traded on the market (e.g. there is no entry fee for a national park) hold only spiritual value and energy from people's perception. Thus, **stated preferences methods** are mostly applied to estimate the economic value of the cultural services of an ecosystem;
- **Supporting services** refer to the functions required for the generation of all other ecosystem services. They distinguish themselves from provisioning, regulating, and cultural services as they often have indirect effects on society or appear over long periods of time. In valuating supporting services, the most widely used methods are **stated preferences methods and cost-based methods**.

2.3. Valuation methods for costs

Evaluating the costs of an NBS relies on the application of the Life Cycle Costs (LCC) methodology. LCC, also referred to as Total Cost of Ownership (TCO), takes into account the overall expenses arising from implementing and maintaining the nature-based solution. The proper identification of LCC offers the information required to determine the necessary investments to implement and maintain the NBS, while also presenting an overview of cost distribution over time.
In the life cycle of a NBS project the following expenditure categories incur[23]:

- **CAPITAL EXPENDITURES (CAPEX)**: expenses related to the initial stages of an NBS project. These include activities like design and planning, conducted by professionals like engineers and landscape architects. Additionally, CAPEX covers costs for obtaining necessary permits from various public entities, acquiring land, and potentially resettling communities if deemed necessary and appropriate. It also involves site preparation and construction tasks carried out by a contracted third-party entity. This may involve activities like planting trees, vegetation, and installing various components of the NBS solution. A subcategory of the CAPEX is the replacement cost, which occur during the implementation period to replace any short-life machinery and/or equipment. Allocation of costs over the years must align with the envisioned physical accomplishments and adhere to the implementation timeline.
- **OPERATING EXPENSES (OPEX)**: the ongoing costs that arise over the duration of the NBS life cycle. These expenses include the management and maintenance of the NBS such as overseeing protected areas, upkeeping urban green spaces, monitoring the quality of air and water, eradicating invasive species, as well as activities like fertilization and the allocation of land use payments to landowners if necessary. Understanding the operating costs of an NBS is important for identifying sustainable funding sources and designating accountable entities to oversee and carry out maintenance and monitoring responsibilities post-project completion.
- **TRANSACTION COSTS**: expenses for upstream studies, technical assistance, and engaging stakeholders. Stakeholder engagement is often necessary for defining benefits, establishing goals, collaboration between the community and the project team to identify specific investments for implementation. Due to their comprehensive and cross-sectoral nature, transaction costs for NBS projects can be relatively substantial. It is often necessary to engage extensively with the community and stakeholders to appropriately define, plan, and implement the project. This

[23] Boris van Zanten, Gonzalo Gutierrez Goizueta, Luke Brander, Borja Gonzalez Reguero, Robert Griffin, Kavita Kapur Macleod, Alida Alves, Amelia Midgley, Luis Diego Herrera, and Brenden Jongman (2023). Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

engagement serves the dual purpose of increasing awareness of the benefits and ensuring the project's long-term sustainability.

- **DISSERVICES**: the negative effects the implementation of a NBS can have on human wellbeing. For instance, certain NBS projects, such as the construction of barriers or embankments, may alter or even destroy existing habitats for native flora and fauna, potentially leading to disruptions in the local ecosystem. Accounting for significant disservices is advised in order to understand the effects on various parties and the distributional repercussions of an NBS project.
- **OPPORTUNITY COSTS**: "those costs associated with the foregone alternative, which can be measured by the net benefit foregone because the resources that provide the services cannot be used in their next beneficial use"[24]. The opportunity costs of a good, service, or resource is equal to their value if used in an alternative way. For example, implementing an NBS would require both land and water resources, which could otherwise be used in an alternative way. In this context, the primary opportunity costs to consider are the net gains that could have been achieved if the land and water resources were allocated to other income-generating activity, such as agriculture, rather than the NBS. Land is a particularly valuable resource for nature-based solutions, as the use of land is higher compared to grey-infrastructure alternatives. Thus, the opportunity cost for land could be significant. Determining the opportunity costs can be accomplished through straightforward calculations, either by quantifying the income foregone due to the resources not being utilized in their most lucrative alternative, or by calculating the cost of compensation in cases involving property rights loss. In the case of agricultural land, the opportunity cost can be calculated using data on the average income per unit of land, while for urban land, the calculation can be based on the market price of land, or, similar to agricultural land, by estimating the profit that would have incurred by the subsequent economic activity. An important factor when determining the opportunity costs is consulting the specific stakeholder groups bearing these costs, such as farmers, local communities, commercial developers, or governmental entities, to be able to conduct an accurate analysis. Finally, double counting between opportunity cost and CAPEX/OPEX cost components will be avoided, for example, by not including land acquisition costs in CAPEX while also calculating the opportunity cost of land.

Table 1 NBS cost components

CAPEX	OPEX	TRANSACTION COSTS	OPPORTUNITY COSTS	DISSERVICES
• Design and planning • Securing permits • Land acquisition • Community resettlement • Site preparation • Construction • Tree planting	• Monitoring labour and technology • Tree and vegetation maintenance • Invasive species removal • Land use (for example, rent or other payments to landowners)	• Scoping studies and other technical assistance • Community engagement / stakeholder outreach • Goal setting and prioritization	• Value of using land for other purposes such as agriculture or residential/ commercial development • Opportunity cost of local labour and materials used for implementing the NBS project	• Negative impacts from NBS (for example, mosquitoes, pests)

[24] Graveline, N., Joyce, J., Calatrava, J., Douai, A., Arfaoui, N., Moncoulon, D., Manez, M. De Ryke H., Zdravko K. (2017): "DELIVERABLE 4.1: General Framework for the economic assessment of Nature Based Solutions and their insurance value". EU Horizon 2020 NAIAD Project, Grant Agreement N°730497

	• Land protection, including managing and controlling access			

Source: Boris van Zanten et al. "Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers" (2023)

3. Translating the framework into real-life work

This chapter describes how the theoretical concepts, valuation logic, and economic modelling principles are translated into a practical workflow. The objective is to operationalise the methodological framework for Milestone 11 and develop a general model that can be applied both to the demo sites and, subsequently, across the Danube Basin.

Given the need to collect and process data systematically, the team developed templates and workflows to ensure coherence and to generate multiple model iterations based on the required context. As such, this approach serves as the operational backbone for translating the theoretical framework into practical modelling steps. These templates fulfil three key functions:

1. Structuring the economic inputs for IO modelling. Although restoration measures differ in scale and ecological specifics, their cost structures (planning, construction, materials, labour, maintenance) are sufficiently comparable to be aggregated into a **standardised cost allocation vector**. The templates consolidate these components and map them to economic sectors, allowing any intervention to be translated into IO-compatible inputs, regardless of country or measure type.

INPUT-OUTPUT ANALYSIS is a macroeconomic tool applied to depict the interlinkages between the main activities of a national or regional economy. Using a matrix representation of an economy to predict the effect of changes in one industry on others and the economy as a whole, it shows how sectors or industries use inputs and provide outputs to interlinked sectors. The resulting coefficients help measure the impact of the increase in demand - the higher the multiplier, the higher the impact on the economy.

Due to differences in national economies' structure (sectors are interlinked differently in the countries along the Danube), it helps show how 1 EUR invested in the upper basin multiplies differently to 1 EUR invested in the lower basin in the same type of intervention. How to be interpreted:

- The output from one industry as a result of the investment project may become the input of another (Industries use the products of other industries to produce their own products);
- The investment money represents a shock for the economy as surplus money is introduced in the economy, triggering demand rising in other sectors;

Main idea: an initial investment creates output in the local economy, as well as jobs, and it quantifies the increase in demand/purchases of goods and services required to deliver that output, with consequences along the supply chain.

2. Screening ecosystem services for selective monetisation.
The templates enable the consistent documentation of ecosystem services, their classification, and their monetisability assessment. Only ES with robust monetary values—derived from market data, avoided costs, or credible literature-based transfers—are carried forward into the CBA. This supports the project's methodological orientation:

- **IO analysis = core evaluation tool**,
- **CBA = selective and complementary**, applied only where data justify monetisation.

CBA helps answer the question: *How much value (i.e. benefits) is created for any 1 EUR of investment (i.e. costs)?*

Under this approach, the following categories of monetary values are part of the CBA analysis[25]:

- **Capital and operational costs**: Necessary for the establishment and maintenance of the NBS included in the strategy;
- **Opportunity costs**: Represent foregone benefits, such as areas taken out of production or land used for NBS that cannot be utilized for other purposes like construction;
- **Avoided Damage Costs**: Refers to the damages prevented due to the implementation of a NBS project (e.g., risks from flood damage);
- **Incremental co-benefits**: Include additional environmental, economic, and social benefits generated by NBS, or ecosystem services (all benefits identified in Stage II).

Thus, CBA plays a **complementary**, not a structural role.

3. Providing a reusable repository for scaling the model. The templates function as a harmonised data structure that practitioners can use when applying the general model to new sites. They contain the indicators, valuation options, and sector-allocation rules that ensure methodological consistency without requiring the creation of measure-specific submodels.
The exploratory work undertaken through these templates—testing ES valuation pathways, NBS classifications, and cost structures—provided essential evidence for the refined, high-level methodological approach. It also forms the basis for the Stage V toolkit that will enable practitioners to apply the general model efficiently and consistently across the Danube Basin.

Overview of the implementation stages

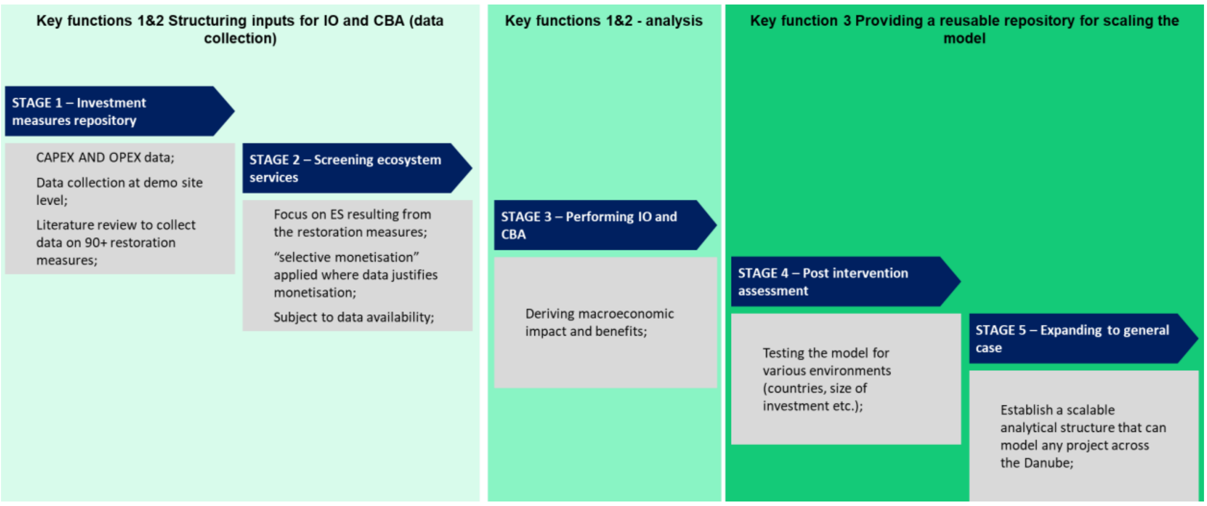
The analytical workflow for Milestone 11 is structured into **five interconnected stages**, moving from creating a knowledge and information base, to valuation, modelling, impact assessment, and finally generalisation.

Given the time constraint, the novelty of the work to be carried out (i.e. testing the model on demo sites being developed under the Danube4All project) and the need to deliver real solutions based on real data that feed into a model to be further employed in the future in other intervention sites at various scales and geographies along the Danube, we propose a **bottom up approach, starting from the demo sites as a test site for the economic modelling.** This approach will allow – for all involved stakeholders – to better understand what can and cannot be achieved at this intersection between ecology and economics, what are the limitations and mitigation measures with respect to data

[25] Coënt, P.L. et al. (2021) 'Is-it worth investing in NBS aiming at reducing water risks? Insights from the economic assessment of three European case studies,' Nature-Based Solutions, 1, p. 100002. https://doi.org/10.1016/j.nbsj.2021.100002.

available and its ability to feed reliable models in order to provide comprehensive pictures of individual sites but which can be further added up to provide larger intervention pictures in wider areas (i.e. intervention in Upper Danube) or across similar types of interventions (like groynes).

Figure 4 Overview of the implementation stage



Source: Author's illustration

Although the stages were initially designed to allow a high degree of granularity, the refined methodological orientation agreed with partners—particularly the emphasis on a high-level, generalisable IO model—ensures that each stage now contributes in a streamlined and strategically coherent manner. Structured around the three key functions mentioned above, the implementation phase requires a few steps to help accomplish the main result, which are summarised below:

3.1. Stage 1 – Structuring the economic inputs of investment measures

As outlined above, in order to fulfil this function, the following actions have been designed:

Data collection at the demo site level

The following table is intended to collect information on the **demonstration sites** in order to use it as a demo for assessing economic benefits using the IO method. Instructions on how to fill in the table are provided in each category.

Table 2 Data collection table – sample for investments at the demo site level

Information Category	Description
1. Project Details	Project name and location (i.e. name of the demo site). *Additional info required:* - *Please provide info on the location of the investment and of the area served from an administrative point of view (on which NUTS2 or 3 is the site located, incl. area of interest/of expected benefits)* Description of the nature-based ecosystem project, including its **objectives**, **scope**, and **target ecosystem(s)**. *Additional info required:*

	- *Is it located in a protected area? Which one? How does that impact the work that needs to be done?* Please provide any useful documents
2. Project Timeline and Stage	Start date and anticipated completion date - *How much does the construction work take?* - *Which is the expected duration of the operation and maintenance stage?* Current stage of development (e.g., planning, design, implementation, monitoring).
3. Budget and Funding	Total project budget and breakdown of costs (e.g., capital investment, operational expenses) as per section 1.2 (table 2 below) Sources of funding (e.g., government grants, private investments, philanthropic donations) for the **construction stage** and the **operation/maintenance stage**.
4. Nature-Based Solutions	Description of the nature-based solutions being implemented (e.g., wetland restoration, reforestation, green infrastructure). *Additional questions:* - *Will the investment: (1) create new ecosystem services, (2) enhance existing ones, (3) reduce/destroy existing ones?*
5. Expected Benefits	Anticipated ecosystem services provided by the project Estimated quantities or magnitudes of benefits. Expected limitations (e.g. normally you would expect to see fishing but because the demo site is located in a protected area, this ES is restricted)
6. Assumptions and Uncertainties	Assumptions made in estimating project costs and benefits *Please refer to:* - *Are there local companies involved in providing the work? Which ones and in which economic sectors are they operating?* - *How many employees are dedicating to the investment work?* Sources of uncertainty and risk factors affecting the accuracy of estimates.
7. Project indicators	Plan for monitoring project implementation and assessing performance over time Indicators used to track progress and measure outcomes.
8. Stakeholders	Description of stakeholder engagement processes and community involvement in project planning and implementation Feedback received from stakeholders regarding project objectives, priorities, and concerns.
9. Environmental and Social Considerations	Environmental impact assessments and mitigation measures Social benefits including impacts on local communities

Financial data regarding the investment – Table 2 line 3 – continued.

Data collected at this stage is in line with insights from the literature, summarized in Table 1 above. After collecting quantitative data about the demo sites, we will be able to start calculating the economic impact of the investment in the demo site. Depending on the granularity of the data collected, we will be able to allocate it by economic sector of the national economies in which the demo sites are located, and compute how they multiply across the economy. The more details we have, the more economic sectors we can include in our analysis, providing a more comprehensive picture of how they interact.

Table 3 Financial data covering the demo site

Name of the demo site	Data about investment	Details	Amount (in EUR)
Upper Danube	*Initial investment – **planning***	*Please provide a brief description of the planning phase – what was needed to set up the investment project (feasibility study, technical studies, on-site measurements, etc.)*	
	1.1. Planning		
	1.1. Approval and permits		
	1.2. Legal support		
	1.3. Accounting		
	1.4. Marketing and communication	*If applicable – in case stakeholders were involved*	
	1.5. Management	*If done by third parties*	
	1.6. Human resources	*Gross payment to employees involved by type of work (planning, approval, legal etc.)* *Number of FTE involved – if possible, by gender*	
	1.7. Other	*e.g. office supplies, subscriptions, software, telecom, delivery – any support products and services used*	
	*Initial investment - **implementation***	*Please provide a brief description of the implementation phase – please refer to: involvement of local companies, transportation of materials / machinery / etc, related work that might have been billed separately,*	
	2.1. Materials used	*If transportation and other related work was paid separately from materials, please specify amounts for each* *Fuels and energy sources used – please consider them as a distinct component and provide data about it*	
	2.2. Machinery/equipment		
	2.3. Construction		
	2.4. Human resources	*Gross payment to employees involved by type of work (materials, machinery operation, construction)*	

		Number of FTE involved – if possible, by gender	
	2.5. Other	*e.g. office supplies, subscriptions, software, telecom, delivery – any support products and services used*	
	Operation and maintenance	*Please provide details on the types of post-implementation activities involved as well as the expected duration of these operations*	
	3.1. Human resources	*Number of FTE involved – if possible, by gender* *Gross payment*	
	3.2. Supervision /monitoring	*Either gross payment or services contracted for monitoring*	
	3.3. Maintenance work	*Expenses with construction, materials, transportation, etc.*	
	3.4. Other	*Anything else not covered above*	

Literature review to collect broader data on NBS restoration measures

In addition to the demo site level data, in order to provide a more general framework of economic impact measurement, we are currently collecting data from NbS case studies that are relevant for river restoration.

So far, Natural Water Retention Measures (NWRM)[26] provided an extensive list of case studies that still require processing and validation of data in order to become a valuable source of monetary value for the modelling exercise. NWRM are *multi-functional measures that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes. Their main focus is to enhance, as well as preserve, the water retention capacity of aquifers, soil, and ecosystems with a view to improving their status. NWRM have the potential to provide multiple benefits (see benefits table), including the reduction of risk of floods and droughts, water quality improvement, groundwater recharge and habitat improvement. The application of NWRM supports green infrastructure, improves or preserves the quantitative status of surface water and groundwater bodies and can positively affect the chemical and ecological status of water bodies by restoring or enhancing natural functioning of ecosystems and the services they provide (see ecosystem services). The preserved or restored ecosystems can contribute both to climate change adaptation and mitigation.*

Therefore, the focus of this stage is to **collect monetary data (CAPEX and OPEX) for the 90+ restoration measures included in the *Matrix of NBS multifunctionality of ecosystem services and economic options (D4.1.)* and to express them by kilometre or sq kilometre, thus obtaining input data for IO on various types of interventions.**

In a nutshell – these are essentially investment costs and should be treated as such into the model. Data used refers to CAPEX and OPEX (the latter produces effects together with the ES services described below).

[26] https://www.nwrm.eu/list-of-all-case-studies

CAPEX data is more readily available compared to ES valuation. In practice, NBS investment produces a shock on demand by increasing the output for the various parts used in doing the investment (construction, materials, equipment, utilities, technical services, legal, marketing, etc). The value of the investment is allocated on the relevant economic sectors by % of contribution.
An example would look like this:
A 10 mil. EUR (NBS) investment in a 15 sq.km area [the restauration of a floodplain] creates a 15 mil. EUR final demand in the whole economy, split by sector: 7 mil. EUR in construction, 4 mil. EUR in manufacturing, 2 mil. EUR in professional services and 2 mil. EUR in administrative services. Of the total additional output created, 9 mil. EUR are in value added, 5 mil. EUR in wages and 1 mil. EUR in taxes. The amount of investment and area / length can be multiplied and the economic impact will multiply accordingly.

3.2. Stage 2 - Screening ecosystem services

Similar to the data collection exercise in Key Function 1, focusing on ES is necessary in order to produce a repository of data regarding the monetised benefits of restoration measures in general. Similar to CAPEX and OPEX mentioned in Stage 1, the starting point for the ES list is the *Multifunctionality matrix developed in D4.1.* Additional sources are also considered, to complement the ES analysis, such as other projects[27].
A short list of ES with (1) the highest potential of transferability of benefits, thus being useful in the modelling, as well as (2) displaying variability of monetary data by country, can be found below. This ES list has a double purpose:

- Represents the list of benefits to select from when applying the general model
- Provides specific data to feed the model either by country or by measure

Based on the repository, the "selective monetisation" of ES and thus inclusion in the model, will be based on the following logic and categories:

A. **ES services that are "market related"** – they generate increased output / higher production of the ecosystem (food, touristic activity, resources, etc.). Their impact is on demand. The higher the ES "activity", the higher the sectoral output.

Based on the table above, the following ES fall into this category. Moreover, their shock on demand is seen on the following economic sectors (*in italic, should be further discussed).*

- API – Arable crop production – *Agriculture (A01 mainly) /* Crop production in general
- PBI – Plant biomass grassland - *Agriculture*
- CFI – Commercial fishing – *Agriculture (A03 – fishing)*
- TPI – Timber production – *Wood production*
- CHI – Commercial hunting (recreational / tourism) – *Tourism, Recreation (sector I, sector R, some H maybe)*
- WF – Wild foods and hunting (to a small extent, but still a provisioning service)
- AES – Abiotic energy sources (hydro)

[27] IDES Tool Manual - Stäps J., Gericke A., Lungu A. and Stammel B. (eds.) (2022). Ecosystem services in floodplains and their potential to improve water quality – a manual for the IDES Tool. Eichstätt, Berlin, Bucharest, https://doi.org/10.17904/ku.edoc.30670

- NWA – Opportunities for non-water-related activities (nature recreation) - *Tourism, Recreation (sector I, sector R, some H maybe)*
- WRA – Opportunities for water-related activities (water recreation) - *Tourism, Recreation (sector I, sector R, some H maybe)*

Using data collected from the literature, we create assumptions (that need to be validated by ecologists), to model the increase in the demand, obtaining macroeconomic benefits (how the investment's operation is multiplied in the economy). The focus of data collection is on output. *e.g. Due to an NBS (from our list), API increases by 10%, which means a 5 mil. EUR final demand in sector A01, resulting in 13 mil. EUR total output, of which 7 mil. EUR are in value added, 4 mil. EUR in wages and 2 mil. EUR in taxes.*

B. ES services with "regulation & maintenance" function – they generate higher productivity rather than higher output, and their impact is on value added, not on output.

How:

- they reduce costs (fertilizers – nitrogen, phosphorus captured, water treatment, flood damage avoided, erosion reduction, avoided treatment cost for water supply) by impacting production efficiency rather than output, by naturally replacing purchased inputs. For instance, nutrient retention in soil and wetlands reduces fertilizers loss, so the same crop yield can be achieved with lower fertilizer use. This lowers intermediate costs while output remains constant, resulting in higher value added (e.g. the agricultural output is still 1 tonne/ha, but pays less on fertilizers, leading to lower production costs but higher margin / VA)
- improve productivity (better soil for economic activities, better water etc.), e.g. the water is treated less by the water company because it contains less chemicals to be cleaned – more water can be treated at the same cost
- or they reduce risks (flood damage control) e.g. less loss to businesses and households compared to no intervention

Based on the table above, the following ES can be included in this category:

- NRI – N retention
- PRI – P retention
- GHG – Greenhouse gases regulation & carbon sequestration
- FRI – Flood risk regulation
- LFI – Low flow regulation
- SRI – Sediment regulation
- SFI – Soil formation in floodplains
- LCR – Local climate regulation/cooling
- FW – Freshwater provision (partially)
- WS – (Cost) of water supply

Assumption: *the impact is on VA[28], as these services do not change the structure of the economy*

[28] VA (Value Added) refers to the value that a specific sector adds to intermediate inputs during production. At the sector level, VA = Output – Intermediate Consumption; GVA (Gross Value Added) refers to the entire economy – as the sum of value added across all sectors in the economy

The modelling includes a VA shock (of avoided cost) S_j VA, for which we need data on avoided costs/ year on the specific sectors (e.g. NRI, PRI – savings in sectors C20-C21, water treatment, maybe health) *An example would look like this: 5 mil. EUR / year of avoided costs in water and fertilizers represent around 12 mil. EUR final demand surplus in the 2 impacted sectors, multiplying to X mil. EUR total output and Y mil. EUR value added, of which wages and taxes are a b c.*
Alternatively, in CBA, where they should be treated at the base value (the value of avoided cost) while the modelling show how it multiplies further in the economy.

C. **ES services with cultural function** – some of them can provide monetary value and thus can be considered that they contribute to final demand increase (first bullet) and are modelled as such (like in A), the other are data-dependant and might be considered for CBA somehow

- NWA, WRA – recreation, tourism → works as ΔD (see point A).
- LAQ – landscape aesthetic quality
- NH – Natural Heritage
- CH – Cultural Heritage
- KS – Knowledge systems

Table 4 Ecosystem services repository

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
monetisation is based on market prices					
provisioning	**Wood production**	m^3 timber	Market price (stumpage)		Vallecillo Rodriguez, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. and Maes, J., Ecosystem services accounting - Part II Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02905-2, doi:10.2760/631588, JRC116334. https://publications.jrc.ec.europa.eu/repository/handle/JRC116334
		m^3/ha/year	Productivity × price	idem	
provisioning	**Wild fish production**	tons/year fish	Market price	€/t (freshwater)	
		biomass/ha	Replacement cost (restocking)	€/t	
provisioning	**Grassland production**	t dry biomass	Forage value	€/t	
provisioning	**Arable crop production**	t/ha	Market price	€/t cereal	Vallecillo Rodriguez, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. and Maes, J., Ecosystem services accounting - Part II Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02905-2, doi:10.2760/631588, JRC116334. https://publications.jrc.ec.europa.eu/repository/handle/JRC116334
		yield stability (%)	Damage avoided (yield variance)	€/ha from risk models	
provisioning	**Drinking water provision**	m^3 potable water	Avoided treatment cost	€/m^3	Horváthová, E. (2022). Analysis of Drinking Water treatment costs – with an Application to Groundwater Purification Valuation. One Ecosystem, 7, e82125. https://doi.org/10.3897/oneeco.7.e82125

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
					Liquete, C., Zulian, G., Delgado, J., Stips, A., & Maes, J. (2016). Mapping and assessing water purification services in Europe: Multi-scale transformations for policy support. Science of The Total Environment, 551-552, 339–351. https://doi.org/10.1016/j.scitotenv.2016.01.129 Mastrorilli, M.; Rana, G.; Verdiani, G.; Tedeschi, G.; Fumai, A.; Russo, G. Economic Evaluation of Hydrological Ecosystem Services in Mediterranean River Basins Applied to a Case Study in Southern Italy. Water 2018, 10, 241. https://doi.org/10.3390/w10030241
		NO_3/PO_4 reduction	Treatment cost avoided	2–12 €/kg N; 15–45 €/kg P	
		m^3 potable water	Cost of water supply	1.42 – 5.51 €/m^3	EEA (2024), Water pricing and household water use in Spain and Estonia. https://www.eea.europa.eu/en/analysis/maps-and-charts/water-pricing-and-household-water-1
monetisation is based on avoided cost / replacement cost / ETS					
regulating	**Flood mitigation**	Change in flood retention volume (m3)/dike height (m) required for flood protection	Avoided flood protection costs	Based on case studies	Vallecillo Rodriguez, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. and Maes, J., Ecosystem services accounting - Part II Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02905-2, doi:10.2760/631588, JRC116334. https://publications.jrc.ec.europa.eu/repository/handle/JRC116334
		Number/area of residential/business/farm properties at flood risk in case of a 100-	Avoided damages of flood events	Depends on country	Kok S., Grondard N., Lenz M.I., Bangalore Suresh N.T., Garcia X., Llorente O., Estrada L., Acuna V., Birk S., 2025. Guidance Document – Cost-Benefit-Analysis in freshwater ecosystem restoration. EU H2020 research and innovation project MERLIN deliverable D3.4. 25 pp.

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
		year flood event			
					Huizinga, J., De Moel, H. and Szewczyk, W., Global flood depth-damage functions: Methodology and the database with guidelines, EUR 28552 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-67781-6, doi:10.2760/16510, JRC105688. https://publications.jrc.ec.europa.eu/repository/handle/JRC105688
				Central value £1.20 m^{-3} yr^{-1}, range £0.19–£1.23 m^{-3} yr^{-1}; replacement cost £2–£50 m^{-3} (mean £14 m^{-3}).	Broadmeadow, Samantha, et al. "Valuing flood regulation services of existing forest cover to inform natural capital accounts." Forest Research (2018)
				Empirical avoided-damage estimates in the £0.2–£1.2 m^{-3} yr^{-1} range.	Defra / Environment Agency (2015–2020). Slowing the Flow at Pickering and Holnicote Natural Flood Management Project evaluation reports.
					FLOODsite (2009). Guidelines for Flood Damage Evaluation (Deliverable D9.1). EU 6th Framework Programme Project. http://www.floodsite.net/html/partner_area/project_docs/T09_06_01_FLOODsite_D9_1_Flood_damage_guidelines.pdf
					Penning-Rowsell, E., Priest, S., Parker, D., Morris, J., Tunstall, S., Viavattene, C., ... & Owen, D. (2014). Flood and coastal erosion risk management: a manual for economic appraisal. Routledge.

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
					UK EA (Environment Agency) (2020). A review of skills and guidance in flood and coastal risk management benefit cost. Assessment Appendix B: user guide for early calculations of potential scheme benefits. https://assets.publishing.service.gov.uk/media/606dcfdcd3bf7f4017cbef20/A_review_of_skills_and_guidance_in_flood_and_coastal_risk_management_benefit_cost_assessment_-_appendix_B.pdf
regulating	**Low flow mitigation**	additional discharge	Avoided drought losses	€/m³ (sector dependent)	Vermeulen et al. (2025) Economic effects of drought on agriculture: Conceptual methods and stakeholders' perceptions, International Journal of Disaster Risk Reduction https://doi.org/10.1016/j.ijdrr.2024.105073 (example from the agricultural sector) Logar, I., van den Bergh, J.C.J.M. Methods to Assess Costs of Drought Damages and Policies for Drought Mitigation and Adaptation: Review and Recommendations. Water Resour Manage 27, 1707–1720 (2013). https://doi.org/10.1007/s11269-012-0119-9
		fewer Q<95 days	Industrial water security value	0.5–5 €/m³	Prochazkova et al. (2023) Industrial wastewater in the context of European Union water reuse legislation and goals, Journal of Cleaner Production https://www.sciencedirect.com/science/article/abs/pii/S0959652623031955 Reddy, S. M. W., McDonald, R. I., Maas, A. S., Rogers, A., Girvetz, E. H., North, J., Molnar, J., Finley, T., Leathers, G., & DiMuro, J. L. (2015).
			Production losses in agriculture	%	Vermeulen et al. (2025) Economic effects of drought on agriculture: Conceptual methods and stakeholders' perceptions, International Journal of Disaster Risk Reduction https://doi.org/10.1016/j.ijdrr.2024.105073 Incorporating ecosystem service values into business planning at The Dow Chemical Company's Freeport, TX facility.

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
					Ecosystem Services, 12, 94–107. https://doi.org/10.1016/j.ecoser.2014.12.001
regulating	**Local climate cooling**	Δ°C	Energy savings (cooling)	0.1–0.5 €/m²/°C/day	
		evapotranspiration	Cooling-service proxies	location-specific	
regulating	**Sediment regulation**	t sediment retained	Avoided dredging cost	8–25 €/t (EU average) Bulgaria: As low as €3 for general dredging projects in the Danube river basin. Romania: Approximately €3.5 (e.g., in the Galati sector). In specific highly-sedimented areas like the Lower Old Danube, significant volumes (700,000 m³/year) were historically dredged, highlighting a major ongoing cost. Slovakia: Around €15 for mechanical dredging including transport.	Panagos et al. (2024) Understanding the cost of soil erosion: An assessment of the sediment removal costs from the reservoirs of the European Union https://www.sciencedirect.com/science/article/pii/S0959652623043 41X DanubeSediment: Sediment Management Measures for the Danube www.interreg-danube.eu/danubesediment

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
				Croatia: Approximately €7.5 for dredging in reservoirs. Austria: Costs can reach up to €20, often involving specific treatments for sediments. Germany: The range is broad, from €10 to €100, depending heavily on specific local requirements and potentially contamination levels.	
regulating	**Soil formation**	mm deposition/year	Increased productivity	20–100 €/ha/year / maybe proxy for agricultural productivity available by country on eurostat	

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
regulating	**Carbon sequestration**	t CO_2eq/year	EU ETS price	40-500 €/t CO_2	Vallecillo Rodriguez, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. and Maes, J., Ecosystem services accounting - Part II Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02905-2, doi:10.2760/631588, JRC116334. https://publications.jrc.ec.europa.eu/repository/handle/JRC116334
			social cost of carbon (SCC	€282.50 per tonne of CO_2 (2021)	Kok S., Grondard N., Lenz M.I., Bangalore Suresh N.T., Garcia X., Llorente O., Estrada L., Acuna V., Birk S., 2025. Guidance Document – Cost-Benefit-Analysis in freshwater ecosystem restoration. EU H2020 research and innovation project MERLIN deliverable D3.4. 30-34 pp. Nordhaus, W.D. (2017). Revising the social cost of carbon. Proceedings of the National Academy of Sciences, 114(7), 1518-1523. DOI: 10.1073/pnas.1609244114
regulating	**Carbon retention**	t carbon stored	Social cost of carbon	100–200 €/t	
regulating	**Nitrogen retention**	kg N retained	Replacement / fertilizer-replacement cost	€2,000 – €3,000 per tonne	
			Avoided treatment	~€2.2/kg N = ≈€2200/tonne	Brink & vanGrinsven (2011), Costs and benefits of nitrogen in the environment
			Damage cost / welfare loss		Brink & vanGrinsven (2011), Costs and benefits of nitrogen in the environment
regulating	**Phosphorus retention**	kg P retained	Replacement / fertilizer-replacement cost	€2000–8000/tonne	Mollinos-Sennante(2011) Economic Feasibility Study for Phosphorus Recovery Processes
			Avoided treatment		Brink & vanGrinsven (2011), Costs and benefits of nitrogen in the environment
			Damage cost / welfare loss		

ES TYPE	ECOSYSTEM SERVICE	INDICATOR	MONETISATION METHOD	VALUES	DATA SOURCES
regulating	**Habitat maintenanc e**	restored area (ha)	Habitat restoration cost	€/ha	La Notte, A., Vallecillo Rodriguez, S., Garcia Bendito, E., Grammatikopoulou, I., Czucz, B., Ferrini, S., Grizzetti, B., Rega, C., Herrando, S., Villero, D., Zurbaran Nucci, M. and Maes, J., Ecosystem Services Accounting – Part III - Pilot accounts for habitat and species maintenance, on-site soil retention and water purification, EUR 30856 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-42051-4, doi:10.2760/636621, JRC126566.
					Schmidt and Albert (2025) Enhancing multiple ecosystem services: Nature-based measures outperform technical interventions in river management https://www.sciencedirect.com/science/article/pii/S2212041625000993?dgcid=rss_sd_all
monetisation is based on WTP / hedonic pricing / travel cost etc.					
cultural	**Landscape aesthetics**	scenic quality index property value increase	Hedonic pricing	+1–5% property value	
cultural		no of tourists	Recreation value	5–20 €/visit	
cultural	**Natural & cultural heritage**	restored sites - revenue from operating them	Tourism revenue	€/visitor or €/site	
cultural	**Unspecific water interactions**	no of tourists / visitors	Travel cost	€/visit x no of visits	
cultural	**Water-related activities**	recreation use	Expenditure method	€/visit x no of visits	Vallecillo Rodriguez, S., La Notte, A., Polce, C., Zulian, G., Alexandris, N., Ferrini, S. and Maes, J., Ecosystem services accounting: Part I - Outdoor recreation and crop pollination , EUR 29024 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-77333-4, doi:10.2760/619793, JRC110321.

3.3. Stage 3 - Performing IO and CBA analysis

Based on the results of Stages I and II – creating the repositories of data, the economic models can be built for any scenario given, they will be fully expanded and tested on the demo sites.

The **IO analysis** is the backbone of the economic footprint analysis and comprises several **calculation steps**:

- Data on National Accounts is extracted for the latest available year (such data usually has a 2-year gap, considering the amount of effort to aggregate it from the microeconomic level). However, it is largely available on any national statistics office or on Eurostat;
- Coefficients are computed for each sector, showing the interaction between economic branches, and how the increase in demand in one sector is used or how it influences output change in another sector. To ensure granularity, we decided to build the tables at the highest level of detail by sector, which means 88x88 matrix or 64x64 in some cases;
- Additional demand generated by an investment project is translated into monetary units belonging to different sectors – e.g. equipment – manufacturing, buildings – construction, IT – information and communication etc;
- Results should be interpreted as additional money generated in the interlinked sectors as a result of the investment in one (or more) target sectors, based on project allocation;
- Based on the number of employed persons by sector, the multipliers help estimate the number of additional jobs to be supplied to accommodate the additional production generated by the project; *A note on gender perspective: the distribution of impacts by gender can be incorporated into our analysis only where sufficiently detailed, investment-level (NBS/restoration) data are available. For a practical and realistic assessment, we propose to pilot this element at the demo-site level (for example, the Upper Danube), where targeted data collection is feasible and is more likely to produce the necessary disaggregated information. Where site-level gender data are not available, employment and socio-economic results will be interpreted by sectoral impact, and the analysis will be complemented with a targeted literature review of studies addressing gender and industry-specific employment effects.*

After building the IO tables for each country in which the demo sites are located, data is included in the model in the following way:

- **Data related to the intervention**: construction costs (outlined in the *Valuation of costs* section) are allocated to various economic sectors based on their use (i.e. €100,000 in construction, €3,000 in legal, €20,000 in manufacturing).
- **Data related to benefits – those values obtained through valuation methods showing a change in demand are considered** (i.e. market prices, production function, revealed preference). For example, the monetary value of additional fish supply expected to be sold on the market is allocated to sector A – fish farming; additional revenue spent by tourists is allocated to recreational activities or food and beverages, depending on their specificity;

Although benefits are expected to be obtained over a long period of time, this instrument can provide reliable results as long as the IO table used takes into account similar macroeconomic conditions. Simply put, IO is a static instrument – the macroeconomic landscape changes the most over economic cycles, not year to year, as such it should be used with caution when estimating effects on longer periods of time (longer than 3-5 years). This means it cannot capture the aggregated benefits over 15 or 20 years of estimation. This is why we propose using only: full data available on costs of the investment and 3-5 years of aggregated benefits.

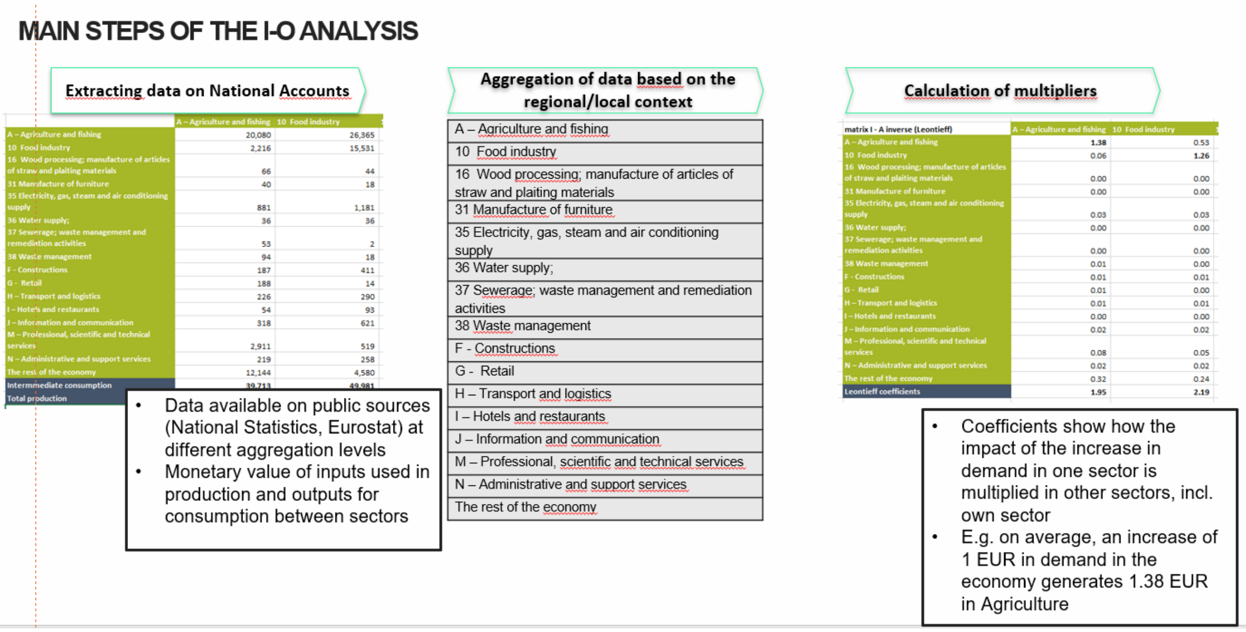
After computing the GVA change, sustained jobs are derived using data on average wages by sector and total employment. The result is given in number of sustained jobs by the displaced demand (additional GVA created).

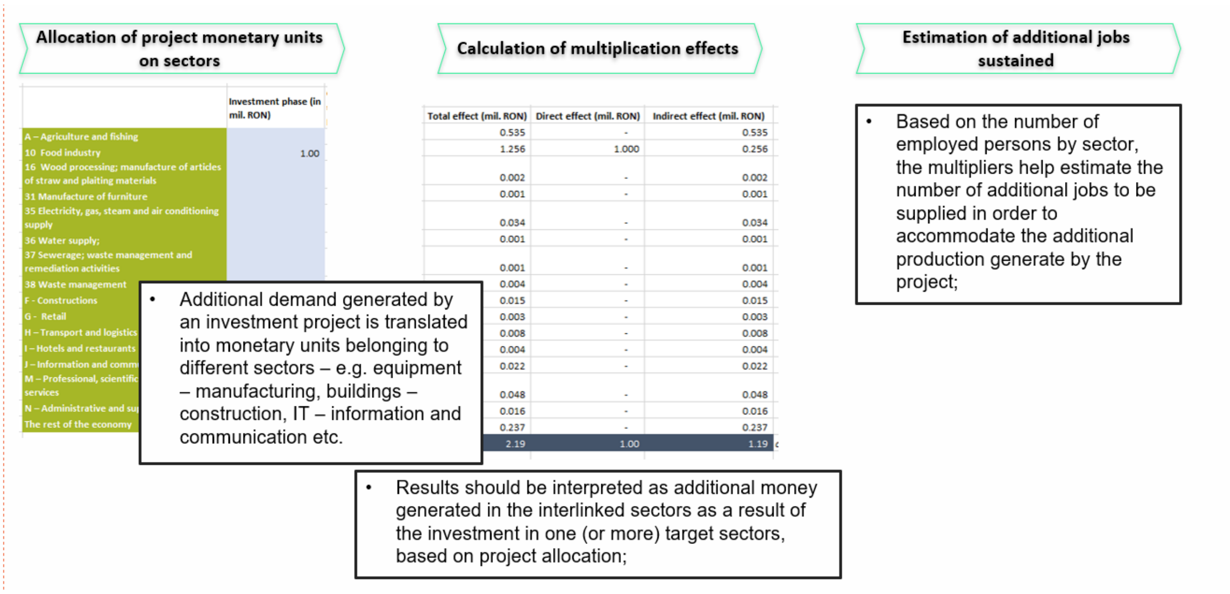
Finally, the general model will have the following components:

- IO table for each country;
- Repository of data on restoration measures (by km or sq. km);
- Repository of benefits that can monetised;
- Allocation by sector of each of them in order to create a customizable tool that will be first tested on the demo sites and then expanded to any combination of measures / benefits;

The table below summarizes the data needs and availability:

INDICATORS	DATA SOURCE	DATA AVAILABILITY BY COUNTRY	YEAR
Supply-Use tables	Eurostat, *naio_10_cp15, naio_10_cp16*	Germany, Croatia, Hungary, Austria, Romania, Slovakia, Serbia	2021
	National Statistical Institute, Republic of Bulgaria / Moldova	Bulgaria, Moldova	2014, 2021
IO symmetric tables	Ukrstat - Ukrainian Statistical Office	Ukraine	2021
employment by sector	Eurostat, NAMA_10_A64	All	2021
wages by sector	Eurostat, NAMA_10_A64	All	2021
taxes	Eurostat, NAMA_10_A64	All	2021





Other considerations regarding the IO analysis:

- IO analysis is a powerful tool to understand the key sectors of an economy, that show the greatest potential to generate (monetary) impact. It is a macroeconomic tool – therefore, it presents an aggregated picture at the national level, despite applying it to lower territorial levels. This implies that *not always the supply and demand interactions between companies happen at the local or regional level, thus the results should be interpreted accordingly.*
- IO analysis is a static instrument – it relies on past (real) data to describe what a potential "shock" (an inflow of money) would cause in interlinked sectors in a specific moment in the past. However, the advantage is that the structure of the economy does not change that quickly.
- Another consideration is that sometimes the allocation of costs within a project by economic sectors are not very easy to make – but an average representation is still a reliable estimation (as magnitude order).
- Finally, it is a *quantitative instrument* that is fed by data - ecology-related projects are not always easy to convert into monetary units, so they should be assessed through the indirect, spillover effects generated that can be converted into money (e.g. reforestation of an area – difficult to measure, but it may help increase ecological tourism, which in turn creates jobs and consumption, which in turn can be modelled).

CBA analysis – main steps:

- CBA ensures that the benefits (enhancements in human well-being) outweigh the costs (reductions in human well-being) before implementing a project. This analysis is crucial as it describes and assesses the direct and indirect effects of the project on human beings and the environment, helping in the selection of the most viable project or program[29].
- The CBA of an NBS should employ an incremental approach by comparing a scenario involving the project with a counterfactual baseline scenario (Business as Usual, or BAU) that lacks the

[29] *IEEP, & European Commission. (2011). Estimating the overall economic value of the benefits provided by the Natura 2000 network. Publications Office of the European Union.* https://ieep.eu/wp-content/uploads/2022/12/Economic_Benefits_of_Natura_2000_Network_Synthesis_report.pdf

project[30]. The "incremental benefits" specifically refer to the extra benefits that come from implementing a project, in contrast to the "gross benefits" that refer to all the advantages that come from a specific site, including all biodiversity and ecosystem services. **This refers to all benefits monetized that result from Stage II.**

- The process of monetization implies that all costs and benefits can be traded off against each other;
- The quantification stage of the CBA uses a net present value (NPV) approach, which estimates the value of the stream of benefits that are expected to be generated over the lifetime of an asset, in this case the natural habitat on which the intervention took place. These values are then discounted back to the present accounting period.
- Three main aspects are involved here:
  - Expected future flow of values – the future annual monetised value of each benefit
  - The asset lifetime – the period over which the flows of values are expected to be generated (usually over 25-30 years, recommendations go even further to 100 years)
  - The discount rate – see explanation below
- Once NPVs are obtained for each benefit, the total value of each intervention is calculated by summing up the costs and benefits, and a benefit-cost ratio is calculated to assess the trade-off between the two (a value higher than 1 implies positive benefits)

Dealing with the time component

The Cost-Benefit Analysis (CBA) follows a structured appraisal framework consistent with established environmental economic guidance[31].

- First, an appraisal period is defined to reflect the expected functional lifetime of the nature-based solutions (NBS), ensuring that long-term ecosystem service flows are adequately captured.
- Second, costs are classified by timing and function, distinguishing initial capital expenditures (CAPEX), recurring operation and maintenance costs (OPEX), and periodic reinvestments necessary to sustain ecosystem performance. This is also relevant to geographic economy analysis with implications to rural development, since it is these OPEX costs that tend to provide employment to close-by areas.
- Third, ecosystem service benefits are quantified as annual flows, expressed as avoided costs or welfare gains, and are assumed to accrue only under continued maintenance of the intervention.
- Fourth, all cost and benefit streams are converted into present values through discounting. Literature discusses various options regarding the discount rate, considering the heterogeneity of NBS employed and the context in which they are implemented. As such, in the European Union (EU), Cost-Benefit Analysis (CBA) for Nature-Based Solutions (NBS) in water ecosystems typically employs low social discount rates, often ranging between 1% and 5%. Due to the long-term, intergenerational benefits of environmental projects, lower discount rates are generally preferred to avoid undervaluing future ecological benefits[32]. The

[30] European Commission Directorate-General for Regional and Urban policy, *Guide to Cost-Benefit Analysis of Investment Projects*, *Economic appraisal tool for Cohesion Policy 2014-2020*, 2014

[31] Atkinson, G. and S. Mourato (2015), "Cost-Benefit Analysis and the Environment", OECD Environment Working Papers, No. 97, OECD Publishing, Paris, https://doi.org/10.1787/5jrp6w76tstg-en.

[32] Schoenmaker, D., & Schramade, W. (2024). Which discount rate for sustainability? Journal of Sustainable Finance and Accounting, 3, Article 100010. https://doi.org/10.1016/j.josfa.2024.100010

European Commission Guidelines[33] generally recommend a discount factor ranging from 3% to 5% for project evaluations, while social discount rates apply lower rates (e.g. 1%-3%) for long-term environmental projects. The choice of lower rates (often <3%) is justified by the "Equivalency Principle" or ethical considerations that give equal weight to future generations' welfare, highlighting that the benefits of restored water ecosystems, such as flood risk reduction or water purification, accrue over decades.[34][35][36]

- Finally, sensitivity analysis can be undertaken to test the robustness of results to alternative discount rates and time horizons, thereby ensuring transparency and methodological consistency in the treatment of intertemporal effects.

3.4. Stage 4 - Assessment of the post-intervention economic impact

Testing the model in multiple areas is necessary to check its robustness and viability across environments. Thus, this part will help answer the following questions:

- How much does 1 EUR of invested money yield in impact in the three sectors of the Danube (i.e. because there are different countries), or based on the type of investment?
- Which interventions are more “profitable” in terms of benefits?
- Where do national economies benefit more or where do local communities benefit more?
- What happens if you invest the same amount in two countries? How do jobs are affected? How much distance or surface is needed in one country to obtain similar effects to another one?
- Limitations of the models will be discussed here as well, including recommendations for further adjustments to the models.

3.5. Stage 5 - Expanding the model to the general case

Stage V focuses on transforming the methodology tested on the three demo sites into a **general, replicable model** that can be applied to restoration investments across the Danube Basin. In line with the methodological orientation agreed with project partners, the general model builds primarily on the **Input–Output (IO) framework**, complemented—where feasible—by **selective, monetizable ecosystem service (ES) benefits** identified through CBA techniques.

The purpose of this stage is not to develop measure-specific or NBS-specific models, but rather to establish a **scalable analytical structure** that works irrespective of the restoration type, provided that a *representative cost structure* is available. Typical restoration investments display similar CAPEX/OPEX profiles even when absolute budgets differ, enabling the IO approach to be generalised across intervention categories and countries.

---

[33] Idem 10

[34] Vicarelli, M., Georgescu, A., Sudmeier-Rieux, K. Cost-benefit and equity analysis of nature-based solutions in Haiti, India, Indonesia and Uganda, Nature-Based Solutions, Volume 6, 2024, 100196, ISSN 2772-4115, https://doi.org/10.1016/j.nbsj.2024.100196. https://www.sciencedirect.com/science/article/pii/S2772411524000879

[35] Le Coent, P. *et al.* (2023). Economic Assessment of Nature-Based Solutions for Water-Related Risks. In: López-Gunn, E., van der Keur, P., Van Cauwenbergh, N., Le Coent, P., Giordano, R. (eds) Greening Water Risks. Water Security in a New World. Springer, Cham. https://doi.org/10.1007/978-3-031-25308-9_6

[36] Markanday, A. et al. Determining discount rates for the evaluation of natural assets in land-use planning: An application of the Equivalency Principle, Journal of Cleaner Production, Volume 230, 1 September 2019, Pages 672-684, https://doi.org/10.1016/j.jclepro.2019.05.107

Accordingly, Stage V produces a coherent set of **tools and templates** that allow future users to apply the model beyond the demo sites:

• A streamlined ES identification and screening tool

A simplified template to document ES potentially affected by a restoration measure, with guidance on determining whether an ES is:

- **monetizable** (eligible for inclusion in CBA),
- **quantifiable but non-monetizable**, or
- **qualitative only**.

This ensures that ES enter the model consistently without requiring measure-specific modelling structures.

• A valuation guidance note

Instructions on how to apply valuation methods only to those ES where credible monetary values can be established, avoiding unnecessary complexity and reflecting Helmut's requirement that ES valuation remains **selective, not exhaustive**.

• IO model allocation templates

Standardised sheets for allocating restoration costs to economic sectors based on typical cost shares, enabling the IO model to be applied even when only approximate or literature-derived cost structures are available.

• A light CBA annex template

A short methodological template describing how to include specific monetizable ES benefits (e.g., avoided damage) where site-specific data permit, without creating separate models for specific restoration measures.

Outcome of Stage V

Stage V delivers a **fully generalised, user-friendly analytical package** that allows other stakeholders to run the Danube4All economic model on future restoration sites. The model retains a coherent structure centred on IO analysis, enhanced—where data allow—by selective and transparent ES valuation. This ensures methodological consistency across cases while reflecting the practical and data-driven constraints highlighted throughout the project.

4. Results – Structure of the General Economic Impact Model

The generic macroeconomic model developed under Milestone 11 represents the consolidated result of a full year of analytical work, testing, refinement, and methodological alignment with project partners. Its purpose is straightforward: to provide a **robust yet easy-to-apply framework** for estimating the economic effects of restoration investments anywhere along the Danube River Basin. The model must work across countries, across scales, and across restoration types — from groyne removal to floodplain reconnection — while remaining grounded in economic reality and transparent enough for practical use by policymakers and river managers.

At the core of the model lies a simple insight: although the ecological functioning of restoration measures varies widely, the way funds are **spent to implement them is strikingly similar**. Planning, design, construction works, materials, equipment, and labour appear in almost every intervention, differing in magnitude but not in their fundamental economic structure. This recognition became the foundation of a **measure-agnostic** economic model.

Previous exploratory work conducted earlier in the project included literature review, internal workshops and discussions, as well as testing various paths of studying such a complex matter in a way that the resulting model becomes more of a tool to be further used on future projects and not a one-time construct. That stage was critical as it helped us understand the range of cost categories, the types of ecosystem services involved, and the valuation methods that could theoretically be applied. The templates became an organised repository of restoration types, ecosystem services, assumptions, valuation logic, and cost structures.

However, as work progressed and the methodological testing became clearer it also became evident that the final economic model **should not be a collection of mini-models**. Instead, it should be a single, overarching macroeconomic model that can accommodate any restoration measure through a representative cost structure. The earlier templates, therefore, remain extremely valuable — but as a **supporting toolkit** rather than a modelling engine. They ensure consistency, help users prepare inputs, and provide the data screening logic for ecosystem services. The model itself, however, is intentionally streamlined and high-level.

Structure of the Generic Macroeconomic Model

The principal component of the general model is an Input–Output (IO) analysis. IO modelling is uniquely suited for this context because the question we ultimately answer is a macroeconomic one: **What happens in the broader economy when 1 EUR is invested in river restoration?**

To answer this, three elements are required:

1. **The total investment cost**, consisting of CAPEX and, where relevant, OPEX.
2. **A distribution of that cost across economic sectors**, derived either from project-specific budgets or from typical cost shares observed in restoration projects.
3. **National IO tables**, which describe how sectors interact and how economic activity propagates through the economy.

One of the most essential methodological conclusions is that the IO analysis **does not depend** on the type of restoration measure, nor on the classification of Nature-based Solutions (NBS), nor on the set of ecosystem services involved. It depends solely on **how money is spent across sectors**. This is why variations among ecological measures—floodplain reconnection, bank stabilisation, side-channel restoration—do not require separate macroeconomic models. Their effects on the construction sector, engineering services, material supply industries, and labour are sufficiently similar for IO purposes. In practical terms, whether 45% of the investment is allocated to construction or 55% does not fundamentally change the type of sectors affected — it only modifies the magnitude of the multiplier. This finding is entirely aligned with the request from partners: the model must remain **simple, general, and driven by economic structure**, not ecological detail.

Inputs to the IO model

Regardless of the restoration measure, three data elements are required:

1. **Total investment cost** (CAPEX + OPEX, when relevant).
2. **Allocation of costs into economic sectors**, using:
    - project-specific cost data when available, or

- typical cost shares (e.g., 40–60% construction, 10–20% equipment, 20–40% labour) derived from literature and partner experience.

3. **National IO tables**, obtained from Eurostat or national statistical offices.

This means **the model does not depend on the specific measure** (e.g., groyne removal vs. floodplain reconnection), because what matters is **how the investment money is spent**, not the ecological configuration of the measure.

Outputs of the IO model

Using the above inputs, the IO model calculates:

- **Gross Value Added (GVA) generated** in each sector
- **Total economic output stimulated**
- **Number of sustained jobs**, derived from sector-level labour coefficients
- **Distribution of effects across sectors**, showcasing the economic structure of each country

Complementary Component: Selective CBA for Monetizable ES

While many ecosystem services cannot be monetised with confidence, certain benefits—particularly **avoided damage costs or market-linked outputs**—can be integrated.

When CBA is applied

CBA is included only when:

- a clear, quantifiable change in an ES can be identified; and
- there is a credible valuation method (e.g., avoided flood damage, additional fish biomass, avoided water purification costs).

This ensures CBA **adds value** rather than introducing methodological uncertainty.

How CBA integrates with the macro model

CBA results are not a separate model. They:

- provide **additional monetary flows** that can be input into the IO model (e.g., increased revenue from fisheries, increased tourism expenditure); or
- are presented as **standalone net present value (NPV)** calculations when their nature does not allow integration into IO.

Role of Ecosystem Services: Selective, Not Structural

Ecosystem services (ES) remain an important component of the model, but their role is different. They are not used to structure the IO analysis itself. Instead, **ES function as indicators of environmental change and as a starting point for selective valuation where economic quantification is feasible**. A limited number of ecosystem services may generate monetizable benefits, such as avoided flood damage, increased fish production, or reduced water purification costs. When robust valuation methods and credible quantitative estimates are available, these benefits can be expressed in monetary terms and incorporated either into the IO model as additional demand shocks or into a standalone Cost-Benefit Analysis (CBA).

Most ecosystem services, however, cannot yet be monetized reliably. In such cases, they remain part of the qualitative assessment of benefits rather than being forced into numerical form. This approach preserves methodological integrity by applying monetary valuation only where the evidence is sufficiently robust and by avoiding overstated precision where data remain limited.

The Final Output: A General, Transferable Danube4All Economic Impact Model

The final general model is composed of:

1. **A cost allocation template**
   - allows rapid structuring of investment budgets into IO-compatible categories.
2. **A macroeconomic multiplier engine**
   - uses national IO tables to generate GVA, employment, and total output effects.
3. **A selective ES valuation module**
   - quantifies monetizable benefits (when possible) and integrates them into the IO impact or presents them in a CBA summary.
4. **A reporting structure**
   - summarises investment effects, ES benefits, and limitations in a consistent, comparable format for any Danube site.

Why This Model Works Across All Restoration Measures

One of the key findings of the exploratory phase was that **although restoration measures differ ecologically**, their **investment cost structures are remarkably similar**. This similarity enables the development of a generalisable IO model that does not require separate models for each type of intervention. Even though restoration measures differ in engineering design and ecological outcomes, **their spending logic is highly similar**.

Cost Component	Measure A	Measure B	Measure C
Planning / Design	10–20%	8–15%	12–18%
Construction	40–60%	35–55%	45–65%
Materials & Equipment	10–25%	15–30%	10–20%
Labour	20–40%	25–45%	30–50%

This similarity enables the IO model to remain valid even when measures differ ecologically.

Ecosystem service benefits, meanwhile, can be added **only when meaningful**, without forcing all projects into a rigid valuation structure.

This ensures:

- methodological consistency,
- scientific credibility, and
- practical usability by river managers and policymakers.

5. List of references

Kok S., Grondard N., Lenz M.I., Bangalore Suresh N.T., Garcia X., Llorente O., Estrada L., Acuna V., Birk S., 2025. Guidance Document – Cost-Benefit-Analysis in freshwater ecosystem restoration. EU H2020 research and innovation project MERLIN deliverable D3.4. 20-21 pp.	https://project-merlin.eu/outcomes/deliverables.html
Johnston, R.J., Boyle, K.J., Loureiro, M.L. et al. Guidance to Enhance the Validity and Credibility of Environmental Benefit Transfers. Environ Resource Econ 79, 575–624 (2021).	https://link.springer.com/article/10.1007/s10640-021-00574-w#citeas
Brander, et al. (2024) Economic values for ecosystem services: A global synthesis and way forward. Ecosystem Services 66, 101606.	https://www.sciencedirect.com/science/article/pii/S2212041624000123?via%3Dihub
Brooks, H., & Guth, M. (2020). Benefits of restoring Europe: Examples of the biodiversity, climate and wider socio-economic benefits of ecological restoration in Europe. Endangered Landscapes Programme, BirdLife Europe and Central Asia, & UN Environment Programme World Conservation Monitoring Centre.	https://resources.unep-wcmc.org/products/WCMC_RT077
EEA European Environment Agency. (2023). Scaling nature-based solutions for climate resilience and nature restoration. Publications Office of the European Union.	https://www.eea.europa.eu/publications/scaling-nature-based-solutions
European Commission. (2022). Commission Staff Working Document: Impact Assessment (Executive Summary). SWD(2022) 168 final. Publications Office of the European Union.	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0168
EU JRC PESETA III project outcomes on monetary impacts of climate change: Szewczyk, W., Ciscar Martinez, J., Mongelli, I. and Soria Ramirez, A., JRC PESETA III Project: Economic integration and spillover analysis, EUR 29456 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-97422-9, doi:10.2760/514048, JRC113810.	
EU JRC PESETA IV project outcomes on monetary impacts of climate change:	https://joint-research-centre.ec.europa.eu/projects-and-activities/peseta-climate-change-projects/jrc-peseta-iv_en
IEEP, & European Commission. (2011). Estimating the overall economic value of the benefits provided by the Natura 2000 network. Publications Office of the European Union.	https://ieep.eu/wp-content/uploads/2022/12/Economic_Benefits_of_Natura_2000_Network_Synthesis_report.pdf
Institute for European Environmental Policy (IEEP). (2022a). Nature Restoration: Contributions to tackling climate change. IEEP Brief.	https://ieep.eu/wp-content/uploads/2022/11/10.11-Climate-change-benefits-of-nature-restoration-brief-new.pdf
Martínez-López, J., Martínez-Fernández, J., & Esteve, M. A. (2024). Provisioning ecosystem services and their valuation in the southwest of Europe: Methodological advances and policy implications. Environment, Development and Sustainability.	https://link.springer.com/article/10.1007/s10668-024-04877-y

Paracchini, M. L., Zulian, G., Kopperoinen, L., & Maes, J. (2025). Sub-regional biophysical and monetary evaluation of ecosystem services: An experimental spatial planning implementation at NUTS-3 level. Land, 14(2), 216.	https://www.mdpi.com/2073-445X/14/2/216
Thünen Institute. (2020). Quantification and regionalisation of economic values of forest ecosystem services in Germany. Johann Heinrich von Thünen Institute. DOI: 10.3220/PB1607428679000. Retrieved from	https://www.thuenen.de/en/institutes/forestry/projects-1/quantification-and-regionalisation-of-economic-values-of-forest-ecosystem-services-in-germany
Trinomics, IEEP, UNEP-WCMC, & IUCN. (2023). Impact assessment study to support the development of legally binding EU nature restoration targets (Final report). Publications Office of the European Union.	https://op.europa.eu/en/publication-detail/-/publication/309f0fa2-2f4a-11ee-9e98-01aa75ed71a1
UNEP-WCMC. (2021). Benefits of restoring Europe: Technical brief. UN Environment Programme World Conservation Monitoring Centre.	https://www.endangeredlandscapes.org/wp-content/uploads/2021/10/Benefits-of-Restoring-Europe-Technical-brief.pdf)
Perosa et al. (2021) A meta-analysis of the value of ecosystem services of floodplains for the Danube River Basin	https://www.sciencedirect.com/science/article/abs/pii/S0048969721011293
Sima, M., Dumitrașcu, M., Grigorescu, I., Costache, A. (2024). Tourists' perception of socio-cultural values of ecosystem services and management perspectives at the Vadu wild beach, Danube Delta Biosphere Reserve, Romania.	
Schmidt and Albert (2025) Enhancing multiple ecosystem services: Nature-based measures outperform technical interventions in river management	https://www.sciencedirect.com/science/article/pii/S2212041625000993?dgcid=rss_sd_all
Atkinson, G. and S. Mourato (2015), "Cost-Benefit Analysis and the Environment", OECD Environment Working Papers, No. 97, OECD Publishing, Paris, https://doi.org/10.1787/5jrp6w76tstg-en.	https://www.oecd.org/content/dam/oecd/en/publications/reports/2015/12/cost-benefit-analysis-and-the-environment_g17a2732/5jrp6w76tstg-en.pdf
Vicarelli, M., Georgescu, A., Sudmeier-Rieux, K. Cost-benefit and equity analysis of nature-based solutions in Haiti, India, Indonesia and Uganda, Nature-Based Solutions, Volume 6, 2024, 100196, ISSN 2772-4115,	https://doi.org/10.1016/j.nbsj.2024.100196. https://www.sciencedirect.com/science/article/pii/S2772411524000879
Markanday, A. et al. Determining discount rates for the evaluation of natural assets in land-use planning: An application of the Equivalency Principle, Journal of Cleaner Production, Volume 230, 1 September 2019, Pages 672-684,	https://doi.org/10.1016/j.jclepro.2019.05.107
Horváthová, E. (2022). Analysis of Drinking Water treatment costs – with an Application to Groundwater Purification Valuation. One Ecosystem, 7, e82125.	https://doi.org/10.3897/oneeco.7.e82125
Liquete, C., Zulian, G., Delgado, J., Stips, A., & Maes, J. (2016). Mapping and assessing water purification services in Europe: Multi-scale transformations for policy support. Science of The Total Environment, 551-552, 339–351.	https://doi.org/10.1016/j.scitotenv.2016.01.129

Mastrorilli, M.; Rana, G.; Verdiani, G.; Tedeschi, G.; Fumai, A.; Russo, G. Economic Evaluation of Hydrological Ecosystem Services in Mediterranean River Basins Applied to a Case Study in Southern Italy. Water 2018, 10, 241.	https://doi.org/10.3390/w10030241
EEA (2024), Water pricing and household water use in Spain and Estonia.	https://www.eea.europa.eu/en/analysis/maps-and-charts/water-pricing-and-household-water-
Prochazkova et al. (2023) Industrial wastewater in the context of European Union water reuse legislation and goals, Journal of Cleaner Production	https://www.sciencedirect.com/science/article/abs/pii/S0959652623031955
Vermeulen et al. (2025) Economic effects of drought on agriculture: Conceptual methods and stakeholders' perceptions, International Journal of Disaster Risk Reduction	https://doi.org/10.1016/j.ijdrr.2024.105073
Logar, I., van den Bergh, J.C.J.M. Methods to Assess Costs of Drought Damages and Policies for Drought Mitigation and Adaptation: Review and Recommendations. Water Resour Manage 27, 1707–1720 (2013).	https://doi.org/10.1007/s11269-012-0119-9
Reddy, S. M. W., McDonald, R. I., Maas, A. S., Rogers, A., Girvetz, E. H., North, J., Molnar, J., Finley, T., Leathers, G., & DiMuro, J. L. (2015).	
Incorporating ecosystem service values into business planning at The Dow Chemical Company's Freeport, TX facility. Ecosystem Services, 12, 94–107.	https://doi.org/10.1016/j.ecoser.2014.12.001