Economic enabling conditions for scaling of Nature Based Solutions

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Summary

The present paper analyses scaling aspects for Nature Based solutions (NBS) focusing on the economic and social characteristics of their implementation. The analysis is based on a discussion of key concepts related to the social and economic characteristics of NBS and applies this lens of interpretation to study how these aspects roll out in a selection of case studies previously presented in two technical papers, published in 2021 and 2022: the first of these papers by Veerkamp et al. (2021) had developed a framework for NBS assessments building on key success factors and limitations and applied it to a range of different European NBS case studies. The second paper by Martire et al. (2022) provided a framing of the concept of scaling for NBS and examined a small selection of the previous case studies on the background of the related framework.

The present paper discusses the socio-economic conditions which can enable or prevent upscaling and particularly focuses on the characterization and distribution of benefits generated by NBS. The objective of this paper is to exemplify this analysis on six selected case studies selected from those previously analised, assessing how socio-economic conditions impact the potential for large-scale implementation of NBS.

1 Introduction

The present paper analyses scaling aspects related to economic and social characteristics of Nature-based Solutions (NBS). In this report we use the definition provided by the European Commission. According to this definition, NBS are "*Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*" (EC, 2023).

NBS address societal challenges such as climate change, disaster risks, food and water security, and human health by protecting, sustainably managing or restoring natural ecosystems. They simultaneously provide human well-being and biodiversity benefits, as they enhance ecosystem services such as erosion control, drought and flood prevention, carbon sequestration, cooling, and wildfire prevention. Additional benefits provided by NBS in urban environments are increased air quality and reduced noise pollution (see, e.g. Climate Adapt, 2023; World Bank, 2023; IUCN, 2020).

This paper builds upon two technical papers published in 2021 and 2022: Veerkamp et al. (2021) that showcased a selection NBS case studies across Europe and Martire et al. (2022) who framed the concept of scaling of NBS. It focuses on the discussion of socio-economic aspects, and in particular aspects of the characterization and distribution of benefits generated by NBS. The objective of this paper exemplifies this analysis in six selected case studies selected from those analysed in the two previous reports and aims to assess how the socio-economic conditions impact the potential for large-scale implementation i.e upscaling of NBS.

1.1 Scope of the report

Martire et al. (2022) introduced and tested an analytical framework for the analysis of case studies to identify barriers and enablers for the scaling of NBS (Martire, et al., 2022). The aim of this framework was to provide guidance for the selection of NBS for implementation in a variety of conditions across Europe. The approaches needed for the implementation and scaling of NBS were mainly focussing on how well they accommodated the goals of climate adaptation, ecosystem restoration and biodiversity conservation. Some of the conclusions made in this first analysis and in a subsequent EEA briefing point to a lack of finance and of knowledge about suitable business models for implementation and maintenance of NBS (EEA, 2023; Martire, et al., 2022). These gaps are connected to a lack of clarity, recurrent in discussions about scaling of NBS, about the distribution of costs and benefits between private actors and society. The report of Martire et al. (2022) also showed that for successful implementation of NBS it is necessary to take a systemic approach to NBS implementation which includes all aspects of design, implementation and management of the measure.

Starting from these previous discussions, this report takes the assessment framework of Martire et al. (2022) one step further by including the socio-economic setting of the context where NBS measures are implemented. For this purpose, the Martire et al. (2022) framework has been detailed with a specific view on socio-economic characteristics of NBS projects and their implementation. The aim of this framework is to detect barriers and enablers for up-scaling of NBS, and to identify basic requirements for governance and business models. A selection of previously presented case studies is taken up once more, investigating governance, economic and legal aspects which could be relevant to scaling up or deep NBS programmes.

2 Socio-economic barriers and opportunities for upscaling of NBS

2.1 Discussions in the EU policy domain

NBS are mentioned, in several EU policy documents, as the preferred solution for societal problems. The 2021 update of the EU adaptation strategy launched in 2013 puts large emphasis on the need of wider implementation of NBS as "… multipurpose, 'no regret' solutions [which] simultaneously provide environmental, social and economic benefits and help build climate resilience" (EC, 2021a). This emphasis on the need for investments in NBS was enforced by the European Biodiversity Strategy (EC, 2020) and the recent proposal for a European Nature Restauration Law (EC, 2022a). NBS are seen as options to reach the foreseen targets and actions for halting biodiversity losses and the legally binding restoration targets with the aim to create synergies between the restoration of particular ecosystems (e.g. peatlands and forests) and climate policy goals (EC, 2022b). In parallel, the European Commission has launched funding opportunities for research and innovation projects under the Horizon programme to close knowledge gaps related to efficiency of NBS (Faivre et al., 2017). Further funding opportunities for NBS implementation and demonstration were created in EU programmes as HORIZON EUROPE, LIFE, ERDF funding and specific programmes under the agricultural and fisheries policies. In the same period, the European Investment Bank (EIB) has launched specific funds (NCFF) for projects halting biodiversity loss and supporting ecosystem-based climate adaptation.

As a result of these initiatives, several pilot projects and small-scale implementations have been implemented. These pilots were frequently financed by research and innovation projects or other ad-hoc financial resources, but failed, in most cases, to establish continuous financial flows for scaling up these initiatives (Hudson et al., 2023). For a wider-scale replications of these approaches, information on the costs, benefits and relevant legal, governance and business models is needed (EIB, n.d.; Hudson et al., 2023). The level of private investments in the implementation of NBS in general and for climate adaptation and biodiversity protection in particular, is still rather low (Hudson et al., 2023).

Despite claims that "benefits of NBS for climate change adaptation are, in most cases, higher than their costs" (UNEP and UNEP WCMC, 2020), NBS projects are rarely upscaled (Knight et al., 2022). Obstacles for upscaling are identified in the perceived high costs associated with their implementation. More importantly, cost benefit analysis for NBS in most cases turn favourable as soon as they include non-tangible benefits (Viti et al., 2022), but these assessments do not take into account how benefits are distributed and return of investment can be ensured. These gaps limit the building of a "business case" for NBS, thus preventing planners and decision makers to incorporate them into wider adaptation strategies (UNEP and UNEP WCMC, 2020).

The World Economic Forum has calculated that, to meet climate change, biodiversity and land degradation targets, the scaling of NBS would require, at global level, at least tripling of actual volumes of investment by 2030 and a four-fold increase by 2050 (Hudson et al., 2023). There is a wide consensus that, to meet such an investment programme, a substantial involvement of private sector investments would be needed: "The challenge of scaling up nature-based solutions is clear and cannot be accomplished without the active support of the private sector in partnership with the public sector" (A. Fayolle, in Hudson et al., 2023, p. 1). This is supported by an evaluation of different case studies by Keesstra et al. (2023), who found that the level of private investments in the implementation of Nature based Solutions in general and for climate adaptation and biodiversity protection in particular is actually rather low. This holds for the major part of the case studies considered in the case study analysis cited above, but is confirmed also by a comprehensive study of physical nature-based projects carried out in Europe an the UK since 2000 by Hudson et al. (2023).

In a recognition of NBS in European context, a study published by the EIB (European Investment Bank) concluded that funding of NBS:

- is dominated by the public sector with a very small share of projects financed predominantly by the private sector,
- is dedicated to small scale projects with more than 80% of the projects having investment costs of less than €10 million and almost half of them with investment costs even below €1 million. (Hudson et al., 2023, p. 3).

Yet, increasing public and/or private finance emerges as a key challenge for upscaling urban NBS (Toxopeus and Polzin, 2021; UNEP, 2021). To overcome this barrier, there is an urgent need to expand knowledge and awareness about NBS functioning, about the way benefits are generated and are distributed, about possible legal, governance and business models and about financial resources or investments into NBS (EIB, n.d.; Hudson et al., 2023).

Frameworks actually used for assessing costs and benefits of NBS (e.g. EC, 2021b; Van Zanten et al., 2023) focus on accounting for quantities of benefits generated compared to costs, rather than investigating ways how benefits are distributed across different public and private actors and society, an information which would be important for identifying and unlocking adequate financing mechanisms. In this context, a more holistic approach to assessment, highlighting the different characteristics of economic, environmental and social benefits associated with NBS in comparison to traditional engineering approaches are particularly relevant (Calliari et al., 2019; Price, 2021; Woodruff et al., 2020). Many of the benefits generated by NBS are non-monetary and for this reason more difficult to measure (Price, 2021). More importantly, the lack of a market for such benefits implies the lack of opportunities for capturing returns of investments. On the other hand, in most cases exactly these wider benefits make NBS so more attractive and create a better Cost/Benefit scoring than traditional investments in adaptation.

2.2 NBS as economic goods

A key challenge of increasing investments in NBS by creating marketable business cases to attract private investments is related to the economic characteristics of the benefits created by NBS which can be referred to as "public goods" (Hudson et al., 2023; Woodruff et al., 2020).

From an economic perspective, benefits are seen as goods and services which can be classified as "public", "private", "common" or "club" goods, depending on the way, consumption of these goods and services can be controlled and managed.

Public goods are defined as social and economic benefits which serve all members of the society without a possibility of controlling access to them and which are not reduced by individual consumption a (Ostrom, 2005). For example, CO_2 reduction in the atmosphere – a benefit provided by many NBS – contributes to mitigate global warming, a benefit delivered to the whole society. Similarly, many NBS implemented as adaptation options, contribute to the general well-being of the local or wider communities, e.g. improving air quality. In these cases, co-benefits are distributed across society. The possibility of **limiting access** to such goods and services users determines possibilities for investors to capture returns of investments.

On the other side, **private goods** are controlled (e.g. with property rights) by single owners and benefits produced as return of the investment belong only to these investors (e.g. food, crops, etc.) who are able to control access and exclude users from the access. Their character of "**excludability**" makes private goods the classic good traded on markets.

Further to these two categories of totally public or private goods, a third category is represented by "**common goods":** in this case, like in the case of public goods, benefits created as common goods or resources can be accessed by all without limitation, so without any possibility of creating returns of investment by fees or other payments. However, the access to the benefits or goods is subject to **rivalry** as consumption of parts of it **subtracts** the possibility of others to equally benefit from the same good. For example, fish stocks are common goods or resources, since access cannot be limited, but conflicts among different fishing groups and stakeholders may emerge, since the resource is limited and finite.

Finally, **club or toll goods** have characteristics of both public and private goods, as access to them can be limited or controlled, but they are not exposed to rivalry, as benefits generated by such goods do not decrease when individuals are making use of from them, e.g. privately managed natural areas.

Figure 1 Economic characterization of goods adapted from Ostrom (2005)

		SUBTRACTABILITY OF USE	
		LOW	HIGH
CONTROL OF ACCESS TO BENEFITS	HIGH	CLUB (OR TOLL) GOODS	PRIVATE GOODS
	LOW	PUBLIC GOODS	COMMON GOODS

2.3 The distinctive economic characteristics of investments needed for creating marketable benefits

The economic characteristics of goods or benefits generated by NBS as described in the previous section determine to which extent involvement of market actors in the generation and management of NBS can generate return of investment and attract private investments.

In the case of private goods or club goods, both connotated by excludability, the possibility of controlling access, for instance for privately produced public infrastructures like irrigation systems allows for directly capturing benefits created raising access fees. In the case of NBS producing benefits under the form of public goods for the whole society without possibility of exclusion (like public infrastructures), public investments, financed by the entire society as taxpayers, will generally represent the most feasible solutions.

In the example of flood protection, **capital intensity** emerges as a further requirement for investments. It is related to the entity of investments required for producing benefits, which might go beyond the investment capacities of private investors (Woodruff et al., 2020). According to an analysis of implemented NBS measures in Europe, despite their predominantly small scale, many nature-based projects are financed involving larger debt issuances (>$15 million) by different backers (Hudson et al., 2023, p. 6). A finding by Keesstra et al. (2023) points indeed to the fact that private or commercial investments in NBS are more focused on NBS of smaller scale which re-construct ecosystems, whereas public investments in NBS are found more often to focus on measures using existing natural areas and their ecosystems.

In cases where the exposure to risks, for instance related to flooding, is diversely distributed, also benefits generated by protection (losses or damages avoided) are heterogeneously distributed. This **heterogeneity of benefits** can open the way to specific payment schemes which are based on the different entity of benefits perceived by individuals. An example are insurance fees as forms of private finance which are related to the value of assets at risk, or drainage fees in reclamation areas.

Finally, investments in NBS for climate change adaptation and biodiversity represent, in most cases, a form of **joint production**, as they generate goods that produce more than one type of benefit which often have different characteristics in terms of **excludability** and **rivalry**. This can pave the way for mixed forms of finance, which recur on public subsidies alongside with private contributions or investments.

2.3.1 Different opportunities for different types of ecosystems

The previously mentioned EIB study (Hudson et al., 2023) provides an indication of the scaling potential, from a financial point of view, of different types of socio-economic systems. Urban, forestry and agriculture have the highest potential, as showed in figure 2 below. These are often limited to “mature” revenue generating NBS, such as in the context of agricultural production (agroforestry) or forestry (for timber production), that however represent a restricted subset of the broader portfolio of NBS for climate change adaptation (Chausson et al., 2023; Hudson et al., 2023, p. 3).

Figure 2 Scaling potential of NBS in different Ecosystems (Hudson et al., 2023, p. 4).

Opportunity	Ecosystem	Characteristics
HIGH opportunity for NBS growth	**URBAN**	• Many policy instruments are readily available for urban nature-based solutions (e.g. use of building codes to encourage / require green roofs) • High population density results in a greater number of people deriving benefits from nature-based solutions, which in turn can enhance demand • Examples: urban heat and flood mitigation, aesthetic greening
	FORESTRY	• Strong potential for revenue streams through carbon credits and ecotourism revenues • Poorly managed commercial forests provide a significant opportunity for nature-based solutions, through the potential for enhanced carbon sequestration and for nature-based actions to achieve policy goals (such as the EU Nature Restoration Law targets) • Key challenge: risk profile of long-term maturity rates linked to the slow growth rates of plantings
	AGRICULTURE	• Significant potential for NBS funding through the common agricultural policy (CAP) • Such funding could be directed towards current NBS instruments under the CAP that are underused, or additional nature-based solutions through CAP reform • CAP reform can also reduce negative incentives that undermine nature-based solutions
MEDIUM opportunity for NBS growth	**RIVER AND LAKES**	• Lack of incentives for private investiment due to the public good nature of benefits derived from these ecosystems (biodiversity improvements are difficult to finance privately) • However, the water management sector can invest in nature-based solutions to meet regulatory requirements and recoup costs from customers
	WETLANDS	• Peatland and wetland areas have significant carbon storage potential • Such ecosystems often overlap with agricultural landscapes, and their absolute area is relatively small due to historic land take actions
LOW opportunity for NBS growth	**MARINE AND COASTAL**	• Very few privately owned sites hinders the opportunity and incentive for private investment • Significant knowledge gaps mean that identifying areas in poor condition (and thus likely to be subject to demand for nature-based solutions) is challenging • A key driver for future nature-based solutions is public investment in risk reducion measures (flood risk, coastal erosion) • Restoring seagrass, kelp forests and coastal wetland areas for carbon sequestration and biodiversity are potential areas of growth

Among the more than 1,300 case studies investigated by Hudson et al. (2023), 76% of the cases studied were located in the urban domain. The more frequent application of NBS in **urban environments** compared to other ecosystems highlighted by this study is noted also by other authors (Dorst et al., 2021; Goodwin et al., 2023). In addition to public green spaces which add value to surrounding privately owned and commercial premises (Raymond et al., 2017; Kabisch et al., 2022; Wamsler et al., 2020), many urban NBS are implemented as parts of private premises, e.g. green roofs and walls as parts of private buildings, where a greater share of the benefits generated by the solutions remains in the domain of the single investor and private benefits are created under the form of value increases of these premises.

NBS in urban areas, like the creation of public green areas, provide benefits to all urban dwellers living in the surrounding of these improved areas, and raise their attractiveness, which translates in increases of real estate prices and rents, while municipalities which benefit from local taxes on real estate properties could thus expect raising tax incomes. In the case of NBS improving urban drainage or flood security, costs for the creation or the improvements of these infrastructures can be, in most countries, passed on the users by taxes or fees, for instance for surface drainage. Whenever adaptation actions as green roofs are undertaken by private investors, e.g. private homeowners, parts of the benefits generated are also enjoyed by an extended group of people over a wider area or contribute to reducing the management costs of public infrastructure for stormwater. This may, for instance, result in reduced stormwater fees where green roofs reduce the pressure on public stormwater systems.

Concerning the **agricultural** sector, NBS transforming agricultural practices directly concern private economic activities and their performance, as changes in crops and agricultural management directly affect farmers' incomes. Benefits are both received by farmers (for example due to the use of more resistant crops or to the disclosure of new markets for niche products) and, in most cases, by the society under the form of enhancement of biodiversity and associated climate services.

In the agricultural sector, the conversion to more nature-based forms of production can also be associated with productivity loss and higher management cost. Such losses in productivity and income need to be compensated by subsidies recognizing the public goods character of the benefits generated. For example, rewetting of agricultural areas on formerly drained swamps or marshlands would necessitate the adoption of new crops and management methods. Investment costs and financial risk and opportunity costs would fall on the farmers, while the society would benefit from the reduction of carbon emissions from the agricultural sector and carbon sequestration, conservation of groundwater reserves and flood protection provided by rewetting. A part of these public benefits can potentially be captured through carbon markets, but a substantial need for public support would remain (Liu et al., 2023; Tanneberger et al., 2022). The CAP (Common Agricultural Policy) provides a number of instruments which could support the roll-out of NBS solutions at a larger scale (Greifswald Mire Centre et al., 2020; Hudson et al., 2023).

Flood resilience and water management services provided by NBS can, in some specific contexts, create benefits which can be framed as "club goods" if only a limited number of actors, for example farmers in a watershed invest jointly in the creation of wetlands for drought and flood resilience or for irrigation. In these cases, management efforts and benefits would rest with a relatively low number of participants, enabling efficient decision making and avoiding free riding. With increasing numbers of participants, for instance in larger irrigation systems, control over water uses becomes more complex, so that the provision of this good as a public service would be more efficient (Ostrom, 2005).

Finally, NBS implemented for the protection from coastal and fluvial flooding related to sea level rise and flood protection create benefits for a wider part of society and are thus generally considered to be a public good under the responsibility of national, regional or local governments (Woodruff et al., 2020).

2.4 Potential financial tools and options

2.4.1 Costs and benefits, efficiency and return on investment

Economic assessments are used to guide the comparison of different adaptation options before selecting the most suitable (and economically viable) one to counteract the impacts of climate change. In this process, NBS may be compared to hard engineering measures and the selection of NBS depends on their costs and on their short and long-term benefits. These considerations form the basis of **cost benefit assessments**, an analysis of overall costs and overall benefits of measures, that generally include all monetary dimensions of costs and benefits over time. Cost-benefit assessments result in a quantitative expression of the two entities, which should be, for qualifying for investment, above the ratio 1:1, that means that benefits over time are larger than the costs of investment and management. Benefits or costs which will occur in a more distant future can be factored in by "discounting" such benefits to net present values (UNEP and UNEP WCMC, 2020). The rate of discounting to be applied is an expression of how much future benefits are valued compared to those occurring in the short term.

Extended cost-benefit analysis also includes non-monetary benefits with social value to be assessed alongside with financial considerations. Such benefits would include, for example, human welfare, environmental health, enhancement of biodiversity or job creation and the distribution of benefits in space and across society. Such non-monetary benefits cannot be captured by an investor in the form of revenues, so would not be applied as an assessment criterion in the case of market driven investments. In the case of public investments, the assessment of such non-monetary benefits can play a major role, as these measures would potentially replace other public investments to obtain the same benefits. With regards to the dimensions to be considered for such extended analysis of benefits, the NBS evaluation handbook (EC, 2021b) provides a wealth of indicators for co-benefits of different types of NBS measures in different spatial contexts, facilitating the identification of potential co-benefits.

Cost benefit analysis can also be used to inform the design of measures with the aim of improving the cost-benefit ratio by, for instance, increasing the amount of potential co-benefits. Cost-efficiency considerations can help comparing different options for the design of measures. For public decision making, investments in NBS can represent a cost-efficient way for reaching other policy objectives without additional investments. This is for example relevant for nature development in flood plains, were the associated economic benefits related to flood protection make this a particularly cheap way of realising large spaces for biodiversity.

Although there is a certain possibility of standardization of the dimension of benefits at this regard, the assessment of the efficiency of NBS depends largely on site-specific or local conditions, so that the use of standard values to be applied to the ex- ante evaluation of NBS is problematic.

2.4.2 Sources of finance

Woodruff et al. (2020) show that a wide set of financing tools exists but is only partially employed. According to the authors, the selection of the most suitable tool should be tailored to the specific public good to be protected and the selected adaptation strategy. For example, with regards to coastal protection strategies, sand nourishment (often classified as NBS) provides, beyond public benefits for adaptation, also benefits for tourism with more stable and wider beaches. Similarly, other nature-based risk reduction strategies (coral restoration as tools to dissipate wave energy and reduce erosion) also generate benefits for resorts and hoteliers (Brathwaite et al., 2022).

Funding of NBS actually largely depends on public sources, with little participation of the private initiative (Moraes et al., 2022). The main financial barriers identified by the authors are related to the challenges of combining private and public sources.

Barriers to an extension of investments in NBS are seen, inter alia, in the lack of basic knowledge about the effectiveness on NBS compared to well-known traditional, grey adaptation measures (Moraes et al., 2022; Toxopeus and Polzin, 2021). A further gap to make clear cases for public or private investments is identified in the lack of assessment tools which are able to integrate different market and non-market benefits (Toxopeus and Polzin, 2021). Monitoring of existing NBS measures is common, but rarely effectiveness of NBS is measured in quantitative terms. Thus, experiences from existing NBS measures do not provide much insight for ex-ante assessments of the efficiency of NBS. Moreover, measurements of existing NBS efficiency and expected benefits may also have a limited value for other cases since it depends to some extent on specific local conditions. The lack of standardization of NBS is a further barrier for the assessments cost-efficiency of NBS investments. Another important obstacle, considering the diverse benefits created by NBS, are regulatory obstacles and silos which hinder the pooling of funding and financing, to the exclusion of some sectors from regulatory initiatives (such as the EU taxonomy), up to regulatory silos which hinder the pooling of funding and financing (Hudson et al., 2023).

As stated above, the main financial instruments used by NBS projects implemented in the EU include direct public funding and grants, e.g. in the frame of research projects (Hudson et al., 2023; Moraes et al., 2022). The temporary nature of these grants represents a hurdle to continuity of NBS (Hudson et al., 2023, p. 6). Market loans are used mainly by private institutions in cases where value capture can guarantee sufficient return of investment, and concessional loans with special conditions, granted by development finance institutions, governments, or municipalities. From a project point of view, there is a risk that the beneficiaries will be unable to make regular repayments on the loan.

Nevertheless, successful cases show that tailored approaches, combining different funding, financing, and revenue streams, are the most effective strategy (Hudson et al., 2023). Potential instruments, open to both private and public investors into NBS, include special dedicated (green) finance and green bonds, used for instance by the city of Paris (Climate Adapt, 2016).

2.4.3 Business models

Assessing whether NBS projects can be viable solutions also for the private sector, requires integral cost-benefit analysis, taking all relevant impacts into account. These include not only the primary adaptation benefits and biodiversity gains, but also provisioning services (e.g. timber production), regulating services (carbon capture) and social benefits (recreation, air and water quality improvements). On the cost side, further to the direct implementation and management costs, also opportunity costs need to be taken into consideration (e.g. foregone agricultural production), as well as social and spatial distributive costs, for example reduced access to resources or uneven social possibilities of access to benefits, for example generated through gentrification or loss of employment. Using such holistic assessments can help creating political consensus for NBS compared to hard infrastructures which would then reveal being less cost-efficient as they would lack the same range of co-benefits.

However, the potential of financing NBS based on marketing of ecosystem services is constrained by several factors, as described by recent research (Chausson et al., 2023). The quantification and mapping of ecosystem services is indeed a complex task and is affected by high levels of uncertainty, let alone with respect to the impacts caused by climate change on these services. Chausson et al. (2023) argue furthermore, that data on ecosystem services flows is not equally available for all geographic areas and ecosystems, privileging those ecosystems that are “instrumental, tangible, or easily measured with numerical metrics” (Chausson et al., 2023, p. 4) and potentially concentrated on commercially mature sectors (such as agriculture and forestry) whilst the possibility of comprehensively assessing the economic

value of benefits produced by biodiversity remains widely debated (see, for example, Norgaard, 2010; Díaz et al., 2018; Pascual et al., 2017).
A conceptual framework for assessing the viability of NBS for upscaling proposed by UNEP (2020) is reported in the figure below.

Figure 3: Framework for the assessment of NBS benefits, costs and impacts (UNEP and UNEP WCMC, 2020 following ; Emerton, 2017).

BENEFITS	COSTS	IMPACTS
PRIMARY ADAPTATION BENEFITS	**DIRECT IMPLEMENTATION EXPENSES**	**TEMPORAL IMPACTS**
i.e. the benefit of reducing climate change related risk, e.g. sustained agricultural productivity	e.g. staff, equipment, transport, infrastructure, maintenance, etc.	when do costrs and benefits fall over time? E.g. rate at which haitat recovery restores ecosystem services, when intervention costs are incurred, interests of future generations, etc.
ADDITIONAL ADAPTATION BENEFITS	**CORE INSTITUTIONAL & ENABLING COSTS**	**SPATIAL IMPACTS**
e.g. mitigation of storms and flood damages, year-round water supplies, sustained farmland productivity in the face of drought, maintenance of species habitat, etc.	e.g. training, development of plans, laws, policies, incentives, etc.	where do costs and benefits fall spatially? E.g. gains and losses for upstream and downstream communities, costs and benefits to ecosystem providers and users, effects across borders, etc.
CO-BENEFIS	**OPPORTUNITY COSTS**	**DISTRIBUTIONAL IMPACTS**
e.g. improved health, better food supplies, new and diversified income opportunities, disaster risk reduction, waterhed protection, enhanced biodiversity, etc.	e.g. foregive income and output due to land some restrictions, etc. **SOCIAL & ENVIRONMENTAL LOSSES** e.g. negative impacts on women, downstream communities, etc.	where do costs and benefits fall demographically? e.g. changes in resource access or income opportunities between women and men, rich and poor, urban and rural, regions, rectors, communities, etc.

The choice of investors (public or private) and of the type of financial resources can be framed in the form of business models. Their design and the actors to be involved depend on the characteristics of the NBS solution chosen to produce a return of investments in monetary terms and to access adequate public funding.
The definition of suitable business models and the selection of the financial instruments depend on three decisions, which regard the questions of (1) how social, economic, and environmental benefits (including both monetary and non-market values) will be proposed, (2) how they will be created and delivered to end users, and (3) how benefits will be captured:

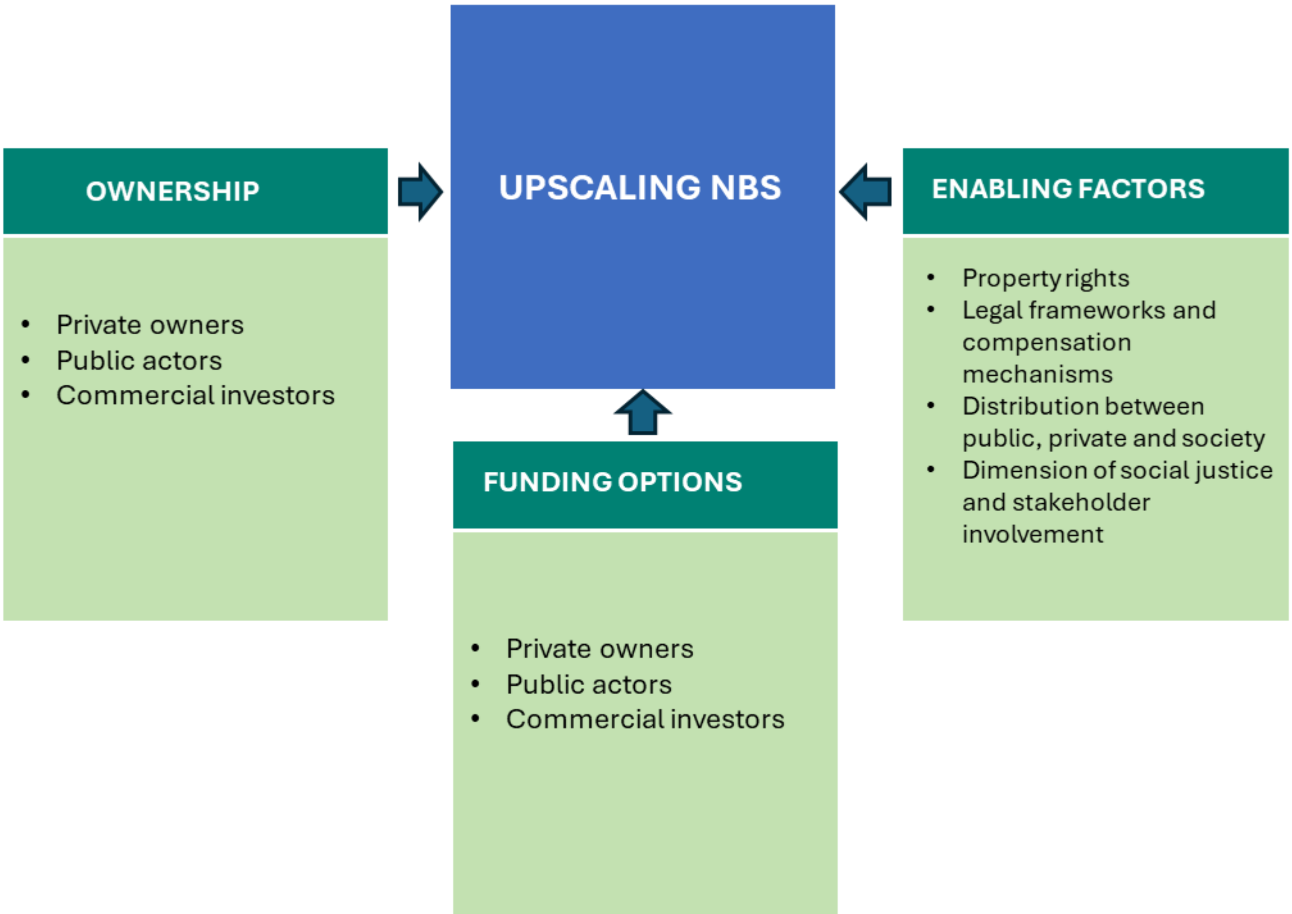
- **Value proposition** concerns the description of values which the project would intend to generate, addressing financial markets as well as political arenas, to define and explain which needs of citizens or other potential beneficiaries and stakeholders will be addressed.
- **Value generation** describes the way these social, environmental, and economic benefits will be created and delivered to end users.
- **Value capture** concerns if and how returns of investment can be realized from these activities (Mayor et al., 2021, p. 5).

These aspects need to be addressed for the creation of business cases, bearing in mind that NBS may require, differently from some hard infrastructures, continuous maintenance activities to keep them efficient, a cost which is compensated by a longer lifetime of most solutions in the case of many NBS. Disregarding ordinary or extraordinary maintenance need as well as future climate impacts on ecosystem services the functionality of the NBS depends on (e.g. water availability) can lead to the creation of stranded assets, where NBS stop functioning because of decay or loss of key elements.

3 A framework for the analysis of socio-economic upscaling potentials of NBS

As argued throughout this report, the identification of suitable business models depends on the way benefits, generated by the NBS, are distributed across the society. These patterns influence the identification of potential actors and financial resources, and, therefore, of suitable forms of governance, e.g. how decisions about investments, legal frameworks and property rights are addressed. The analysis of real examples of NBS implemented in Europe to address different climate change impacts in different ecosystems allows to anchor theoretical considerations to the practice. Based on a selection of case studies investigated in previous assessments for their upscaling potential, an integration of the previously proposed assessment framework (Martire, et al., 2022), is suggested here to specifically address socio-economic factors. The framework integration is composed of three components: actors and owners, funding opportunities, and enabling factors, as illustrated in the following scheme (Figure 4).

Figure 4: A Framework for the analysis of socio-economic potential of NBS.



3.1 Ownership

3.1.1 Private owners

Implementation of NBS by private owners is particularly successful in those cases where benefits can be at least partially realized in the private sphere and can create a return of (private) investments. Such private investments actually play a particular role in the urban environment, where NBS are often created on private premises or as urban infrastructure and greening which increase the value of private properties.

3.1.2 Public actors

Most NBS relevant for biodiversity conservation and climate adaptation are owned by public bodies or by institutions using public finance. Public ownership ensures that NBS can be produced, as a "public good" or public infrastructure, in a way which does not depend on the need of generating marketable benefits generating a return of investments where all benefits can be enjoyed by all members of society without limitations.

Many NBS projects actually promoted and/or owned by public actors are furthermore mostly realized as demonstrative projects and thus do not yet have the status of routine investments for climate change adaptation (Goodwin et al., 2023; Hudson et al., 2023). Despite this important role of public investment and ownership in the actual landscape of NBS, the implementation of grey solutions still dominates every-day policy making. Traditional approaches based on grey solutions have influenced existing governance strategies and continue driving long term decisions made in public administrations. They also shape the patterns used for interactions with stakeholders. Moving the implementation of NBS towards the status of the "new normal" for public infrastructure would require transformations in public decision making. Such transformations include, inter alia, new approaches to decision making which evaluate grey and green options against each other at different levels, and across sectoral policy goals, considering also the need for specific available knowledge, trust in the efficiency of measures among decision makers and stakeholders, conflicts of interest and new forms of stakeholder involvement (Wamsler et al., 2020; Frantzeskaki et al., 2020).

3.1.3 Commercial actors

Promotion of NBS by private business follows patterns similar to those of private actors as long as benefits can be captured by the commercial activity to cover investment and maintenance costs but would possibly expect a quicker turn-over, so that long lifetime of NBS could be less important as a criterion. Value capture can occur, in these cases, due to a reduction of the risk of business interruption or crop failure (insurance value) provided by the NBS, for instance, due to a mitigation of flood or drought risks, or due to increased profits from increased values of production. Such value increases would also require an adequate value proposition as part of a specific business model, to ensure access to specific markets for, e.g., nature friendly products. Investments made by commercial activities do not only include the costs of creation of NBS, but also maintenance costs and potential losses in income, as for instance in agricultural activities and entail long investment horizons.

3.2 Funding options

3.2.1 Private owners

Public benefits generated by the private investment (as a reduced pressure of stormwater on the sewage system by the retention capacities of green roofs) can justify a reduction of public fees. Such a fee mechanism has been applied to stormwater fees, for example in Hamburg and Basel (see chapter 4). Such tax or fee reductions are particularly efficient in the long term since they can cover the expenditures made for the maintenance of the measures.

Reductions of taxes or fees and other forms of financial incentives, specific financial products and grants can reduce the gap between costs sustained and benefits received also for commercial actors and can be used actively to promote such investments. In terms of policy measures to promote and facilitate the generation of commercial investments into NBS, tax and fee reductions could be framed as a compensation for benefits these investments generate for the wider public, or the society as a whole. This could be the case in specific subsidies provided by climate friendly farming practices, for instance, by the Common Agricultural Policy (CAP) (Liu et al., 2023; Tanneberger et al., 2022; Greifswald Mire Centre et al., 2020).

Specific financial arrangements are needed, which consider the potentially longer investment horizons entailed by NBS projects, the capacity by investors of aligning corporate interests (image, long term perspective for creating for the market services) and the capacity to capture the needed return of investment from markets, as for instance in the case of water utilities investing in the protection of groundwater.

For example, NBS can correspond to long-term strategic needs of utilities or corporate investors in need for instance, of resilient supply chains reliant on natural systems or of a social licence to operate, and of on levers to increase customers' ability and willingness to pay either on a regulatory or voluntary basis.

3.2.2 Public owners

Considering the long-term maintenance needs of most NBS implementation, the funding by grants bears a risk of disruption, leading to malfunctioning of NBS and their transformation into stranded assets.
In cases where public funding of NBS creates benefits which can be captured by private properties (e.g. increased real estate values), such value increases can be, in some cases, captured by the public under the form of real estate taxes, e.g. financing of the cloudburst plan in Copenhagen (City of Copenhagen, 2014).

3.3 Enabling factors

3.3.1 Property rights

Property rights determine who can primarily produce values and how and by whom values can be captured. Availability of sufficient funding for land acquisition in large scale projects is a key issue, as direct land ownership can enable the realization of NBS interventions. Land ownership would, in many cases enable actors to directly operate in the target areas. Yet, the acquisition of land is in some cases not eligible for specific finance (e.g. EIB funds). This is an issue for a rewetting project in the province of Friesland (NL) where a local buy-out of farmers is planned in view of better protection of the groundwater of large parts of the province (Personal Comunication, Mindert de Vries, October 2023)[1]

3.3.2 Legal frameworks and compensation mechanisms

Legal obligations, for instance in land use plans or building codes, can be used to drive the implementation of NBS solutions by private investors, for instance the obligation to realize green roofs, as applied in Basel or Munich, appears to be a success (chapter 4). Yet many local authorities hesitate to apply such generalized obligations in view of reinforcement and monitoring (Clar and Steurer, 2023) and prefer incentives over legal coercion. In the case of Hamburg, the real estate sector successfully opposed plans by the local authorities to make green roofs obligatory on all suitable roofs in the city area.
In other cases, restoration activities can be promoted to “repair” damages created by economic activities that have strong environmental impacts in the surrounding area. This is the case for dune restoration near the Bevano river mouth (Italy, chapter 4), where a public-private agreement involves the energy company that, mainly in the past, managed large offshore hydrocarbon extraction activities.
Both cases put into evidence the need for control and monitoring to enforce legal and contractual obligations. Funding for monitoring is thus necessary for designing and implementing NBS and for monitoring and possibly enforcing long term maintenance of measures.

3.3.3 Distribution of benefits between public, private and the wider society

Implementation of NBS is particularly successful in those cases where benefits can be, at least partially, captured by private owners.
Benefits created by urban NBS can be captured by private actors and companies as parts of building values, under the form of reduction of management costs (e.g. due to better insulation provided by green roofs or of their longer lifetime) or in the form of immaterial values, as for example increases in quality of life granted by the availability of a privately used green outdoor spaces. Among the case studies analysed in this report (chapter 4) the green roof case is particularly relevant, since the availability of green roofs affects the economic performance of private investments.

3.3.4 Dimensions of social justice and stakeholder involvement

Stakeholder and citizen participation in nature-based solutions is increasingly recognized as promising (Ferreira et al., 2020) and a key process for enhancing the NBS social acceptance and their implementation (Giordano et al., 2020). In the NBS project lifecycle suggested in the EC Handbook for evaluating NBS (EC, 2021b), stakeholders are engaged from the first step of the process and are key throughout the entire NBS lifecycle. Similarly, in the step-wise framework for designing NBS assessments (Veerkamp et al., 2021),

[1] Case study of the Horizon 2020 NBRACER project https://nbracer.eu/regions/province-of-fryslan/

stakeholder involvement starts from the very beginning of the process, when the assessment purposes and characteristics are defined. Key questions to be addressed for the design of decision processes refer to the real need for including stakeholders (should the assessment be expert-driven, or stakeholder driven?), the "stakes" to be assessed (which stakeholders concerns need to be included?) and the desired level of participation (is consultation enough or is there a need for more advanced mechanisms as co-creation and co-management?). Stakeholder-led approaches (e.g. interviews, surveys) to the assessment of NBS can complement data-led approaches and help build narratives that integrate different stakeholder perspectives. Indeed, the participation of stakeholders in the identification of co-benefits that NBS is strongly supported by literature (Giordano et al., 2020), as NBS is still seen as an unusual approach by certain communities (Moraes et al., 2022; Anderson and Renaud, 2021). Successful involvement of stakeholders can be a crucial element for scaling as it increases consensus and ownership which can be used as a basis for subsequent NBS implementation in the same area.

Although these theoretical approaches are widely recommended in policy documents and scientific and technical literature, practical examples reveal that stakeholder involvement is still limited compared to its full potential. Moreover, case studies (chapter 4) show that recognizing the different perceptions of NBS and of benefits generated by them among stakeholders is a complex task.

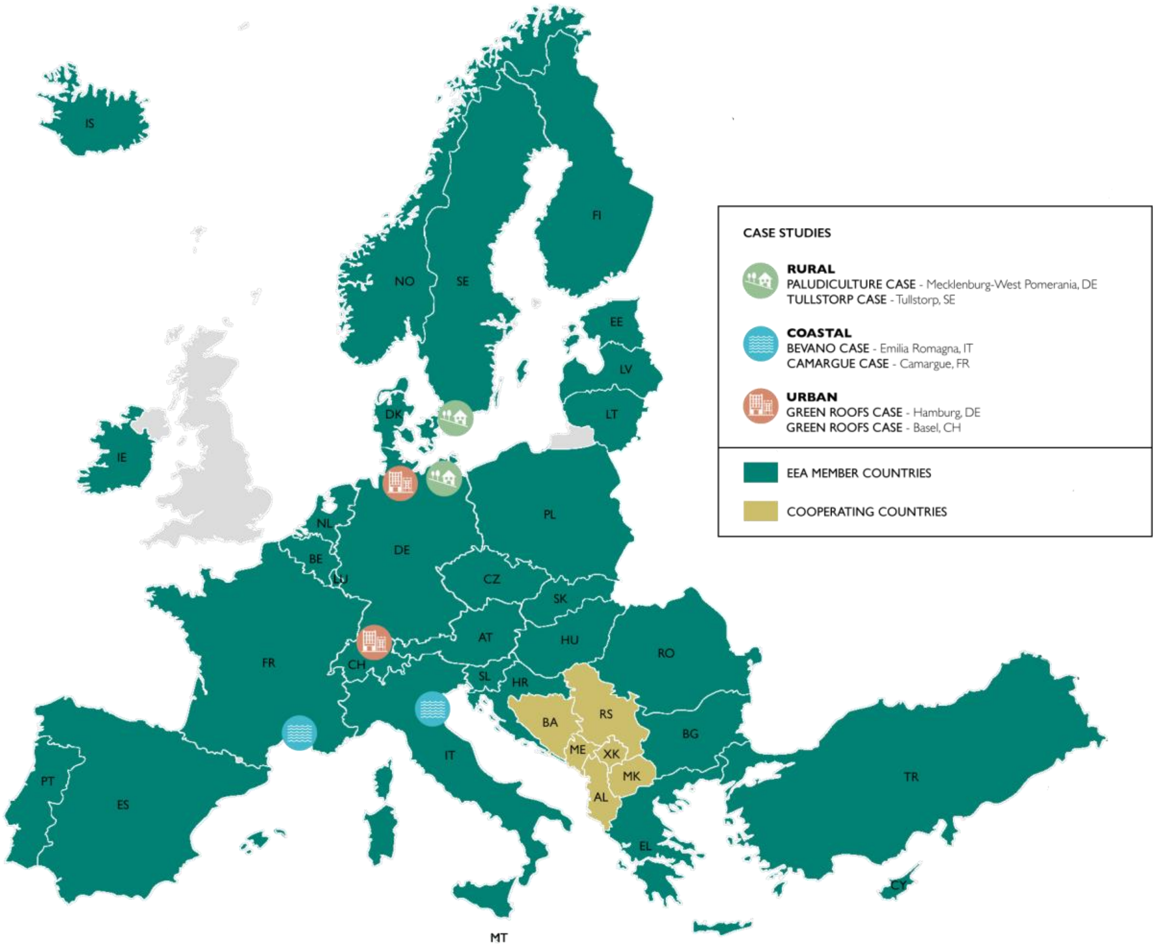
However, case studies also prove that an involvement of stakeholders from the beginning of the project increases the success of the initiative. This is both the case of Basel, where stakeholders were involved in the design of the incentive system for green roofs, tailored both to business and to citizens, and the case of Hamburg, where stakeholders were involved to set together the common goal of "100 hectares in 10 years" that currently shapes the City's Green Roof Strategy. The fact that potentially not all stakeholders have been equally involved allowed for a single interest group (the building sector) to prevent the city administration from creating a general obligation for the creation of green roofs throughout the city, arguing that such an obligation would not allow to reach the political goals in terms of annual number of dwellings with affordable rents to be realized (Richter and Dickhaut, 2019, p. 44).

In case where NBS can be framed as public infrastructures, such as coastal protection, the dilemma of choosing between grey and green infrastructures needs to be tackled in different areas, including knowledge, trust in the efficiency of measures among both decision makers and stakeholders.

Initial scepticism by citizens towards nature-based solutions is a quite common issue that can be addressed by dedicated awareness raising initiatives. This is demonstrated by the Bevano case study (chapter 4), where the attitude towards NBS (that may partially limit the access to the beach) is gradually changing thanks to targeted initiatives aimed at enabling a common understanding on the value of the implemented actions. A similar situation is found in Camargue, where the abandonment of the sea dyke in favour of a natural defence system, created some concern in the local population that felt to be less protected from flooding.

4 Case Studies

The analysis framework described in the previous section was used to analyse socio-economic factors in six case studies located in five European countries: Sweden, Germany, Switzerland, Italy and France. Case studies represent different types of ecosystems, located in rural, urban, and coastal areas.



4.1 PALUDICULTURE: PEATLAND REWETTING AND PALUDICULTURE (MECKLENBURG, GERMANY)

4.1.1 Context

The Greifswald Mire Centre (GMC) estimates that around 1.3 million hectares of agricultural land (8% of the total agricultural surface) would need to be rewetted to avoid around 42 millions of tons of CO_2 equivalent emissions annually (Schäfer, et al., 2023), a quantity of emissions which corresponds to more than half of the German emissions from the agricultural sector (61 million tonnes of CO_2 equivalent) and to 80% of all peatlands emissions of the country.
Until 2030, the objective is to rewet around 50,000 ha every year. The precise target is to rewet and convert to paludiculture 450,000 ha, which would include all former drained arable land and 50% of the drained grassland, which is owned by private farmers.

4.1.2 Actors and owners

4.1.2.1 Private owners – investments

Agricultural land used for rewetting under paludiculture schemes consists generally of private property used for the generation of income and requires the substitution of traditional crops with those compatible with rewetting, unless a buy-out and transformation of rewetted areas into (publicly owned) protected areas is foreseen. Peatland rewetting can decrease the value of the land, particularly if the new production has lesser market value and comes with a high risk of temporary or permanent income losses for farmers. Farmers need to invest in the new crops and the creation of new value chains for these crops which ensure that income losses caused by rewetting can be compensated. Depending on the size of the transformation, the entire economy of the rewetted regions will be impacted.

4.1.3 Funding opportunities

For classical production systems (arable or grassland) transforming current CAP support into specific paludiculture incentives is a major issue. Additional funding is needed to compensate opportunity costs faced by farmers for the transformation phase and for the development of new value chains and markets. These incentives can be directed to the farms, to the processing companies involved in new value chains, to the biobased-products or to potential investors. They can be complemented by fiscal incentives, de-risking instruments (guarantee mechanisms) and complemented by training programmes aiming to familiarize farmers to their new crops.

4.1.4 Enabling factors

4.1.4.1 Property rights

In general, tenure of agricultural land in Northern Germany is private. The drained peatland is exploited by farmers who are either leaseholders or owners of the land. Ownership is not likely to change after rewetting so that both the landowner and the farmer (who can be the same person) need to agree on the transformation.
The transition to a rewetted situation comes with risks of depreciation for the land assets affecting their owners. In case of public land ownership, this may not be a big issue since in the long term, the land may regain its value. For private owners however, asset depreciation may be a serious issue that needs to be properly anticipated. A transition period during which compensation mechanisms could be accessible to landowners willing to sell their properties may be considered until paludiculture crops are produced, new streams of income are established, and the land has regained value. Regarding land leases, publicly owned land could be used to pioneer the integration of specific measures related to peatland protection and rewetting.

4.1.4.2 Governance barriers and opportunities

Specific governance bodies such as the waterboards in the NL or else at catchment level need to be in place, with adequate representation of the stakeholders to enable concerted decisions on water level control or infrastructure development and maintenance.

Public and private coordination needs to be in place to enable the establishment of new value chains. Markets alone will not have the capacity to enable these without strong support from the public sector. Ad-hoc governance mechanisms need to be in place to monitor and adapt regulation, incentives, training to de-risk the emerging value chains.

So far, paludiculture has remained mostly experimental. The challenge to move from small scale experiments to large spots of land is huge: costs in transformation phase relate to reimplementing water control structures, and farm transformations require substantial coordination efforts with other farms in the area. Water infrastructure required for rewetting need to be operated in a concerted manner and provision for its maintenance costs be part of the plan.

4.1.4.3 Policy and Legal frameworks

Out of the 1.3 million ha of drained peatlands used for agriculture in Germany, only around 1 million ha are convertible to paludiculture: some peatlands are located in protected areas where even biomass production would not be allowed. Other areas may face water shortages to maintain the water tables close to the soil surface during dry seasons.

Several land use policies, including agriculture and forestry policies and subsidies, as well as nature protection areas, do not take soil types (e.g. their organic or mineral character) into account. Afforestation programmes for instance can be implemented in peatland areas, which could induce water table depletion and peat degradation but need to select suitable tree species.

Another aspect to consider is the integration of peatland protection or rewetting in land lease agreements. In agriculture these agreements are often of long duration (e.g. more than 10 years) which is a challenge for the transformation of farming practices. They also rarely integrate clauses specific to peatland management which is assumed to remain unchanged over the lease duration.

Finally, since rewetting changes the regional hydrology, it may also affect adjacent areas with mineral soils. This can generate specific risks for urban settlements and other infrastructure (infiltration, instability, etc.), as well as for other farming practices. These risks induce liabilities that need to be covered by specific measures. On the other hand, rewetting also reduces land subsidence and related risks (building instability, saltwater intrusion in coastal areas).

4.1.4.4 Technical and systemic barriers

Selecting the suitable crops and creating new value chains which can compensate income losses at farm level takes time. Moreover, to implement entire new value chains, coordination on crop selection is required across farmers of the rewetted area. Currently, the experiments reported did not manage to tackle this issue.

Crop management also needs to be adapted to the local context and technical environment. Harvesting for instance often requires specific machinery that can work in the field only if water table levels are not too close to the soil surface. This requires specific governance mechanisms and infrastructure for the management of the water table, adequate equipment and technical skills, as well as coordination between farmers to align expectations and land management.

4.1.4.5 Distribution of costs and benefits

Embarking in the transformation of their farming systems means taking big economic risks by farmers and entail costs at the farm level which microeconomic opportunity costs need to be considered which depend on the former level of CAP subsidies, on the maintenance costs of the drainage systems (Förster, 2009), on the potential market and prices of the new products compared to the profitability of the former production. Further potential costs, which stretch across the entire area to be rewetted, include the establishment and maintenance of hydraulic infrastructure, the acquisition of technology and machinery for the management of water tables, as well as investments in capacity building, knowledge transfer, advisory services, and the promotion of innovation. They need to be completed by the investment costs

in the new product value chains: transportation, transformation and marketing of the new Paludiculture products.
Finally, since rewetting can affect the hydraulic regime of wider areas, farmers need to address liabilities related to specific risks of changes in water tables, that need to be covered by specific measures to be borne by the private investors or compensated by public subsidies. On the other hand, rewetting also reduces land subsidence, which may reduce certain risks (building instability, saltwater intrusion in coastal areas) and generate benefits for the wider society. The liabilities induced by the rewetting process on the surrounding land and infrastructure can require the establishment of insurance or guarantee mechanisms, based on a thorough examination of the induced risks and a clarification of the "owner" of the liability. Another approach to be considered is to create buffers (i.e. transition zones) between rewetted areas and the land or infrastructures at risk.
In Germany, the total financial requirement of a paludiculture scenario aiming to rewet 1.05 million ha by 2050 has been estimated at EUR 21 billion, of which about 60 % account for the climate protection bonus (compensating farmers and landowners) and 24 % for the costs of conversion to paludiculture[2], corresponding to a total amount of 2,000 EUR/ha.
In terms of climate benefits, the main one is obviously the reduction of peatland emissions accounted for in the LULUCF reporting of the country. This facilitates the achievement of the net-zero target of the country. The total societal benefits of rewetting of these peatlands in Germany have been estimated at €67.5 billion in avoided negative climate damages. These benefits, which exceed the financial requirements for the project, are provided to the society as a "public good".
A benefit of paludiculture which can be captured at the farm level, so as a "private good", is based on the production of biomass capturing CO_2, that can be utilised in long-lasting products, e.g. in the building sector. In this way, part of the carbon removals allowed by the biomass production could also contribute to the sink function of the land or the agricultural production. Such storage could generate carbon certificates eligible to the EU certification of carbon removals under discussion, which would represent a form of capturing benefits for the farmers.
The paludi-biomass could further be used to substitute fossil-based materials (e.g. fossil fuels or fossil-based insulation products), which would provide a further form of private capturing of benefits at farm level and would, at the same time, increase also the rate of decarbonisation of the economy creating a benefit for the whole society as a public good.
In terms of climate adaptation, an appropriate selection of the plant varieties to be cultivated, could offer increased stability of the yields and of their associated revenues to the farmers. An appropriate mix of these plants should be selected to enhance the biodiversity in the landscapes, reducing farmer's risks of losses and damages from climate related impacts. A well designed paludiculture landscape could offer several ecological services such as water buffering (particularly in summer), nutrient retention, water quality protection, local cooling and habitat provision for specific and rare species, benefits which in part can be captured by farmers (e.g. water buffering which reduces climate related risks) and for the local society which would be able to benefit from an attractive landscape.

4.1.5 Social barriers and enablers

The positive appreciation of drainage in rural societies should not be underestimated. For centuries, humans have been fighting against pests and related diseases in wet regions. In addition, drained peatlands have proven to be productive and to enhance the welfare of local communities. A very important fear related to rewetting is the re-invasion of pests and mosquitoes that needs to be taken seriously into account to increase the acceptability of the transformation.

[2] These figures do not include the costs of rewetting of 20% of the peatlands that are not converted to paludiculture.

4.2 TULLSTORP STREAM (TULLSTORPSÅ), SWEDEN

4.2.1 Context

The Tullstorp stream (or Tullstorpå) is located in the southern plains of Sweden (Skåne County). The case study is about both restoration of wetlands and development of a multifunctional system with water reservoirs, recirculating irrigation and customized drainage in a catchment used mainly for agriculture. The overall aim of Tullstorp stream projects has been to improve the water quality and flood protection in the catchment area and improve climate resilience of the regional agriculture (Climate Adapt, 2022; TSEA, 2020). Work done in Tullstorp stream is run by the Tullstorp Stream Economic Association (TSEA) which was founded by the local farmers and landowners in 2009.

The measures have been developed in two development projects with slightly divergent initial goals and activities. During the first project (2009-2013) the focus was on meandering of the riverbed, the restoration of riverbed vegetation and wetlands and the development of buffer zones and restoring biodiversity. The first project was initiated because of the poor ecological state of the stream, and focus was more on ecological benefits (incl. improvement of the retention of nutrients). Since 2009, decrease in nutrient leakage has been achieved with actions including establishment of at least 50 new wetlands and the restoration of 25km of the river course (NEFCO, 2023).

The second project, also referred to as Tullstorp stream project 2.0, started with an initial pre-study where different measures and possibilities were researched. The focus has been more on climate-proofing the agricultural activities in the area (e.g., preparing for drought and extreme rain events). This project (2019-2025) is ongoing and aims to construct a system with multifunctional water reservoirs (wetlands) with recirculating irrigation and customized drainage. The project is carried out in two pilots and their implementation is underway: one focusing on the restoration of the old mill water retention basins and the other on the construction of a new water retention basin. See for more comprehensive description (Martire, et al., 2022).

4.2.2 Actors and owners – third sector association and private landowners and farmers

The Tullstorp stream case study is one of the examples of a bottom-up initiative based on a group of private actors - farmers and landowners - initiating the project. Local farmers and landowners founded the Tullstorp Stream Economic Association (TSEA) which has been responsible for the different development projects in the area. Thus, a third sector actor, an association, was established to facilitate the overall management of the stream area owned by the landowners and farmers, solve challenges in more integrated manner and to coordinate the small-scale interventions performed on single small wetlands. The Association has approx. 60-80 members and its Board of representatives of stakeholders (7 members) is responsible for the projects run by the association is running (Climate Adapt, 2022). The project manager working for the association is responsible for the administrative work (e.g., applications, reports, documentation) and landowners can thus choose how much they want to be involved.

4.2.3 Maintenance

Maintenance is organized in two different ways: either each landowner or a central maintenance organisation is responsible for the maintenance of the measures. For half of the landowners the association has acquired a separate maintenance organisation to perform the annual tasks and help the landowners. In practice, for instance, the green areas surrounding the waterbodies are cut annually and water regulation systems (e.g., wells and such) are checked and maintained. Every 3-5 years sediment is removed from the sediment traps and every 5-10 years all plants are removed from the water bodies. However, there has lately been discussion with the local authorities whether it would better for the nutrient reduction not to remove the plants. (C. Bonthron, personal communication, October 24, 2023.)

A monitoring programme has been developed to study the effects of the first Tullstorp stream project. A measuring station is used to assess the overall impacts of the interventions. Monitoring includes water flow, quality, and zoo-benthos communities. Fish surveys are also conducted annually in five to seven river stations. The complete evaluation of the effectiveness of the pilots has been made within the Tullstorp stream project 2.0 (Climate Adapt, 2022). A final evaluation of the first Tullstorp project is running from 2023 to 2025. Aim of the evaluation project is to assess the effects of the implemented measures so far. The project is executed together with the County Administrative Board, co-financiers, and number of different experts. Also, functional outcomes (e.g, frequency of flooding and performance under drought) are evaluated as part of the ongoing final evaluation (C. Bonthron, personal communication, October 24, 2023).

4.2.4 Funding opportunities - mix of direct public funding and grants

Tullstorp stream projects have been financed with public funding from County Administrative board of Skåne[3] and Region Skåne, and with funding from an NGO (WWF). Ensuring funding has been seen as the main challenge of the project implementation. Planned measures are quite costly and the current funding system in Sweden (through *Landsbygdsprogramme* – Rural District Programme) can support only actions like river and wetland restoration, but not yet the construction of water retention basins and irrigation systems (Climate-ADAPT, 2023). Funding for completion of the entire Tullstorp stream project 2.0 hasn't yet been secured and identification of public funding is crucial to support the full-scale implementation of the project. TSEA has started dialogues with various organisations and authorities to secure the financial resources and continuation of the project (see for more details TSEA 2020).

Main financier of the first Tullstorp stream project is the County Administrative Board of Skåne. The first Tullstorp project cost approx. SEK 60 million (approx. EUR 6 million). The second project, including the pre-study and the pilots of the Tullstorp stream project 2.0, were granted by the LOVA grant (*lokala vattenvårdsprojekt* (LOVA) - local water management projects) of County Administrative Board of Skåne. WWF and Region Skåne also co-financed the pre-study of the second project. The cost of the pre-study was SEK 0.5 million and the cost of the pilot-project (including management, method development and pilot implementation) is about SEK 10 million (about EUR 1 million) (Climate Adapt, 2022). Tullstorp stream project 2.0 has also received grants from the Baltic Sea Action Plan Fund (BSAP Fund) to perform a pre-study on controlled drainage for the Tullstorp stream. In 2022, it received another grant to continue the project with the construction of two full-scale drainage systems (NEFCO, 2023).

4.2.5 Enabling factors

4.2.5.1 Property rights

Each landowner owns the land exploited in the development projects (transformed from arable land or grazing land to a wetland) and remain the owners of the wetland areas and related installations. They have transferred use rights to TSEA for the areas included in the restoration of the stream and subsidies for the areas included in wetland restoration (Climate Adapt, 2022; Stjernqvist, 2021) with the aim of compensating their loss of productive areas.

4.2.5.2 Legal framework

There is no legal obligation for public institutions to create such nature-based solutions as in the Tullstorp stream project. The County Administrative Board develops an action plan for regional green infrastructure in which wetland projects developed by TSEA are linked (TSEA, 2020). The EU Water Framework Directive (WFD) and its environmental quality objectives is said to facilitate the implementation of the first Tullstorp stream project. The WFD was still under development when the first project was initiated in 2009, but local stakeholders were motivated to prepare for the introduction of new legislation (Graversgaard et al., 2018). One of the reasons for initiating the first project was the poor ecological state of the Tullstorp

[3] Country administrative boards (*länsstyrelse*) is a Swedish Government Agency in each of the counties of Sweden. Region Skåne refers to the regional council of Scania (Skåne) County in Sweden. The regional council assembly is the highest political body in the region and its members are elected by the population of Scania County, as opposed to the County Administrative Board (länsstyrelsen) which guards the interests of the state in the region under the chairmanship of the county governor.

stream. Thus, measures implemented within the project were contributing to the achievement of the Good Ecological State that is a primary goal of the Water Framework Directive (2000/60/CE) (Climate Adapt, 2022).
All river restoration measures performed during the first Tullstorp stream project and the construction of multifunctional wetlands within the Tullstorp stream project 2.0 need formal approval by the Swedish Environmental Court (Climate Adapt, 2022).

4.2.5.3 Distribution of Costs and Benefits

Increase in crop yield and improved cultivation are stated as the main benefits for the farmers and landowners of the area. These economic benefits are generated over time, through increase in the overall resilience of the territory to the impacts of climate change – both in terms of better resistance to drought and intense rainfall periods, and for landowners to able to rely on better managed water resources in the area (Climate Adapt, 2022). Better managed water resources refer to the system to be developed in Tullstorp project 2.0 with multifunctional water reservoirs, recirculating irrigation, and customized drainage. These measures are benefitting landowners and farmers by providing better water supplies, increased harvests, new crops and smoothing the growth. Also, possible negative impacts to crop and yields need to be considered if measures are not properly implemented. Landowners buy-in is seen critical.
The aims of the first Tullstorp stream project was to deliver ecological benefits: reduced nutrient supply in the Baltic Sea; less flooding, erosion, and cleaning needs; increased biodiversity in and around the waterways and wetlands and good ecological status in watercourses and coastal waters. Already after 4-5 years since the project start, positive impacts have been registered for birds associated wetlands. Living conditions of fish and bottom fauna are more or less unchanged. The nutrient leakages to the sea have significantly improved for phosphorus, but for nitrogen the improvement is evident only during summer period due to the uptake in the newly created wetlands (Vorhies and Winkler, 2016) In addition, the ecological status (WFD) has improved from ‘bad’ to ‘moderate’.
As the work is progressing, in addition to the economic and ecological benefits, Tullstorp stream projects have increased their focus on the social benefits for the area and local landowners and farmers. For instance, in general, Swedish agriculture is seen to benefit from the projects through increased production of food and gaining better resistance to extreme periods of wet and dry weather (e.g., capacity of soils to absorb water during intense and prolonged rains is improved by customized drainage) (TSEA, 2020). Increasing and enhancing opportunities for recreation were stated as the secondary objectives of the first Tullstorp stream project. Measures were also seen as an opportunity to create recreational wetlands.

4.2.6 Social barriers and enablers: Stakeholder involvement

The involvement of landowners from the start of the project is seen as an important factor in enhancing the project ownership and approval. This has been even called the ‘Tullstorp method’ which is based on the strong commitment of landowners, bottom-up, voluntary approach and learning through demonstrative cases (Climate Adapt, 2022). The Tullstorp method also emphasises a holistic perspective on the catchment area: nutrient retention, biodiversity and other ecosystem services in the landscape should be seen equally important (Stjernqvist, 2021). TSEA is also disseminating knowledge and expertise gained in Tullstrop stream projects to other catchment areas such as the Ståstorp stream. The Tullstorp method for restoration of the Ståstorp stream is ongoing, which also demonstrates the scaling potential of the project to other areas facing similar kind of challenges.
The overall bottom-up approach is seen to form a strong sense of ownership, to facilitate the approval and implementation of the project. The project is said to be strongly supported and encouraged by the stakeholders. However, for some landowners and farmers, it has been difficult to accept the long duration of the implementation and completion of the measures, which has also dampened the initial enthusiasm (Climate Adapt, 2022).
Based on Stjernqvist’s (2021) evaluation report of the Tullstorp stream project, the following positive drivers were identified for the success of such projects: 1) holistic perspective on the catchment area, 2) generate integrated objectives to the project and these need to be driven by the landowners, based on voluntary actions, 3) a democratic organisation to manage the activities, which enhances the joint decision making about wetland establishment and management, 4) a democratic leadership, 5) integrating

landowner's ideas and knowledge on the interconnectivity of agriculture and local environment, 6) continuous development of practical wetland construction methods, adapted to local context and 7) full-time employed project manager. On the other hand, Stjernqvist (2021) highlights the following barriers – or identified improvements needed – with respect to current practices: 1) funding system and long-term policy for funding needs to be developed (e.g., unclear what subsidies projects can apply for, no long-term assurance for the funding), 2) regulations and guidelines don't acknowledge the holistic system perspective on wetlands, and there isn't a balance between agricultural production and wetland establishment and 3) review the Swedish interpretation of EU wetland regulations. See for more comprehensive evaluation of the project Stjernqvist (2021).

4.3 GREEN ROOFS – HAMBURG AND BASEL

4.3.1 Context

Green roofs are considered as an option for extending green spaces and supporting biodiversity in urban areas. They are also able to reduce rainwater run-off. Green roofs can be set upon flat roofs of existing or new buildings. Green roof systems consist of a waterproofing layer, a drainage system, filter cloth, a lightweight growing medium, and plants. Initiatives for using flat roofs in urban areas as spaces for additional urban green have been undertaken in many cities, promoting the construction of green roofs or enforcing the creation of green roofs with legal measures. The study considers two different approaches to green roof strategies in Europe presented on the Climate Adapt platform, in the cities of Hamburg (Germany) and Basel (Switzerland).

4.3.2 Actors and owners

Green roofs are parts of buildings, owned by private, corporate or public actors. Owners take the decision to invest into the creation of a green roof on the top of their new or existing building and cater for their maintenance.

Buildings are strongly regulated by urban planning rules and statutes. Public authorities thus have an important role in influencing their form and physical characteristics, and can drive the implementation of green roofs in their constituencies. This can happen either by using statutory obligations for the creation of green roofs, or by offering incentives which compensate additional investment and maintenance costs for building owners either as a long term policy, or more frequently, with the objective of increasing acceptance of these solutions and creating markets. Green roof policies set up by municipalities can thus play an important role for the implementation of green roofs in the building sector.

4.3.3 Funding opportunities

Both Hamburg and Basel have created incentives to promote the realization of green roofs in their cities. These incentives, paid in relation to the surface of the green roofs, and linked to minimum design requirements (minimum thickness of the growing medium and types of plants used to ensure their functioning for rainwater harvesting and supporting of biodiversity), cover part of the additional investment costs of green roofs.

Subventions for initial investments depend on the availability of public funding and are, in both cases considered, limited in time. Public funding was offered in Basel in two phases between 1996 and 1997 and between 2005 and 2007. Amounts offered were in this case CHF 20/m^2 in the first period, and CHF 30-40/m^2 in the second period, where only the more expensive installation on existing roofs was considered, while flat roofs on new buildings had to be realized as green roofs by obligations of the regional planning legislation (Brenneisen, 2022). In Hamburg, a subvention first scheduled for the period from 2015 to 2019 has been extended to 2028. It is limited to buildings that are not subject to statutory obligations for the creation of green roofs, and covers between 40% of the overall costs of realization for private and ca €30, depending on thickness of layers and extension of the roof, for commercial investors (Richter and Dickhaut, 2019, p. 47; Stadtportal hamburg.de, 2023).

In Hamburg the incentive programme has been funded with support from the National Environment Agency[4], while in Basel funding from the regional energy saving fund has been used.

Both cities have used reductions of stormwater fees as an incentive for the creation of infiltration areas on private premises. 50% discounts on the fee are offered both in Hamburg and in Basel. The reduction of the fees corresponds to the average retention rate produced by green roofs, so is directly proportional to the reduction of rainwater discharge into the public sewage system.

[4] https://www.hamburg.de/bukea/4549510/bue-gruendachfoerderung-pressemitteilung/

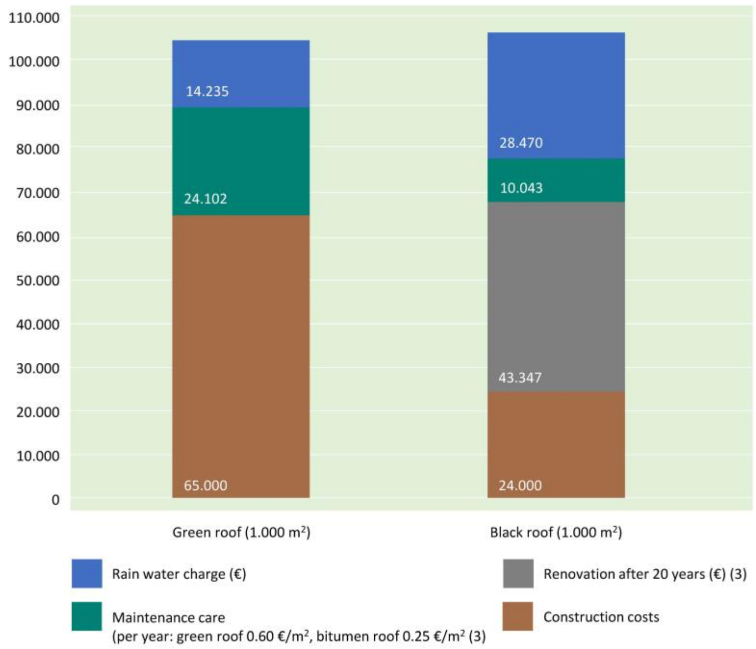
In the case of Hamburg, the authors of the study evaluating the local strategy conclude that such reductions do not appear to increase the interest for green roofs, but have, at best, a deadweight effect. Indeed, in the first years of the green roofs programme, which coincide with the introduction of reductions of the stormwater fees for green roofs, no requests for reduction of the tax have been made by owners of newly created green roofs (Richter and Dickhaut, 2019, p. 45).

Table 1: Economic life cycle assessment over 40 years (Source: Free and Hanseatic City of Hamburg, 2017, p. 17)

TYPE OF COSTS	GREEN ROOF	BLACK ROOF
1. ONE-TIME COSTS		
CONSTRUCTION COSTS	65000	24000
Green roof costs (EUR/m²) (1)	41	
Sealing costs (EUR/m²) (2)	24	24
Renovation after 20 years (EUR) (2)	0	43,347
SUM OF ONE-TIME COSTS	65000	67347
2. RUNNING COSTS (OVER 40 YEARS)		
Maintenance care (per year: green roof EUR 0.60/m², bitumen roof EUR 0.25/year) (2)	24,102	10,043
Rain water charge (EUR)	14,235	28,470
SUM OF RUNNING COSTS (EUR)	38337	38513
TOTAL SUM OF A 40-YEAR CYCLE (EUR)	103337	105859
Difference in cost compared to green roof (EUR/m²)		+2,522
TOTAL SUM OF A 40-YEAR CYCLE (EUR/m²)	103	106
Difference in cost compared to green roof (EUR/m²)		3

(1) Average value of buildings 4,6,7,3 in the study; (2) Average value of real costs, in orderr to obtain the same basis; (3) Interest rate 3%/year

Figure 5: Graphic illustration of a life cycle assessment over 40 years (Source: Free and Hanseatic City of Hamburg, 2017, p. 17).



4.3.4 Costs

In the absence of financial support to investments, costs for the installation of green roofs fall entirely onto the building owner. Costs of green roofs vary according to the type of roof implemented and whether the green roof is installed on an existing building or part of a new construction. The city of Hamburg has used, in a life cycle assessment for green roofs, additional costs of ca. EUR 40/m^2 with respect to traditional black roofs (Free and Hanseatic City of Hamburg, 2017, p. 17).
The building and real estate sector used the higher investment costs caused by green roofs as a motivation for opposing, in Hamburg, a statutory obligation obligatory on all new and refurbished buildings, as this would raise housing costs and thus contrast the city’s strategy to accelerate the construction of accessible housing. (Richter and Dickhaut, 2019).
Green roofs require continuous maintenance over time, which is paid by the owner of the premise.

4.3.5 Benefits

Green roofs provide benefits for the urban climate by regulating rainwater run-off, as they store the rainwater, and by reducing and slowing down its release into the public sewage system. They contribute to the mitigation of the urban heat island effect by evapotranspiration and by increasing the albedo of roof surfaces, contributing to cooling down the urban climate. In addition to these benefits provided to the community, they also generate private benefits for building owners or occupants, such as the mitigation of indoor temperatures (green roofs provide additional thermal insulation for the upper floors of buildings). Public management of the sewage system benefits from lower rates of run-off, which help decreasing investment and maintenance costs of the sewage system. Public administrations benefit from delayed and/or reduced runoff in terms of reduced maintenance and investment costs for the sewage canalization and treatment system.
Owners of buildings with green roofs can benefit from a reduction of public fees, which recognizes the contribution green roofs provide for public stormwater management. Both cities offer a reduction of stormwater fees to owners of green roofs, which is related to the green roof surface and to the roofs’ capacity to delay and reduce run-off. In both cases the fee is reduced by 50% for green roof surfaces. These benefits are constant over time, starting from the installation of the green roof.
Additional public services generated by green roofs (reduction of damages related to surface flooding, biodiversity, air quality improvement, etc.) are available for the public, but do not generate any compensation.
Furthermore, green roofs reduce management costs of buildings as they improve the thermal insulation of the roof creating benefits in terms of reduced heating and cooling costs in the floors directly beneath the roof. Green roofs also protect roof structures and reduce maintenance costs for roofs, extending the roofing membrane durability.
Under certain circumstances, green roofs could become a quality attribute acknowledged by the market, as in the case of the regeneration of the Hamburg Hafen City, where high quality green roofs and rooftop gardens were obligatory elements of the urban strategy for the building stock, which aimed at high real estate values for the revitalization of the former harbour area.
Yet, in the case of Hamburg, this acknowledgement has not been observed, as the authors of the economic feasibility study confirm: “The buyers sometimes do not even know that the building has a green roof” (Richter and Dickhaut, 2019, p. 45).

4.3.6 Enabling factors

4.3.6.1 Property rights

Green roofs are set up as integral parts of buildings, and as such no changes in property rights are necessary for their implementation.

4.3.6.2 Legal frameworks and compensation mechanisms

Green roofs are indirectly connected to the functioning of public infrastructure in the sense that they alleviate potential pressure on public sewage systems. They furthermore improve living conditions and public health in urban areas by sustaining or enhancing urban biodiversity and reducing the urban heat island effect as they increase albedo and evapotranspiration. This function is independent from the ownership of the measure and from the public or private character of green roofs, e.g. from public access rights to green rooftops and rooftop gardens. As the form and structure of buildings and their transformation underlies public laws, regulations, and plans, planning authorities with competences on urban planning and bylaws have a role in regulating the construction of green roofs.

Green roofs can become part of urban planning statutes, which oblige building owners to create a green roof in case of new construction or refurbishment of existing buildings. This approach has been taken by Basel since 1999 as an element of the regional planning legislation and is increasingly being applied in single urbanization plans in Hamburg, too. In the period between 2010 and 2017, 94% of new urbanization plans in Hamburg include obligations and provisions for the creation of green roofs (Richter and Dickhaut, 2019, p. 42). While in the 1990ies such obligations were often limited to auxiliary buildings (carports, etc.), the obligation has, subsequently, extended more frequently to main buildings with flat roofs, and minimum requirements for green roofs in terms of thickness and types of plants are rising. Yet, there is no general urban statute or legal obligation which would require the installation of green roofs in all parts of the city, as introduced in Basel in 1999. Because of this lack of a generic obligation, building interventions taking place in the dense built-up area of the city are not subject to legal obligations to create green roofs.

It is also possible to enforce the creation of green roofs as a measure to compensate or mitigate biodiversity losses. The city of Hamburg is using such mitigation requests for obliging investors to create green roofs. Such a request can be made in the case of single buildings, but is used increasingly for justifying obligations for green roofs as part of new land-use plans (Richter and Dickhaut, 2019).

Such generic statutory obligation to create green roofs have generated higher rates of implementation, for instance in Basel where ca. 46% of roofs are now green roofs (Brenneisen, 2022), and Muenchen, where, as a consequence of a generic obligation covering the whole city, 20% of the roofs are green. (Richter and Dickhaut, 2019).

4.4 BEVANO DUNE RESTORATION: PUBLIC-PRIVATE PARTNERSHIP FOR THE RESTORATION OF THE DUNE BELT IN THE SOUTH OF THE BEVANO RIVER MOUTH (RAVENNA, ITALY)

4.4.1 Context

The mouth of the Bevano River is a meandering estuary located near Ravenna (Emilia Romagna region) in the eastern coast of Italy, south of the Po River delta, bordered by the Adriatic Sea. In the last 4 kilometres of its course, the Bevano River – after briefly meandering in its little basin between the Ronco and the Savio rivers – is enriched with the waters of four gutters, shaping its wide estuary. The beach is about 30 m wide, with a sinuous longitudinal profile with wide and articulated intertidal zones. The area includes about 5 kilometres of coastal dunes, still well preserved. Behind coastal dunes, the site hosts pine forests, while two wetlands (Ortazzo and Ortazzino) are located next to the mouth. The area is located between Lido di Dante and Lido di Classe, two coastal towns with sandy beaches, used for tourism.

The site is part of the EU Natura 2000 network (the area is a Special Conservation Area and a Specially Protected Area according to the EU Habitat and Birds Directives) and it is a RAMSAR site. At the national level, part of the area (64 ha) is a natural state reserve (coastal dune of Ravenna and Bevano river mouth). The whole area is part of the Regional Park of Po river Delta.

The whole area suffers from subsidence, partly due to natural causes (sediment compaction) but strongly affected by hydrocarbon extraction activities (methane gas) that largely takes place in the marine area of Emilia Romagna. The high subsidence rates make the area particularly vulnerable to sea level rise and storm surge. Also for this reason, the area has been considered (according to the risk maps elaborated under the EU Floods Directive) in "high risk of flooding", i.e. subject to frequent flooding with a 10-year flood frequency.

The beach stretch in front of Bevano river mouth is classified as "stable" with regards to erosion, according to the regional classification system of coastal areas (ASPE indicator), but is located close to other stretches in erosion (data displayed in the Regional Geoportal), both to the north and to the south. The area is free from robust defence structures and has not been subjected to beach nourishment in the past.

The restoration project (Riged-RA restoration and management of coastal dunes of Ravenna, 2013-2016) involved the construction of a windbreak barrier made of wooden paling to reduce the wind speed and favour the deposition of sand. In that way, the generation of embryo dunes was stimulated and sand loss towards the inland was prevented. The windbreak barrier consisted of a grid of fences parallel to the coast, held together by wire, with a total length of 465m. The intervention was inspired by the implementation of similar techniques in France, in a large coastal area at the mouth of the Rhone River. The intervention is currently monitored through aerial Vehicle (UAV) surveys. In 2021, the positive impacts of the intervention were clearly visible in terms of larger sand volume and improved vegetation cover. However, the devasting storm that hit the Emilia Romagna region in November 2022 strongly damaged the wooden structure. This fact arises the problem of maintaining this type of interventions in a future looking perspective where extreme events caused by climate change are expected to occur with increasing frequency and intensity..

Several ecosystem services are provided by the natural area around the Bevano river mouth, including the following:

- Regulating services: the pine forest near the beach lowers the local temperature (climate regulation) and removes pollutants from the atmosphere (air quality regulation). It also favours carbon sequestration and storage: as trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues. Pine forests also protect the inland agricultural crops from the sea salt spray. The coastal dune belt can counteract storm surges, by dissipating wave energy, mitigating inland flooding and contrasting beach erosion. It also functions as a sand reservoir for the dune-beach system.
- Provisioning services: a continuous dune belt (topographically higher than the remaining area) increases the water infiltration potential and favours the formation of freshwater lenses, thus increasing freshwater availability in the coastal shallow aquifer and contrasting saltwater intrusion.

- Cultural services: the area provides a space that can be (partially) used by visitors that can enjoy the landscape and experience new forms of tourism that are alternative to mass beach tourism.
- Supporting services: the dune belt provides living spaces for plants and animals, enhancing local biodiversity. Diverse plants and animals also support the functioning of the whole ecosystem, thus underpinning other ecosystem services.

4.4.2 Actors and owners

The project was designed and coordinated by the University of Bologna (Integrated Geosciences Research Group) with the collaboration of the municipality of Ravenna, and the Flaminia Foundation, a consortium of private and public companies that promotes the development of universities and scientific research. The EID Mediterranée[5], a French public company operating in the environmental field since 1982, also provided scientific advice. The Integrated Geosciences Research Group of the University of Bologna implemented monitoring activities to track its effectiveness The research group provided the detailed characterization of the physical system in all its components (geomorphological, geological, hydrogeological, vegetational, meteorological-marine systems), that was fundamental to design, scale and guide correctly the structure and increase its effectiveness.

Permits and authorizations for the intervention were issued by the technical offices of the Municipality of Ravenna, Carabinieri for Biodiversity (Italian police department), and the Po Delta Park, which are the managing bodies of the study area. Bureaucracy and time needed to obtain authorizations and permits hindered the implementation of the NBS in the case study area.

However, the involvement of the managing authorities of the area and the creation of a multidisciplinary working group with experts in different fields of environmental sciences ensured an integrated approach to the management of the coastal belt.

4.4.3 Funding opportunities

The project was financed by ENI (Ente Nazionale Idrocarburi)[6] according to the provisions of the “VI collaboration agreement between the Municipality of Ravenna and Eni S.p.A. 2011- 2014”. The collaboration agreement is part of a long-term and consolidated partnership between Eni and the Ravenna municipality started in 1993 as compensation for the activities of hydrocarbon extraction in the marine area of Emilia Romagna region. The agreement has been periodically renovated through specific agreements. The latest agreement is the ninth one and was signed in 2021. According to the Eni sustainability reports, the partnership pursues the local development of the territories in which it operates, supporting the realisation of several interventions including those aimed at the preservation of the coastal environment. The total Eni’s financial commitment has been EUR 72 million.

The VI collaboration agreement (2011-2014) envisaged a budget of EUR 11.5 million and specifically included restoration and strengthening of the coastal dune of the Bevano mouth. The agreement was then activated through a specific research agreement between Eni and Flaminia Foundation. In the following years, the budget is being gradually reduced, due to the progressive reduction of Eni extraction activities in the region.

The limited budget allocated to the NBS implementation did not allow to scale the intervention to a wider area. Indeed, the intervention was conceived as a pilot project, whose results should have been exported to similar sites in the coastal area of Emilia Romagna. This did not happen, especially due to limited funding availability in the following years. Indeed, the available budget from Eni started to decrease and the limited resources were used to finance other environmental interventions along the coast with more direct economic benefits (highest priority in the political agenda). In particular, funds have been mainly used for annual sand nourishments to ensure beach tourism during summer, a consolidated economic sector for the Emilia Romagna Region. The lower available budget also limited the development of monitoring

[5] EID Entente Interdépartementale pour la Démoustication du Littoral Méditerranéen (Interdepartmental Agreement for Mosquito Control on the Mediterranean Coast)

[6] ENI, is an Italian multinational energy corporation.

activities that are being done with a reduced frequency and mainly developed within training and research activities with students at the University. Beyond economic barriers, the high urbanisation of the coast (with many beach tourism facilities) works as spatial constraint and might limit the scaling out of this type of intervention to other areas of the region.

4.4.4 Enabling factors

4.4.4.1 Property rights

The beach area, partly belonging to the natural reserve, is state property. The whole area is managed by the Regional Park of Po River delta where its territory is completely included and by the Carabinieri for Biodiversity of Punta Marina for the natural state reserve.

Another part of the area (about 500 ha, Ortazzo and Ortazzino wetlands behind the dune area) belongs to a private owner (real estate company). Although the Ravenna municipality and the regional authority for the Po River Delta Park had manifested their interest in acquiring the area in the past, a recent transaction (2023) confirmed the private ownership, without the public bodies having asserted the right of pre-emption. However, the area remains subjected to a rigorous environmental protection, being part of the Natura 2000 and Ramsar networks, where severe constraints prevent any building or economic activity that transform the territory. Notwithstanding, the private transaction created some concern (particularly expressed by the NGO Italia Nostra) about possible hidden intentions to downgrade the area towards less rigorous constrains.

The marine area in front of the mouth of Bevano river is part of an area of about 110 km^2 in concession to ENI for the hydrocarbon production. The area hosts the platform Angela Angelina (A.C 27.EA), located at 2 km away from the coast, in front of Lido di Dante.

4.4.4.2 Legal framework and compensation mechanisms

Although there was no legal constraint to realise the intervention on the coastal dune, the Eni economic contribution can be framed as compensation for the environmental impact caused by the offshore hydrocarbon extraction. The project is legally framed in the collaboration agreement between Eni and the Ravenna municipality. Any economic activities allowed in the area and the usability of the area from visitors are regulated by the Delta Po River Park and by the Natural State Reserve that established clear zonation of the site.

4.4.4.3 Distribution of benefits between public, private and the wider society

The main benefits related to the implementation of the intervention are environmental benefits that can be hardly monetised.

The dune restoration guarantees greater ecological and environmental continuity and favours the increase in biodiversity (reduction of habitat fragmentation).

Indirect economic benefits derive from various enhanced ecosystem services provided by the restored area (see contextualisation).

Besides, dune preservation reduces erosion and help maintain the beach width. A well conserved beach and dune system is able to attract visitors also through the organisation of sustainable forms of tourism. In this regard, part of the beach area (close to the towns of Lido di Classe and Lido di Dante) is always accessible from visitors, part is accessible only after the nesting period, while the core part is an integral reserve with no access. The Visitor Center of the Po Delta Park "Bevanella" organises guided tours on payment, so that economic benefits of restoration activities can be somehow perceived by the park manager.

Finally, benefits for Eni can be assessed as return in terms of its commercial image, since the company promotes its operations in the framework of a sustainable path towards the energy transition, according to the principles of equity and inclusivity.

4.4.4.4 Dimension of social justice and stakeholder involvement

A clear socioeconomic obstacle for the implementation of NBS in the Bevano case was related to an initial scepticism from the local population that feared that access to the beach would be impeded. It was, however, only limited to a sandy pathway that runs through the middle of the area, to avoid uncontrolled trampling. Since the positive results of the intervention are quite visible (well conserved dune landscape), people have gradually started to accept the imposed limitations. The installation of information signs with clear explanation further supported the acceptance process and favoured visitors' environmental awareness. Free organised tours for citizens enhanced the creation of an overall positive attitude towards the intervention.

4.5 CAMARGUE COASTAL WETLANDS RECONSTRUCTION

4.5.1 Context

The Camargue coastal wetland reconstruction has taken place in the former saltworks of Salin-de Giraud, in the southeast of the Rhône delta. The area is part of the Camargue Regional Natural Park and the UNESCO Man and Biosphere Reserve. This site represents a vast coastal area of 6,500 ha in the municipalities of Arles and Saintes-Maries-de-la-Mer, partially transformed and used for industrial salt production from 1950 to 2008. Since most of the area (i.e., around 70%) is situated at an altitude of less than 1m above sea level, the territory is exposed to a high risk of flooding. For centuries, this risk was reduced through the construction of dikes that led to the almost complete polderization of the delta by mid-19th century. Therefore, the drastically reduced sediment inputs from both the Rhône River and the Mediterranean Sea have had considerable effects on dune formation, erosion and water distribution, increasing the vulnerability of the area (Segura et al., 2018).

4.5.2 Actors and owners

In 2011, the *Conservatoire du Littoral*[7] purchased 6,500 ha of the Camargue saltworks from the salt production company (i.e., Compagnie des Salins du Midi) and passed ownership to the coastal protection agency. As the Conservatoire managed to purchase only part of the saltworks, the area is still affected by the surrounding operating saltworks that maintain the ownership of the heart of the area and determines the hydrological management. Moreover, the site is surrounded by agricultural land, mainly used for rice production and cattle grazing.

The conservatoire started a large restoration project. In coordination with the Regional Natural Park of the Camargue, in partnership with the Tour du Valat Research Institute and the National Society for Nature Protection as co-managers in conjunction with the municipalities of Arles and Saintes-Maries-de-la-Mer, and follows the coastal protection strategy adopted by Bouches-du-Rhône –the public authority in charge of managing marine submersion risk in the Camargue area, which consists of allowing the coastal line to move freely with the natural formation of sandbars, while maintaining and strengthening existing infrastructures further inland to safeguard people and properties.

Furthermore, several foundations have participated in the funding of the restoration works, among these the MAVA foundation which had a primarily environmental scope (it has been closed in the meantime), the partnership with Coca-Cola foundation is framed within a general commitment to safeguard the freshwater resources it uses. Similarly for the Total foundation, who's involvement, framed as patronage (*mécénat*) has expanded from a scope related to cultural heritage towards environmental values (Lavoux et al., 2011, p. 54).

4.5.3 Funding opportunities

Funding was provided by the Conservatoire di Littoral, the Ministry of Ecology, the Water Agency and the Department Council of Bouche du Rhone (see table below). A further contribution, possibly successively revoked, was expected from the Grand Port Maritime de Marseille as a compensation payment for environmental losses caused by the port's expansion.

[7] The *Conservatoire du Littoral* is a French public foundation, mainly government funded, placed under the supervision of the national Ministry of Ecological Transition and Territorial Cohesion (https://www.conservatoire-du-littoral.fr/).

Table 2 Funding (Lavoux et al., 2011, p. 48 *Translated by Deepl*).

AGENCY	AMOUNT SPENT (M €)
Conservatoire du Littoral (including €5m from the ERDF)	15
Ministry of Ecology	10
Water Agency	9
Grand Port Maritime de Marseille	8
Council of Bouche du Rhone department	3

Restoration works were partly implemented within the European LIFE+ MC-SALT project (2011 – 2016). National funds came from the Water Agency (*Agence de l'Eau Rhône-Méditerranée-Corse*) and, at the subnational level, by the Région Sud, Département Bouches-du-Rhône, as well as from private funds (WWF, Total Foundation, Coca-Cola Foundation, MAVA Foundation).

4.5.4 Enabling factors and barriers

4.5.4.1 Property rights

The acquisition of the land by a public institution has represented the basic condition for the implementation of the project.

4.5.4.2 Legal framework and compensation mechanisms

The *Conservatoire du Littoral,* the only landowner of the case study area, acquired land by private agreements, by pre-emption or, sometimes, by expropriation. Land may also be given to it by donation or legacy.

The purchase of the Camargue coastal wetland by the *Conservatoire du Littoral* occurred in accordance with the wetlands conservation strategy set up by the Grenelle Environment Round Table, deployed in 2010 by the then President of France, and whose objective was to define the key points of government policy on ecological and sustainable development issues for the coming five years and called for the acquisition of 20,000 hectares of wetlands by 2015.

Among the entities contributing to the purchase of land the "Grand Port Maritime de Marseille" should have participated due to an obligation to compensate environmental damages caused by the planned expansion of the port into an environmentally highly valuable natural area, but the payment had not taken place as of 2011 due to conflicts about the comparability of areas potentially lost by the ports expansion and those purchased in this initiative (Lavoux et al., 2011, p. 59).

The change in the business strategy of the saltworks, who decided to maintain the ownership of key areas. has had an important impact on water management and biodiversity objectives for the site. The main impact is that certain areas of the wetlands that had initially the objective of reducing the salinity levels to favour more brackish and freshwater habitats, were again heavily influenced by the hydrological management for salt production and became more salty habitats.

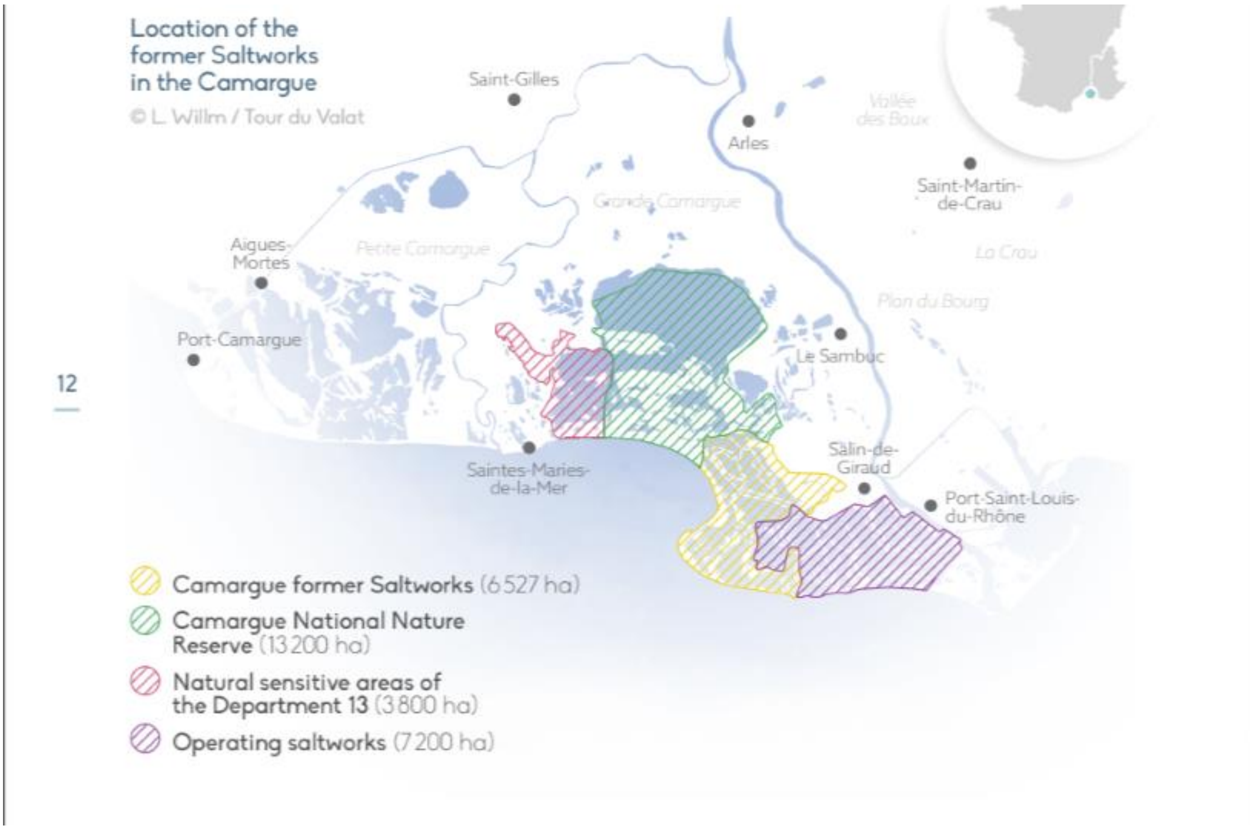


Figure 6: Map displaying the location of the former saltworks in the Camargue (source: Segura et al., 2018, p. 12**).**

As regards the implementation of the engineering works needed for the hydraulic restoration of the site, they had to comply with both the EU Natura 2000 and the Water Framework directives that required a positive environmental impact assessment.

The coastal restoration project is fully consistent with the guidelines adopted by the *Direction départementale des territoires et de la mer* (DDTM) of the Bouches-du-Rhône – that is the public authority in charge of managing marine submersion risk in the Camargue area. The adopted strategy consists of allowing the coastal line to move freely with the natural formation of sandbars, while maintaining and strengthening existing infrastructures further inland to safeguard people and properties.

4.5.4.3 Distribution of benefits between public, private and the wider society

In the initial phase, the land was purchased for "EUR 45 million for an initial tranche of 5,100 ha put up for sale by the salt works enterprise (Lavoux et al., 2011, p. 47). According to a report by the General Council for the Environment and Sustainable Development (Lavoux et al., 2011) land was purchased by the Conservatoire du Littoral, with contributions from other agencies (see Table 2). These costs have not been considered in the subsequent analysis of costs and benefits.

The main benefits considered for the wetland restoration project are based on the flood protection services, which represent an economic public service. This service has a double character, on the one hand side, the wetland contributes to an important reduction in public expenditure for the protection against flood risks, which would have occurred without the wetland (EUR 13 to 17 million of investments for the reconstruction of dikes, EUR 7 to 24 million for the construction of groins, at least EUR 800,000 in annual maintenance) (Segura et al., 2018). Thus, restoring and maintaining the seafront dike (including breakwaters and numerous groins) would be much more expensive than maintaining the dike constructed further inland and protected by the wetlands to prevent flood disaster.

Since the maintenance of most of the dikes surrounding the lagoons stopped, the investments for hydraulic reconnections amounted to less than EUR 1.5 million. Finally, the restoration project resulted in the elimination of electric pumping as a water management tool, decreasing operational costs (i.e., EUR 30 to 60,000/year) (Segura et al., 2018).

Due to these reasons the selected adaptive strategy has been assessed as the least expensive and most efficient option for coastal protection.
Further benefits created by the project have the characteristics of "public services" provided to the society, as the strategy is expected to generate positive economic benefits to some groups as fisheries due to the restoration of fish migration and fish nursery function.
The site does not generate direct income from tourism since all access is free of charge.

Table 3 Economic assessment (Source: Segura et al., 2018, p. 34 Table 3)**.**

CHALLENGE	ACTION	BENEFITS	INDICATORS
1. Coastal erosion	Defense infrastructures located along the seafront are no longer maintained (9 km)	Savings in public funds: €13 to 17 million investment for the reconstruction of dikes, €7 to 24 million for the construction of groins, at least €800,000 in annual maintenance	Savings due to the absence of maintenance work on seafront dikes
2. Management of sea flooding risk	Investments only on the inner protection dike (linear: 16 km)	Investment of 7 to 13 million euros, plus 80 K€ to 140 K€ for annual maintenance Salt production is maintained on the nearby private property of the Salins group	Cost for maintaining and adapting the inner protection dike
3. Hydraulic management of the former saltworks	Investments for hydraulic reconnections Maintenance of most of the dikes surrounding the lagoons stopped Gravitational water management	3 investment phases: < €1.5 million Savings related to maintenance of the dikes surrounding the lagoons Savings related from no longer using pumping stations: € 30 to 60,000 / year	Costs of hydraulic works Cost of natural water management compared to artificial water management

Further to the societal benefits of an enhanced protection against climate change related to flooding, the protected area supports the development of scientific knowledge, inspiration for art and design, recreational opportunities created for the local community and tourists that now can freely access parts of the site, with an increased aesthetic, ecological, and landscape value of the Rhône delta area. Landscape changes and increased wilderness induced by ecosystem restoration has created natural and scenic views of coastal and marine seascapes. Cyclist groups and pedestrians frequently visit the site during nice weather conditions. Access to the beach is regulated but accessible, which was not the case when it was a private property dedicated to salt production.

4.5.5 Social barriers

One barrier encountered in the NBS implementation is the scepticism or opposition from local stakeholders accompanied by issues related to its cultural acceptance. Indeed, it has not been easy for the local population to accept that the seafront dike was abandoned. This created a need for improvements of the communication and collaboration with the nearby community to increase acceptance for the revised protection strategy.

4.6 SUMMARY OF FINDINGS FROM CASE STUDIES

In all case studies considered, NBS produce environmental and social benefits that make them, at least partly, “public goods”. In several cases, they also produce benefits which can be considered “private goods” or potential “club goods”.

Only one of the six case studies considered in this work is primarily promoted and financed by private actors and serves the production of private goods as a primary or principal scope (improvement of buildings quality in the green roof case). In the case of the watershed restoration in Sweden (Tullstorp stream), a public investment is made to create benefits for society as a whole, improving water quality in the catchment and the Baltic sea. The second part of the project, which focuses on increasing flood and drought resilience in the catchment, would produce significant benefits for the farmers in the catchment. This change could potentially give place to a change in the business model, introducing a “club goods” model with contributions from farmers to the costs of implementation and maintenance, in analogy to, for example, to drainage associations. This model in its current design as an implementation of a public infrastructure supported by a bottom-up governance scheme is already “scaled out” with an analogous implementation in a nearby catchment.

In the case of green roofs, an economic lifecycle assessment shows that the long-term balance between costs borne by the investor and benefits captured from green roofs is almost equivalent to a traditional flat roof, without factoring in better thermal insulation and potential individual welfare benefits from green roofs, which can serve as green outdoor spaces in dense urban areas. Furthermore, due to governance arrangements (division of stormwater fees from sewage fees), investors in green roofs can capture benefits provided to the public in terms of stormwater retention, while other environmental benefits provided to society (heat reduction, biodiversity increase, and improvement of air quality) are normally not compensated.

Table 4 Comparison of the six case studies investigated in this report: private or public investment promotion, financing and types of goods.

	INVESTMENT		TYPES OF GOODS PRODUCED		
	DECISION/PROMOTION	FINANCING	Access control	Substractability	
				low	high
TULLSTORP	Private		high	Club good (resilience)	
		Public	low	Public (water quality)	
GREEEN ROOFS HAMBURG	Private	Private	high		Private (living quality,value)
		Public (Incentives)	low	Public (stormwater)	
GREEN ROOFS BASEL	Private (legal obligation)	Private	high		Private (living quality,value)
		Public (Incentives)	low	Public (stormwater)	
PALUDICULTURE		Private (planned)	high		Private (crops)
	Public	Public	low	Public (CO_2 capture)	
BEVANO DUNE	Private (compensation)	private			
			low	Public (biodiversity, coastal protection)	
CAMARGUE					
	Public	Public	low	Public (biodiversity, coastal protection)	

A third case where potential investments by private actors are foreseen is the Paludiculture project. In this case in particular, high risks and potential costs for private investors in front of new and potentially less valuable crops and increased management costs (liabilities, water management, marketing) are quite high, while the necessary return of investment for private actors is expected to come only in the long term. On the other hand, rewetting provides benefits in terms of carbon emissions reduction to the society. In this case, public grants and subsidies necessarily play an initial enabling role and will be crucial for the project to be started. Whether returns of investment will be sufficient to benefit farmers can depend on the development of sufficiently strong new value chains and products. Such development of new markets will require further public funding. In the case of Hamburg, the development of supply chains for green roof materials, competences, and supply chains, was one of the reasons for incentivising the programme for green roofs in the city.

The two projects focussed on coastal NBS entirely depend on public funding, either directly (in the case of Camargue), or as a payment made by a private entity to compensate the public for damages caused by their commercial activity (in the case of Bevano).

The main benefit expected from the Camargue case is an improvement of coastal flood protection in the area using the re-establishment of wetlands as an integral part of the coastal defence system. In this case, the triggering factor was the change in land ownership from a private to a public actor, the Conservatoire du Littoral, and the resulting change in land use (from salt production to ecological restoration). The NBS implemented in this case have the characteristics of a coastal infrastructure that makes the area more resilient to sea level rise induced by climate change, and a quantification of benefits generated by the measures has been made to support the implementation. This assessment was based on the quantification of cost savings for public expenditure for construction and maintenance of coastal protection measures, while further benefits like recreational opportunities and enhanced biodiversity identified as public goods, were considered co-benefits.

The case of the Bevano Dune reconstruction project relied on funds mainly provided by a commercial actor, with the objective of compensating environmental damages - in particular subsidence in a low-lying coastal area - caused by the actor's activity on the coastline. Benefits generated by the measure have the character of public goods, i.e. coastal protection and increase in biodiversity for the protected area. The nature of this funding source determined the cessation of the investment over time and the lack of funding for maintenance and monitoring.

5 Conclusions

The new framework of analysis has provided some insights into the socio-economic factors that determine the scaling potential of NBS. Among these, the distribution of costs and benefits among private, public actors, and society as a whole, appears as a key determinant. This distribution will determine whether and under which conditions private and/or public investments can be made available to implement interventions, and to cover their maintenance and monitoring costs.
In all cases considered, NBS produce benefits for the wider society which can be framed as "public services".

Private finance:

- In some cases, benefits for individual actors or groups also exist. These benefits could be interesting for private investors due to their potential for generating good return on investment. In the case of small investors, expected non-monetary benefits from NBS can also contribute to investment decisions, as illustrated in the case of green roofs. Green roofs can provide benefits in terms of aesthetic and wellbeing, which would turn into monetary value for buildings produced for the real estate market, while for owner-occupiers these benefits would rather be of immaterial character.
- In specific cases, private actors are already available for promoting and investing in NBS, because they expect sufficient private return of investment.

Subsidies covering initial investments and new value chains:

- The upscaling of such private initiative is nevertheless supported by public incentives such as subsidies and tax reduction to cover the initial investment in the case of Hamburg (green roofs). Legal obligations were used for the same purpose in Basel.
- The creation or promotion of new markets can be supported by such incentive programmes, as in the case of green roofs. In other cases, such as Paludiculture, more substantial public investments for product innovation would be required, because initial costs for potential investors appear rather high.
- Proper consideration of benefits to society without immediate market value (biodiversity, human well-being, CO_2 reduction) could be made as a form of payment for ecosystem services: e.g. in the transformation of agricultural practices, carbon storage stormwater management, etc. Such compensation measures could help promoting market investments into NBS.

Legal obligations:

- Using regulation to integrate NBS as the "new normal" can also be a first step to scale out such measures. For instance, in the case of Basel, green roofs are defined by law as the new normal solution for building flat roofs. This is feasible in cases where (private) return of investment can be reached, in particular, if at least parts of the public services produced by these investments are returned to investors in form or tax or fee reduction.
- For large-scale projects with public interest, such as flood and coastal protection, a different socio-economic dynamic was observed. These investments can be considered as alternatives to traditional forms of public infrastructure. Therefore, in these cases, extended cost-efficiency considerations would need to be applied as is usually done for technical infrastructure for such purposes.

NBS as public infrastructure:

- Larger scale projects such as watershed transformation are implemented as public investments despite private (collective) interests being relevant (see Tullstorp stream case). Findings by Keesstra et al. (2023) suggest that private or commercial investments in NBS might be easier to implement if the scale is smaller and requires relatively higher investment for constructing the NBS. On the other hand, large scale NBS, based directly on natural ecosystems, are more likely to be financed by public sources.

- Risks for long-term maintenance: Private investments in NBS bear a risk of long-term continuity. Continuous investments are needed to maintain NBS and monitor their outcomes. If they cannot be ensured, a potential risk of failure should be considered. However, NBS are known to need less maintenance than hard engineering structures, which may make NBS attractive in the future when they become more mainstream measures.

List of abbreviations

ABBREVIATION	NAME	REFERENCE
EEA	European Environment Agency	www.eea.europa.eu
NBS	Nature Based Solutions	https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en
EIB	European Investment Bank	https://www.eib.org
ENI	Ente Nazionale Idrocarburi (Italian publicly traded company)	www.eni.com/en-IT/home.html
CAP	Common Agricultural Policy	https://agriculture.ec.europa.eu/common-agricultural-policy_en
TSEA	Tullstorp Stream Economic Association	https://tullstorpsan.se
LOVA	LOVA grant (Lokala vattenvårdsprojekt (LOVA) local wáter management project	
MAVA	Mava foundation	https://mava-foundation.org
WWF	World Wildlife Foundation	https://www.worldwildlife.org/

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