RECONECT

Holistic ecosystem based framework for assessment of NBS

Deliverable D1.7

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Abstract (for dissemination, 100 words)	This is the final report addressing the holistic ecosystem based frameworks and focuses on the state-of-the-art analysis of the relevant frameworks. It describe the RECONECT approach and how it builds upon the existing frameworks, mainly the one developed in the FP7 Project PEARL.
Keywords	Ecosystem based frameworks, holistic approach

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Executive Summary

This deliverable builds on D1.1 by providing more details about how RECONECT will build on PEARL and EKLIPSE. RECONECT builds upon the PEARL framework which has been successfully applied in several case studies in Europe and outside, while the evaluation part of the framework will integrate the EKLIPSE approach to suit large-scale NBS for rural and natural areas. This has been done by grouping challenges into three categories being WATER, NATURE and PEOPLE and evaluating them in relation to spatial and temporal dimensions for the cases with and without consideration and deployment of NBS.

This deliverable explains how the RECONECT framework starts from the view that risk emerges (or co-evolves) from actions and interactions within and between human systems and the natural environment. The framework will consider that human systems are socio-technical systems that consist of a social system (for example actors, behaviour, institutional structures) and a technical system, for example (urban infrastructure, drainage, flood defences, industrial networks, agricultural systems, nature-based solutions, etc.). These two co-evolve through decisions about the use of the natural and human system and its development, changing infrastructure, policy and regulation through strategic management and governance.

As the current condition of any system is the outcome of complex interactions it is important to define the system and its scale. This deliverable explains that while the physical/natural system is relatively easy to define (by following the water movement) the social system boundaries are more challenging as there are complex relations and feedback mechanisms that are difficult to capture. Therefore, RECONECT uses a transdisciplinary partnership of researchers, industrial partners and authorities/agencies at local and watershed/regional level so that the proposed “solutions” contribute not only to reduce hydro meteorological risks, but also to enable multiple benefits for the governance.

This deliverable lists the positives and challenges of NBS related frameworks that have been developed in the past. It explains why and how the PEARL and EKLIPSE will be used to inform the development of the RECONECT framework. The framework will be available to all.

This report is primarily meant for the project partners developing or supporting the design of the RECONECT framework. Furthermore, the provided analysis of the existing frameworks, can also be beneficial for researchers and practitioners that are co-creating and collaborating to create the Ecosystem based frameworks beyond RECONECT.

The RECONECT framework will combine the strength of existing conceptual frameworks in multiple ways to ensure that it will be of use to researchers, industrial partners (SMEs and large consultancies) and authorities/agencies at local and watershed/regional level. By integrating different perspectives from relevant stakeholders the framework will not only reduce hydro-meteorological risks, but also enable multiple benefits investment and management strategies.

Based on the evaluation of the existing frameworks, it is recommended that the RECONECT framework is developed using the frameworks from the PEARL and EKLIPSE projects.

The PEARL framework focused on the assessment of risk and impacts from floods and by doing that it was also assessment solutions which included NBS at urban scale. Therefore, the framework is taken as a basis in RECONECT but needs to be enhanced to accommodate more NBS solutions (i.e. large scale) and to accommodate and account for the benefits. This is where we see the potential for innovation and integration with other frameworks such the one developed in EKLIPSE. It is recommended that EKLIPSE impact evaluation framework will be expanded for evaluation of large scale NBS in rural and natural areas. This will be done by grouping challenges into three categories being WATER, NATURE and PEOPLE and evaluating them in relation to spatial and temporal dimensions for the cases with and without consideration and deployment of NBS.

The framework continues with the identification of key stakeholders using the methodology of social innovation proposed and developed in WP4. In RECONECT the local municipality where the NBS will take place is also a partner and therefore the identification and analysis of stakeholder's role is done with their input.

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List of tables

Tables must also explicitly be referred to in the text. Tables without reference should be removed. Caption for tables appear above the table.

Abbreviations

Agent Based Models (ABMs)
Asian Development Preparedness Center (ADPC)
Drivers-Pressures-State-Impact-Response (DPSIR)
Ecosystem based approach to disaster risk reduction (Eco-DRR)
European Environment Agency (EEA 1999)
Expert Working Group (EWG)
Flood Resilience Index (FRI).
Flood Resilience Measurement Tool (FRMT)
Mapping and Assessment of Ecosystems and their Services (MAES)
Massive Open Online Course (MOOC)
Natural Based Solutions (NBS)
Partnership for Environment and Disaster Risk Reduction (PEDRR)
Pressure-State Response (PSR)
Research and Innovation (R&I)
RRCA (Root and Risk Cause Analysis)

1 Introduction

This report provides a preliminary review of the holistic ecosystem-based framework developed in previous research to evaluate the impacts of Natural Based Solutions (NBS). A full review report will be updated in M24.

1.1 Background

RECONECT aims to rapidly enhance the European reference framework on Nature-Based Solutions (NBS) for hydro-meteorological risk reduction by demonstrating, referencing, upscaling and exploiting large-scale NBS in rural and natural areas. In an era of Europe's natural capital being under increased cumulative pressure, RECONECT will stimulate a new culture of co-creation of 'land use planning' that links the reduction of hydro-meteorological risk with local and regional development objectives in a sustainable and financially viable way.

To do that, RECONECT draws upon a network of carefully selected Demonstrators and Collaborators that cover a wide and diverse range of local conditions, geographic characteristics, institutional/governance structures and social/cultural settings to successfully upscale NBS throughout Europe and Internationally. To achieve these ambitious goals, the RECONECT consortium brings together an unprecedented transdisciplinary partnership of researchers, industrial partners (SMEs and large consultancies) and authorities/agencies at local and watershed/regional level fully dedicated to achieve the desired outcomes of the project.

This report summarises the work in Task 1.1 within Work Package in RECONECT that investigates existing holistic ecosystem-based frameworks to enable assessment of NBS for different socio-economic and climate conditions and different temporal and spatial scales. This Deliverable will first be a Milestone that concentrates on the existing Frameworks (M13), while the next version (M24) will focus on enhancements.

This report is for the members of RECONET to help the design process of the new framework. We want to ensure that the framework does not duplicate a pre-existing framework and instead to ensure it is an advanced approach. The document will also be used by practitioners who work in the space of nature based solutions as a helpful overview of the different frameworks on the market.

1.2 Purpose/objectives

RECONECT will build on previously developed conceptual frameworks to implement a holistic ecosystem-based approach to assessing impacts of NBS options. The holistic framework will aim to analyse the risk due to extreme hydrometeorological events and it will build upon the PEARL framework which has been successfully applied in several case studies in Europe and outside. The evaluation part of this framework will build upon the EKLIPSE framework and further enhanced to suit large-scale NBS for rural and natural areas. This deliverable will collect and classify the existing resilience frameworks from the literature. The advantages and limitations of these frameworks will be evaluated such that RECONECT will further enhance the methodologies to establish an advanced approach that is applicable for large-scale NBS for rural and natural areas.

The preliminary report is meant for the internal purpose and targets the project participants.

1.3 Links to other deliverables in RECONECT

Interacts (not simply as input) with the following tasks:

- D1.3: Social innovation approach. In particular the development of an up-scaling strategy based on demand-and-supply analysis to assess the needs of the demonstrators and collaborators.
- D1.5: Tools, models and DSS for the implementation of NBS

Besides, the deliverable represents the framework for the activities in WP2 on Demonstration, WP3 on monitoring and evaluation and WP4 on overcoming barriers and upscaling.

2 Taxonomy/Classification of existing Frameworks

RECONECT aims to contribute to European reference framework on Nature Based Solutions (NBS) by demonstrating, referencing and upscaling large scale NBS and by stimulating a new culture for 'land use planning' that links the reduction of risks with local and regional development objectives in a sustainable way. In order to contribute successfully to the NBS field it is important to have a strong overview and understanding of past frameworks. This section **provides a preliminary review of the holistic ecosystem-based framework developed in previous research to evaluate the impacts of NBS.**

2.1 CORFU

The overall aim of CORFU was to enable European and Asian partners to learn from each other through joint investigation, development, implementation and dissemination of short to medium term strategies that will enable more scientifically sound management of the consequences of urban flooding in the future.

Overview of the framework

To better understand the impacts of flooding such that authorities can plan for adapting measures to cope with future scenarios, the project developed a modified Drivers-Pressures-State-Impact-Response (DPSIR) framework to allow policy makers to evaluate strategies for improving flood resilience in cities. The DPSIR Framework is an approach that has been used to understand and evaluate the state and performance of various social-environmental systems. The DPSIR framework was originally developed by the European Environment Agency (EEA 1999), although its genesis can be seen in relation to forerunner frameworks such as the Stress-Response framework developed by Statistics Canada in the 1970s, and was later extended as the Pressure-State Response (PSR) framework (OECD 1994).

The framework, aims to allow researchers to explore environmental management questions under a range of scenarios, to investigate the effects of changes, and to evaluate the effectiveness of responses to address these questions. In this framework, the Drivers, Pressures, States, Impacts and Responses are linked through a modelling chain representing a flow of information and data (Figure 1). The framework incorporated several key principles. First, it is a flexible approach that can be applied to real-world urban examples with various geographical, environmental and socioeconomic conditions. The framework is also flexible in that any model of the framework can be replaced and improved. Second, present and future states are considered, by considering changes to urban form, and climate change among other pressures and drivers. Third, the approach is necessarily interdisciplinary, bringing together economists, engineers, architects and social scientists. Finally, existing policies and legal frameworks have been considered.

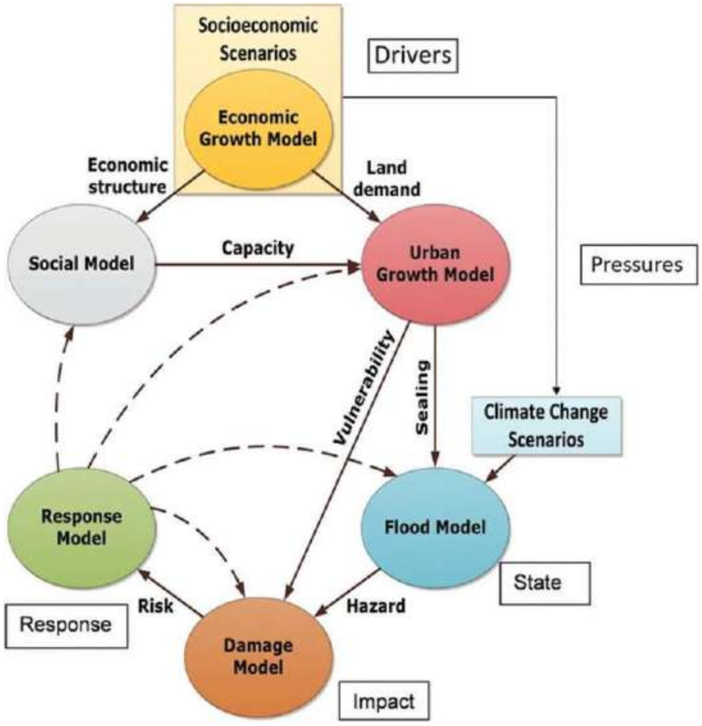


Figure 1 The CORFU's DPSIR framework

The framework relies upon the original definition of drivers and pressures, where drivers are the 'social and economic developments that put pressure on the environment'. Four drivers and two pressures have been considered in this framework, and given in

Table 1.

Table 1 Drivers and pressures

Drivers	Pressures
• Economic growth and structural change • Population growth • Demographic change (including changes to the age profile) • Changes to adaptive capacity	• Urban growth • Emissions scenarios

How is the framework different from others?

The enhanced DPSIR framework is a useful approach for structuring and systematising flood risk management problems, analysing root-causes, the relationships and basic interdependences as well as a logical chain of models. Second, due to its generic nature, the framework can accommodate its application to range of models in various cities. An important element of this research is that such frameworks can be applied to developed and developing countries, no matter the state of economic development or urban complexity. The framework also allows for the replacement and improvement of submodels. These could include improvements in the modelling of urban development, flood hazard modelling and impact assessment.

Critique of the framework
One theoretical challenge is in discretizing the different elements of the framework. One clear example of this is with climate change, which itself can be broken down into the relationship between economic growth, energy use, emissions and changes in weather patterns. The challenge here is to disentangle these forces and relationships from an inherently complex and messy reality. Scale problems arise in the development and application of DPSIR frameworks. Cities are both local and global phenomena.

2.2 PEARL

The main goal of PEARL is to develop adaptive, sociotechnical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe.

Overview of the framework

The PEARL holistic assessment of risk recognises that risk emerges or co-evolve from the different interactions of human system (social, institutions, economy, etc), the physical environment and the technological developments. In summary the framework included the following steps as presented in figure 2.

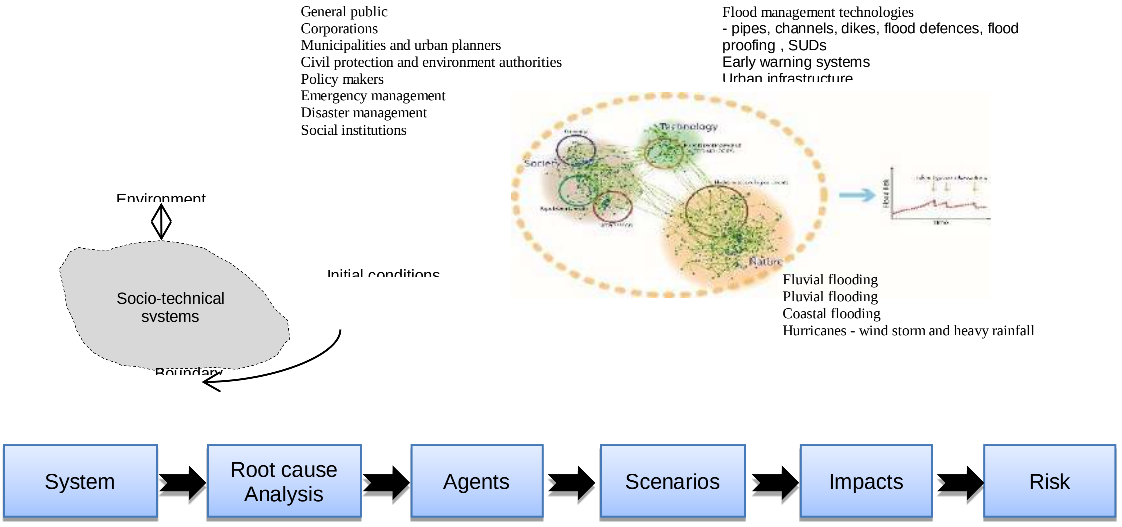


Figure 2 PEARLs Overall Holistic risk assessment framework

System Identification

The starting point in the development of the holistic risk assessment framework is the Ontology for flood risk assessment. A ontology is a formal, coherent representation of knowledge and concepts, that effectively is a formal meta-language that can be used for model specification. The connection between the different concepts highlighted the interdependencies among different subsystems. The drafting of the ontology, contributed to the formulation of a systems thinking approach to formulate different feedback loops. An intermediate step between the Ontology and the ABMs

(Agent Based Models) is the MAIA framework (Modelling Agent system based on an Institutional Analysis meta-model) from Ghorbani (2013), which helps to decompose, structure and conceptualize socio-technical systems with an agent-oriented perspective.

Root Cause Analysis

From the systems perspective the approach is enhanced with the results from the RRCA (Root and Risk Cause Analysis). Such analysis helps with the identifications of relevant actors and stakeholders, domain knowledge, systems and theories. This knowledge helps to define the boundaries of the systems and the relevant issues and scales of application (Spatial and temporal).

PEARL RRCA investigations centre on an in-depth qualitative investigation of the root causes and drivers of risk in different case studies, with a desk-based literature review undertaken alongside semi-structured key informant interviews. In addition to informant interviews in key institutions, the work includes interviews with affected stakeholders, whether by sector (e.g. port, tourism) and / or directly affected population groups. Through a deeper understanding of root causes – grounded in investigation that takes the disaster event, rather than other pre-defined lines of analysis, as its starting point – the RRCA Framework illustrates the involvement of actors across spaces in disaster creation and mitigation, the historical pathways that define existing policy decisions and the role of institutions from the local to the supra-national. The focus of institutional assessment work also moves from one centred exclusively on disaster management actors to one that incorporates wider development policy and practices, and the implications of other policy domains for disaster risk.

Institutional model – ABM Claim

Institutions are “rules and norms held in common by social actors that guide, constrain, and shape human interaction” (IPCC, 2014b). Institutions can be formal, such as laws, policies, directives, regulations, strategic plans, or informal, such as norms, conventions and cultures (IPCC, 2014b). Institutional analysis is used to study socio-technical systems using ABMs as institutions help develop tangible assumptions about agent decision making and behaviour (Ghorbani, 2013).

The ABM built for this study is based on the MAIA meta-model (or framework), which helps to decompose, structure and conceptualize socio-technical systems with an agent-oriented perspective (Ghorbani 2013; Ghorbani et al 2013). The framework also captures and explains agents’ behaviour, characteristics and decision making, and defines their relationship with social structures. The Claim ABM model is described in more detail in deliverable 1.6.

Scenarios and alternatives

Scenario analysis aim to assess the effect of possible changes in terms of climate, land use and population dynamics which cannot be controlled by local planning entities. On the other hand, alternatives analysis will be carried out to identify desired and undesired implications of directives (for example EU Floods Directive), regional or country wise policies, plans and decisions made in the case study areas, and their amendments before testing and implementing them on the actual system.

Vulnerability assessment

To assess risk, the Holistic framework requires the input from vulnerability assessment and from the formation of related hazards. The indicators describing the components of vulnerability on the ground were set by the results of the RRCA Method. Nevertheless the vulnerability assessment can also be conducted as a stand-alone exercise to inform policy makers, planners and managers or to be integrated in future planning and management processes.

Hazard Analysis

Pearl developed new approaches for flood hazard assessment, in particular for coastal urban areas. Pearl used a wide variety of existing tools and models available to assess flood hazards. The output of the hazard analysis is a series of maps for the study area and respective scenario depicting the changes in water depth and velocities in the modelling area. This maps are used as an input for the other model in the impact analysis framework to estimate the impacts of the flooding event on a particular sub-system in the urban area.

Impact analysis

The PEARL framework included a wide spectrum of impacts ranging from qualitative risk perception to quantitative economic costs of floods and their relation to health impacts. Different models and tools were developed in PEARL to assess different impacts. The economic damage methodology addresses direct and indirect, tangible and intangible impacts/damages. It proposed a business interruption economic model that can help in the estimation of cascading effects to other urban services due to extreme hydro-meteorological events. The following impacts were addressed in PEARL, including the development of models for the assessment.

- Direct tangible – Damage to properties
- Direct intangible – Crowd simulation - flood risk model
- Direct intangible - Public health assessment model
- Indirect intangible – Traffic disruption
- Indirect tangible – Economic Damage model
- Cascading effects

Flood Risk Mapping and Visualization

The output of the holistic flood risk assessment framework contains information about vulnerabilities, hazards and the potential impacts to different sub-systems or models within the tool kit. The information will be combined using GIS Maps to represent risk changes in space. As part of the PEARL framework different visualization methods and tools were used including the following:

- *Flood Risk Maps*
- *3D Visualization*
- The Web LP (Learning and Planning Platform)

The learning and planning platform was populated with the risk analysis results for each EU case studies. The data set included the output of the different models and methods developed at each case study, including different scenario runs to provide enough exploration space for the stakeholder mode function. It also included the “Flood Tools” module which allowed a customized experience in which different combination of choices by the stakeholders will extract different modelling results from the platform’s database (e.g. Labiosa et al., 2013). The platform also integrated other tools like the Flood resilience index.

The objective of the resilience index developed during the PEARL project was to valuate an urban system’s flood resilience depending on the scale of work. To measure flood resilience in urban spaces, the index takes into account several indicators based on the notions of the five R’s of resilience regarding flood management: Reflect, Relief, Resist, Response, and Recovery. In the process of calculating the FRI, five different dimensions are analyzed (Physical, Natural, Social, Economic, and Institutional) in order to reflect the overarching nature of flood resilience. In the case of small scales within the urban fabric, the urban functions of the different properties are defined and the availability of critical requirements is assessed. The evaluation of flood resilience is expressed through the value of Flood Resilience Index (FRI).

The FRI considers a multi-scale risk assessment that starts with the analysis of the urban system, considering different scales. The flood risk assessment is respectively characterized through different scales (macro and micro) with variations in land use, assets and vulnerability as well as differences in variation of strategies. Figure 3 presents a screenshot of the Web learning and planning platform, including the FRI tool.

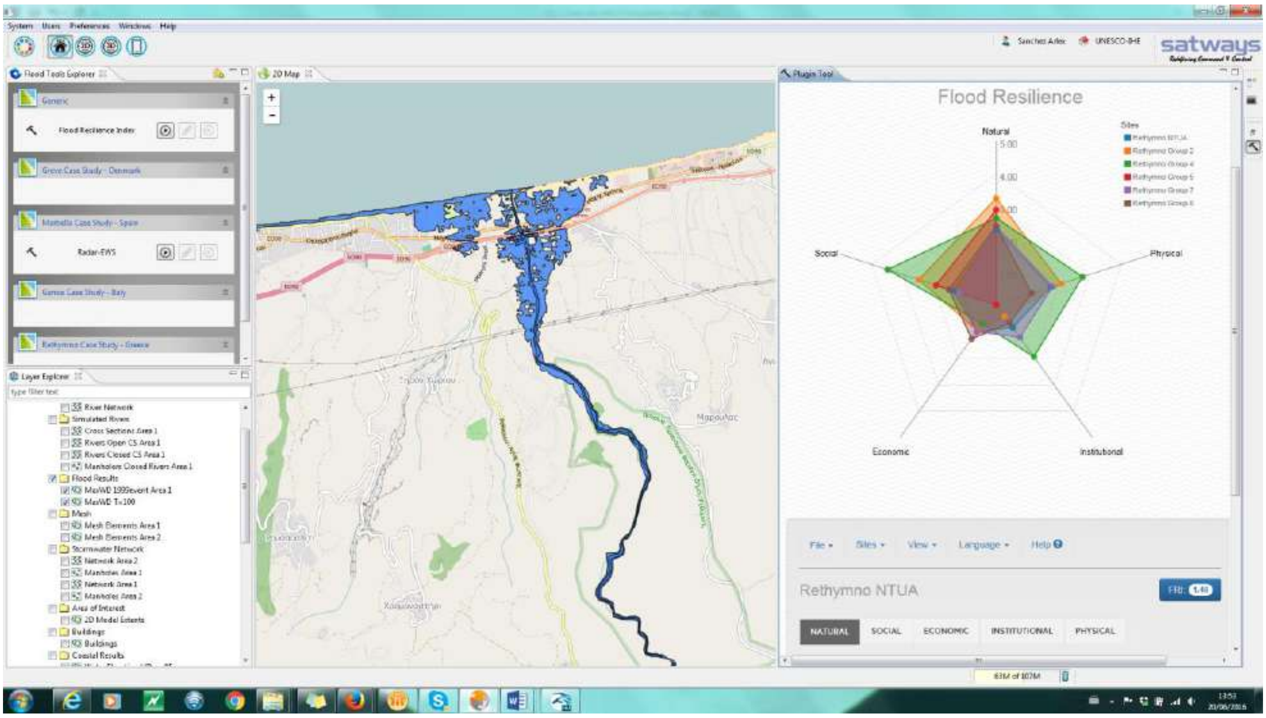


Figure 3 Visualization tool of flood risk and FRI index

How is this framework different from others?

Given the initial research activities on the FRI framework, the PEARL project integrated the FRI methodology into an a software application (PEARL FRI Tool) to support stakeholders identify vulnerabilities at city scale and guide them to specific measures that could improve the resilience of their region. The integration was implemented in the PEARL Knowledge Base and demonstrated via the PEARL web-based learning and planning platform. This way, stakeholders would not only identify in which dimension their city is most vulnerable, but they would be provided with additional functionality to explore different strategies for adaptation in response to flood risk.

Example of where the framework has been used?

During the project, the PEARL approach was tested in EU case study areas such as Rethymnon in Greece; Marbella, in Spain; Genoa, in Italy; Hamburg, in Germany and in international case studies such as Saint marten in the Caribbean and Ayutthaya in Thailand. For example for the flood resilience index assessment a number of stakeholders were asked to assess the resilience of their city in each dimension consisting the FRI by assessing the value of the indicators one-by-one. The stakeholders were divided into groups, each of them giving their own independent assessment online. The results were visible with lower marks to the economic indicators, while all stakeholders agreed that the city's resilience against floods was low with respect to economic aspects.

2.3 OPERAs/OPPLA

The OPERAs project was an EU FP7 project conducted between 2012 and 2017 focusing on operationalizing ecosystem services into practical decision-making. Ecosystem services as a concept was beforehand starting to be accepted in policy frameworks and OPERAs was a means to provide practitioners tools and general support in the practical decision-making (OPERAs, 2018).

Overview of the framework

The stated purpose of OPERAs was to gather best practice from a number of Exemplar cases and synthesize this knowledge into a form (tools, methods, instruments) that can support both policy-making and practical decision-making on ecosystem services, see Figure 4 (OPERAs, 2018). Thirteen Exemplars founded the basis for the OPERAs project and analyses was carried out in clusters of Exemplars having common features to synthesize knowledge at a meta level corresponding to the cluster theme (Nicholas et al., 2014). An indicator framework to support these analyses was developed based on effectiveness/efficiency (Figure 5) (Schmidt et al., 2014). Knowledge based on the Exemplars was collected into a number of ideal types to form a sort of theoretical framework for describing case studies (Krause et al., 2016).

A number of tools was developed in OPERAs to support practical implementation of ecosystem services and as well a guide for good practice in the choice of instruments when working with ecosystem services (Tuomasjukka et al., 2016).

The main output of the OPERAs project was the establishment of the OPPLA platform (OPPLA, 2019) that provides a marketplace and a community where stakeholder can share experiences through documentation of case studies, tools and policies related to ecosystem services, nature based solutions and the like.

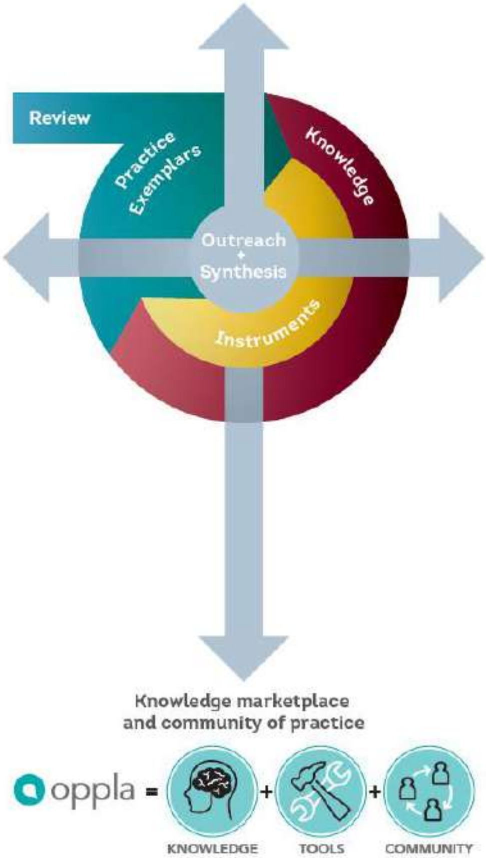


Figure 4 The research approach adopted by the OPERAs project where knowledge is gathered from practice and synthesised into instruments that can be shared and used by others in their decision –making (OPERAs, 2018)

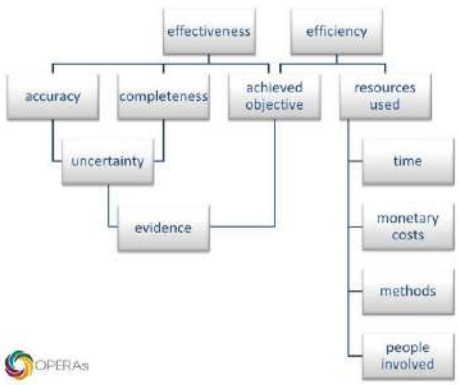


Figure 5 Indicator framework from OPERAs

How is this framework different from others?

This framework is very unique in that it does not provide a very structured view to how to best put ecosystem services into practice; it rather provides a set of guiding principles to keep in mind when operating in the field (Figure 6) and use very structured descriptions of case studies as a means to showcase what these means in practice (OPERAs, 2018).

The structured description of case studies is also the backbone of OPPLA, where a very large number are described in-depth for other practitioners to learn from (OPPLA, 2019).

Figure 6 Key messages from the OPERAs projects. (OPERAs, 2018)

Critique of the framework

As the framework is based on knowledge transfer between practical projects it will be challenging to apply in cases where that somehow differs in a way that makes it difficult to match it to previously explored cases. This also exemplifies that uses need a very high knowledge about their own project in order to be able to identify the relevant case studies to learn from, which might not always be the case in practice.

2.4 EU-CIRCLE

It is presently acknowledged and scientifically proven that climate related hazards have the potential to substantially affect the lifespan and effectiveness or even destroy of European Critical Infrastructures (CI), particularly the energy, transportation sectors, buildings, marine and water management infrastructure with devastating impacts in EU appraising the social and economic losses. The main strategic objective of EU-CIRCLE was to move towards infrastructure network(s) that are resilient to today's natural hazards and prepared for the future changing climate. Furthermore, modern infrastructures are inherently interconnected and interdependent systems; thus extreme events are liable to lead to 'cascade failures'.

Overview of the framework

The EU-CIRCLE project has defined a holistic framework aiming to identify and assess the risks caused by multiple climate-change stressors and climatic hazards to heterogeneous interconnected and interdependent critical infrastructures. This is considered to be the first step to ensure the resilience of vulnerable technological, social and economic systems to climate change impacts and improve climate proofing ability of the existing critical infrastructures (in terms of identifying indicators and reference states, anticipated adaptive / transformation activities, and investment costing). The framework allows to identify climate-driven CIP risks and to elaborate relevant capabilities (anticipation, absorption, coping, restoration, and adaptation) to ensure their resiliency. Figure 7 shows the main components of the EU-CIRCLE risk management framework (Sfetsos et al. 2017), including:

1. Establishment of CI (or regional) climate change resilience policy, or specific business orient decision that will be addressed.
2. Identification, collection and processing of climate related data and secondary hazards.
3. Identification of assets, systems, networks, and functions.
4. Assessment and evaluation of risks.
5. Selection and implementation of protective programmes, including adaptation options, to modify risk level and to implement those options.
6. Measurement of effectiveness.

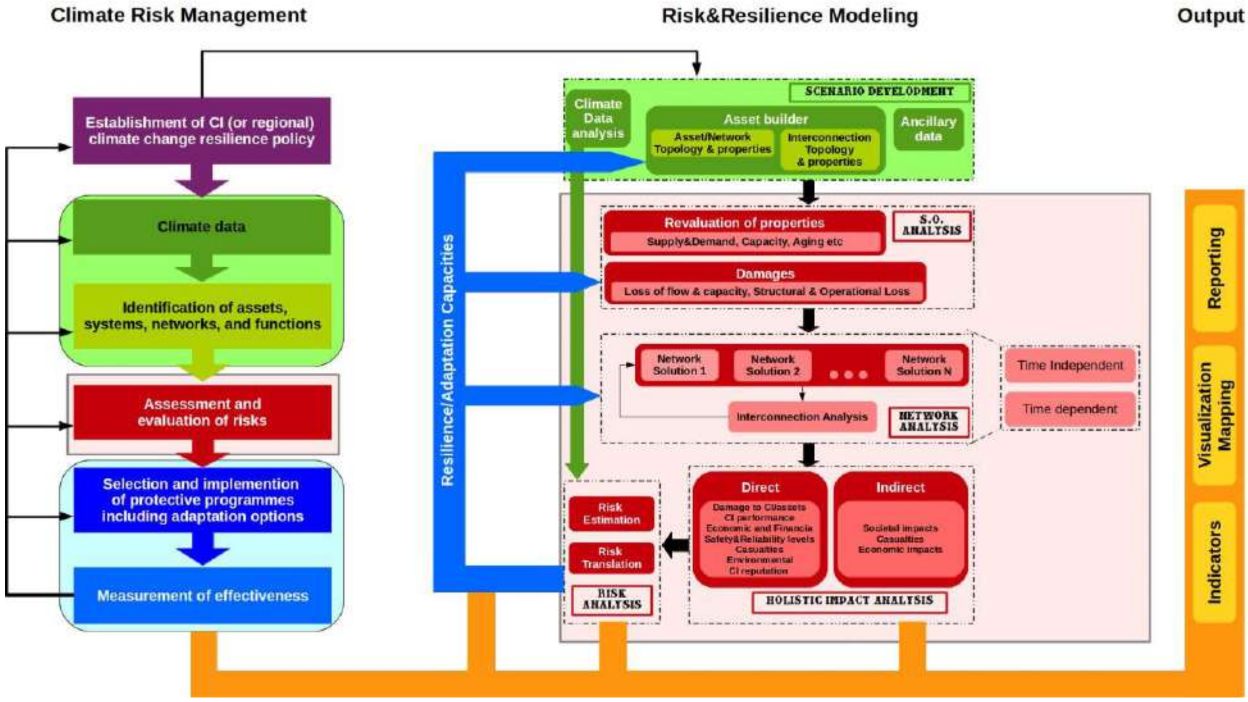


Figure 7 EU-CIRCLE Resilience Framework (Sfetsos et al. 2017)

The EU-CIRCLE resilience framework will determine what constitutes critical infrastructure resilience and their key components are summarised briefly below:

1. Resilience of what – the context which is critical infrastructure, their networks and interdependencies as incorporated in Layer 1
2. Resilience for what – the disturbance which is climatic hazards, including current and future climate change represented in Layer 2

3. Risks and Impacts – which includes the consequences of a hazard and the likelihood of the occurrence, detailed in Layer 3
4. Capacities of critical infrastructure such as the ability to anticipate and reduce the impact; ability to buffer and bear; ability to be repaired easily and efficiently included in the final Layer 4
5. Resilience parameters i.e. properties that indicate different capacities are also included in Layer 4

How is the framework different from others?

The EU-CIRCLE resilience framework has multi-dimensional components, incorporating risks and capacities with the focus on critical infrastructure, their networks and interdependencies and climate hazards including current and future climate change. Multiple scientific disciplines can work together using the platform and they are supported to understand interdependencies, validate results, and present findings in a unified manner, providing an efficient solution that integrates existing modelling tools and data into a holistic resilience model in a standardized fashion. The analyses may refer to any part of the risk assessment and resilience evaluation workflow.

A number of pilot cases are considered as examples for demonstrating the proof of concept and testing the aforementioned framework, using real-world cases. The EU-CIRCLE approach, applied to the case study of the coastal flooding in Torbay UK and its impact on urban infrastructures.

2.5 Safe & SuRe

The Safe & SuRe project was an Engineering and Physical Sciences Research Council funded fellowship that aimed to develop sustainable and resilient solutions for urban water management at a time of global uncertainty. Researchers developed new paradigms so that existing urban water systems can be better used, managed, regulated, planned, operated, rehabilitated, retrofitted and redesigned to cope with global uncertainties (Butler et al., 2017; Mugume et al., 2015). The researchers collaborated with a range of practitioners and policymakers including the Environment Agency, Water Industry Forum, Northumbrian Water, and the Environmental Sustainability Knowledge Transfer Network, to ensure that they meet the needs of stakeholders.

Overview of the framework

A significant output from the project is the Safe & SuRe interventions framework illustrated in (Figure 8; Butler et al., 2017). It provides a diagrammatic representation of the relationship between threats and their consequences, and enables opportunities for intervention to be identified in order to design a more resilient system. It addresses the emerging threats, the intervening water system, impacts on system performance (expressed as levels of service), and the social, economic, and environmental consequences of the level of service failure. It aims to provide greater clarity to decision makers, allowing better informed choices to be made. The framework also connects the additional global challenges of climate change, energy, food production, agriculture, and health; all of which may be threats to water management and/or consequences of water system failure.

The urbanisation framework example in figure 7 illustrates its use to the threat of increasing urbanisation. The framework and concepts can be applied to many different systems and sub-systems including water supply, wastewater treatment, urban wastewater systems, and flood management applications.

The framework allows for the identification of the role and need for four types of intervention strategies: Mitigation, Adaptation, Coping, and Learning. These intervention strategies enable water problems and challenges to be addressed in a holistic manner. They provide a logical foundation for the analysis of reliability, resilience and sustainability, enabling greater consistency in assessment methodologies and methodical identification of opportunities for intervention.

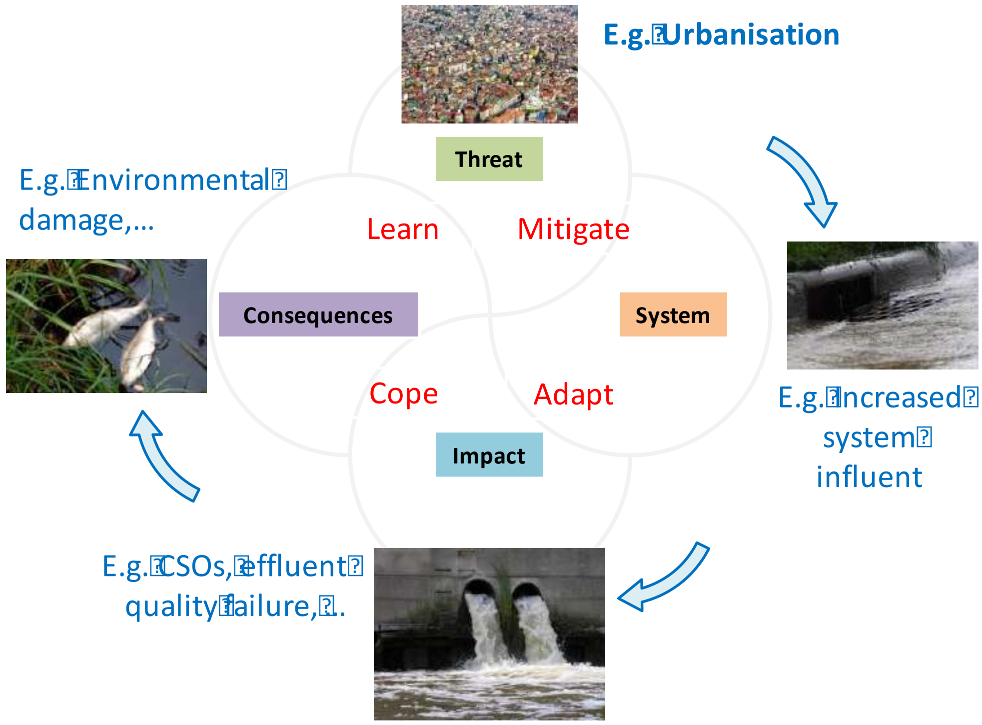


Figure 8 The Safe & SuRe interventions framework applied to the threat of increasing urbanisation

The four types of intervention are defined as follows:

Mitigation intervention addresses the link between threat and system. Mitigation intervention usually creates long-term actions to ameliorate threats. Using the example in Figure 7, an example of mitigating urbanisation could be urban planning and policies to manage urban development to mitigate impact on the sewer system.

Adaptation intervention addresses the link between the system and impact. Adaptation includes adjustments carried out in a specific system in response to an actual or anticipated threat to minimize failure consequences. Using the example in Figure 7, an adaptation intervention could be the implementation of permeable paving, to reduce urbanization effects (mitigate the threat) and also be a means of adapting to reduce excess storm water runoff entering the sewer system.

Coping intervention addresses the link between impact and consequence. It is defined here as any preparation or action taken to reduce the frequency, magnitude or duration of the effects of an impact on a recipient (people, nature, financial etc.). In the example in Figure 7, a coping strategy could be to reduce the impact of organic effluent on river ecology by water aeration (increasing the oxygen saturation of the water).

The negative consequences of a threat cannot be eliminated entirely by mitigation, adaptation, and coping. The final intervention, therefore, is **Learning**. This is embedding experiences and new knowledge into best practice. Unlike the other interventions, it doesn't need to address a specific threat, impact, or consequence and is relevant to all four quadrant models. There are many approaches to learning, which can include learning from past events, developing pilot schemes to generate new knowledge for best practice, and learning from others. Good data collection and effective communication strategies can also facilitate learning. In all cases, it is important that lessons are learnt from both good and bad practices.

How is this framework different from others?

The Safe & SuRe framework moves away from the traditional one direction analysis. It facilitates analysis in different 'directions' as illustrated in (Figure 9) and to this end multiple applications are being explored.

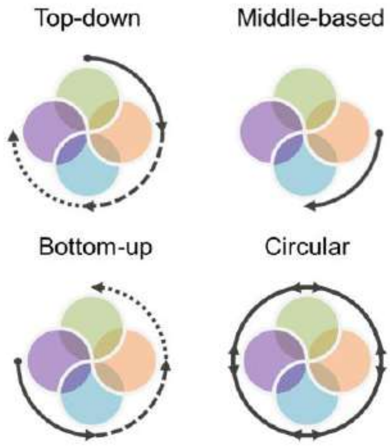


Figure 9 The Safe & SuRe framework facilitates analysis in different 'directions'

A Top-down analysis is threat based, mitigation focused, and relies on identification of potential threats that may then be embedded in the planning process. Top-down methods move clockwise around the framework, typically from threat (urbanisation in the example of Figure 1) to impact or threat to consequence. Risk assessment, for example, typically uses a top down approach to evaluate the effects of a given threat (whether on level of service or society, economy, and the environment).

The Middle based approach shifts the emphasis from identification and analysis of multiple threats to the more easily identifiable and measurable response of the level of service provision to system failure. The key benefit here is that multiple threats that result in the same system failure mode can be addressed with a single analysis, thereby enabling a more comprehensive resilience assessment and improving the adaptation development process.

A Bottom-up analysis is conventionally consequence based and coping focussed, starting with identification of potential social, economic, or environmental consequences and progresses anticlockwise around the framework.

The final analysis approach facilitated by this framework considers the threats, system, impact, and consequences as part of a Circular arrangement, with a focus on learning. This addresses all components of the framework because, where mitigation, adaptation, and coping actions have been implemented as part of a comprehensive strategy, assessment of their efficacy is vital to inform learning and ensure that strategies, processes, and actions are updated.

Critique of the framework

Currently, the framework is only a diagram/concept. In order for the framework to be more useful to practitioners, it needs to be translated it into an interactive tool that would be user friendly for practitioners and provide clear outputs to decision makers, allowing better informed choices to be made. This would provide a platform to commence a conversation around resilience and a means of recording the conversation. It would allow the users to understand the definition of resilience, how it applies within the context of a project or strategy and how practically interventions can enhance resilience. The tool would help to bridge the gap between resilience strategy and the asset planning/operations teams who be responsible for delivering resilience enhancements through interventions.

2.6 EKLIPSE

The EKLIPSE Horizon 2020 funded project aims at building an innovative, ethical, and self-sustainable EU support mechanism for evidence-informed policy on biodiversity and ecosystems services. The project and the developing mechanism is reactive, looking at this from the end-users' perspective. Project partners facilitate the development of the support mechanism through the project. And their role is to facilitate linkages between science, policy, and society, through different actions, such as knowledge synthesis, identifying research priorities, and building the Network of Networks that will support the other actions. One distinctive characteristic of the project is the open call for requests so that policy-makers and societal actors can discuss and express their needs. When eligible requests are progressed, they often lead to the need for Expert Working Groups, knowledge syntheses, or different kinds of foresight events such as conferences and events or science cafes. An outcome of this process was an impact evaluation framework with a list of criteria for assessing the performance of NBS in dealing with challenges, an application guide for measuring how NBS projects fare against the identified indicators in delivering multiple environmental economic and social benefits, and make recommendations to improve the assessment of the effectiveness of the NBS projects.

Overview of the Framework

As is mentioned before this frame is the result of one of the requests answered under the umbrella of the EKLIPSE project. This request was put into EKLIPSE by the European Commission DG Research and Innovation to help building up evidence and knowledge base on the benefits and challenges of applying NBS. The outcome of this process was an impact evaluation framework with a list of criteria for assessing the performance of NBS in dealing with challenges, an application guide for measuring how NBS projects fare against the identified indicators in delivering multiple environmental economic and social benefits, and make recommendations to improve the assessment of the effectiveness of the NBS projects.

To develop this framework, EKLIPSE sent out a Call for Expertise and selected a range of experts that covered a broad range of expertise (natural and social sciences, practitioners, planners, and architects) and geographical representation to form the EKLIPSE Expert Working Group (EWG) on Nature-based Solutions.

The EWG developed and holistic framework for assessing the co-benefits (and costs) of NBS across elements of socio-cultural and socio-economic systems, biodiversity, ecosystem, and climate. The approach enables the assessment of impacts related to specific NBS actions within and across ten challenges areas (Figures 9 and 10). The framework was based on a quick scoping review of the literature (Collins et al., 2015; Dicks et al., 2014) combined with expert consultation within and outside the EWG.

The NBS impact assessment framework (Figure 10 and Figure 11) builds on and supports several other closely related concepts, including the ecosystem approach, ecosystem-based adaptation, and mitigation, green and blue infrastructure and ecosystem services (European Commission, 2015). The European Commission, through MAES (Mapping and Assessment of Ecosystems and their Services), is assisting Member States in the process of mapping and assessment of ecosystems and their services, as well as assessing the economic value of such services, and incorporating these values into EU and national accounting and reporting systems (European Commission, 2013).

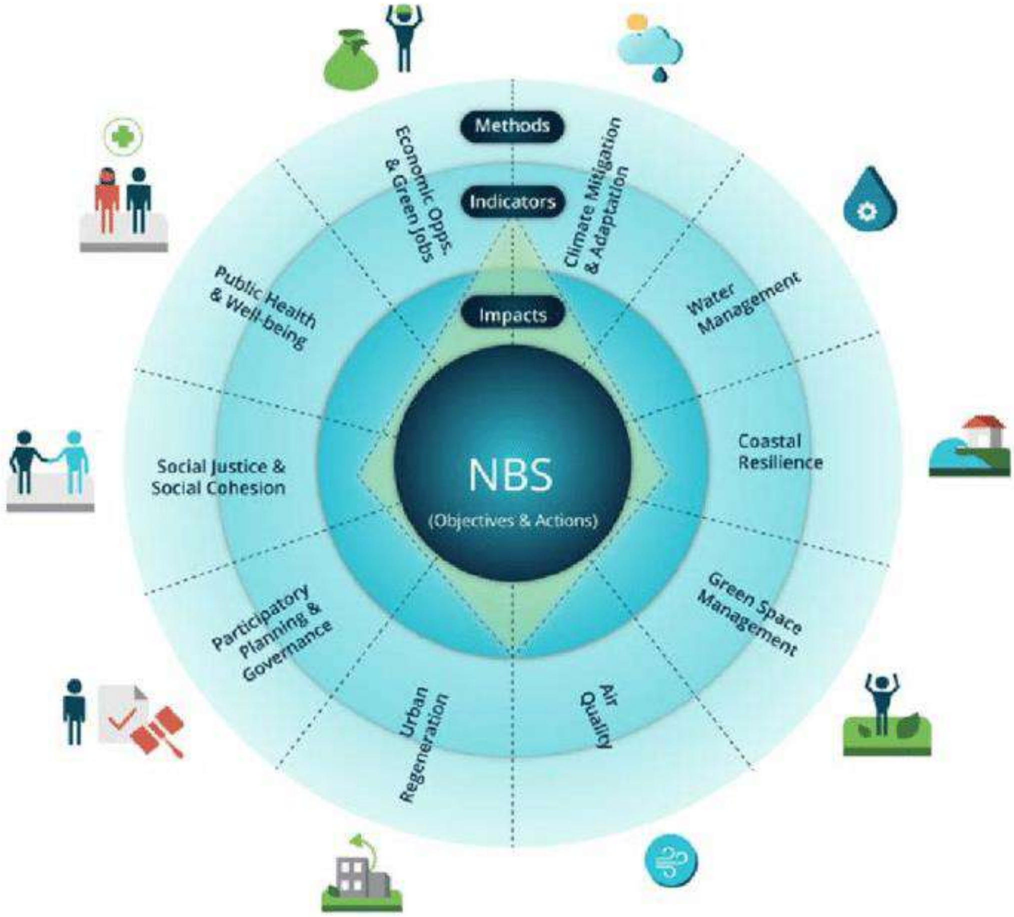


Figure 10 The ten climate resilience challenges considered in this impact assessment framework (Raymond et al. 2017a)

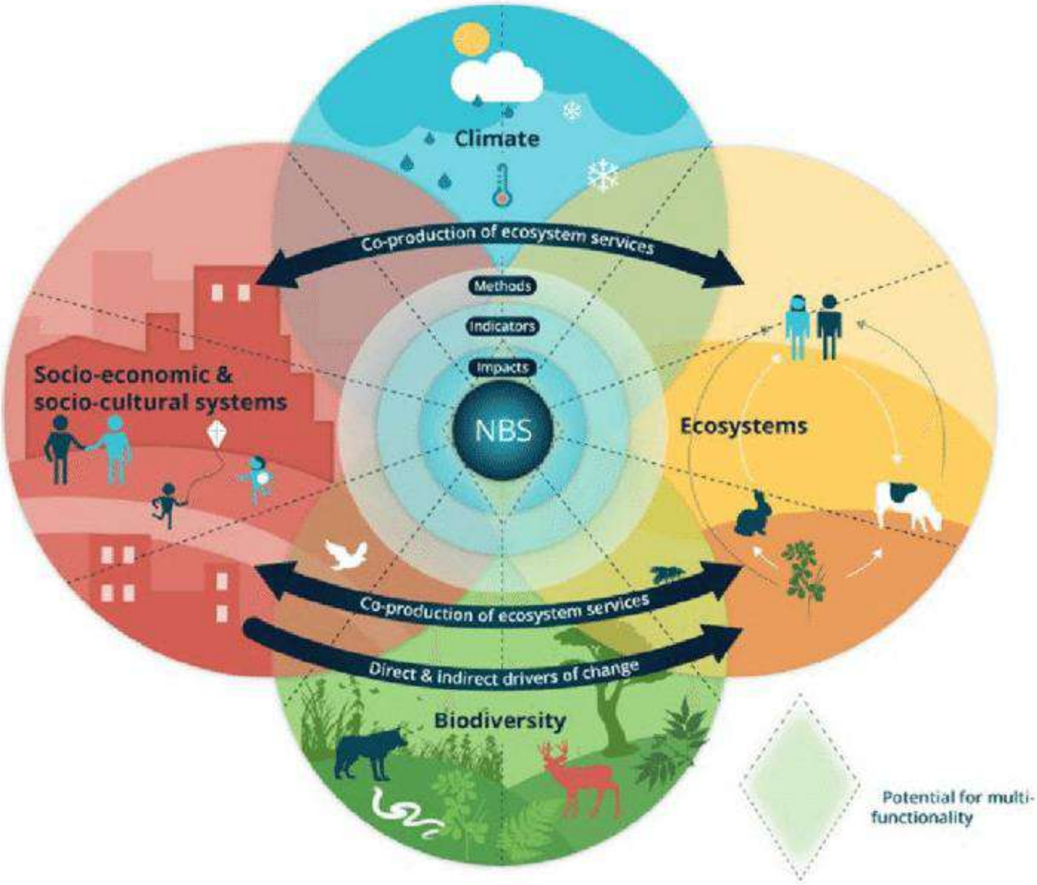


Figure 11 Framework illustrating the relationships among elements of biophysical and social systems, climate resilience challenges, and the NBS actions, impacts, indicators, and methods for addressing each challenge (Raymond et al. 2017a)

The approach takes into consideration that a specific NBS project directed towards a given challenge has an associated set of objectives and actions. Each action has an associated set of expected impacts, and these impacts can be assessed using a set of indicators, using specific types of methods for assessing those indicators (Figure 10). The classification has been designed specifically for the purpose of this framework, but it is acknowledged that each of the ten challenge areas can be expanded or reduced to consider all the multi-functional aspects of NBS. There is potential for indicators and methods to apply to more than one challenge area, as illustrated by the diamond body in Figure 10 and Figure 11.

How is this framework different from others?

This holistic framework systematically identifies the potential of NBS to provide synergies across ecosystem services together with co-benefits (or costs) in other different elements (socio-cultural, socio-economic system, environment, biodiversity, ecosystems, and climate). Furthermore, building on the mapping and assessment of ecosystems and their services (MAES, European Commission, 2013), this framework does not prove a single answer for the assessment of NBS impact, but rather, it recognises the potential for NBS impacts to vary across social and ecological contexts, and across temporal and geographical scales. By providing an impact evaluation framework with a list of criteria for assessing the performance of NBS projects in dealing with challenges of different sources (i.e., hydro-meteorological risk reduction, climate resilience, etc.). The identified indicators are exemplary and not exhaustive, and researchers and practitioners interested in NBS projects could enrich the impact assessment framework with additional operational and context-specific metrics and methods for valuation and assessment.

Also, the socio-ecological context in which NBS are embedded is integrated into this framework. Traditional ecosystem service assessments, such as the MAES framework, mainly focus on the linkages between stocks and flows of ecosystem services and their benefit to humans (as expressed through biophysical or monetary values), whereas the present NBS impact assessment framework recognises the potential for a range of other social, economic and environmental impacts. This broader view is reflected in the conceptualisation of the co-production of ecosystem services among and across climate, ecosystems, socioeconomic systems, and socio-cultural systems (Figure 11). The arrows in Figure 11 are not intended to represent causal or explanatory pathways, but rather to conceptually represent the complex interrelationships among aspects of the socio-economic and sociocultural systems, ecosystems, biodiversity, and climate.

Critique of the framework

This is a guiding framework that requires further operationalization and tailoring to a specific geographical and institutional context to ensure successful implementation. However, this approach provides a holistic and globally applicable tool for multiple stakeholders for a better NBS action planning process

2.7 ThinkNature

NBS aims to help societies to address a variety of environmental, social and economic challenges in sustainable ways. They are actions which are inspired by and supported by nature. Some involve using and enhancing existing natural solutions to challenges, while others are exploring more novel solutions, for example, based on how non-human organisms and communities cope with environmental extremes. NBS are energy and resource-efficient, and resilient to change, but to be successful they must be adapted to local conditions. In order to achieve more sustainable and resilient societies, NBS are an important topic on the EU Research and Innovation policy agenda. The ThinkNature project is part of Horizon 2020, the EU Framework Programme for Research and Innovation.

Overview of the framework

The main objective of ThinkNature is the development of a multi-stakeholder communication platform that supports the understanding and the promotion of nature based solutions in local, regional, EU and International level. Through dialogue uptake facilitation and steering mechanisms as well as knowledge capacity building, the ThinkNature Platform will bring together multi-disciplinary scientific expertise, policy, business and society, as well as citizens. This platform will be efficient, fluent to use and attractive to a wide variety of actors and stakeholders because it merges all aspects of NBS in a clear, pyramidal methodological approach. It will create a wide interactive society that builds new knowledge with a wide geographical scope.

How is the framework different from others

This platform will be efficient, fluent to use and attractive to a wide variety of actors and stakeholders because it merges all aspects of NBS in a clear, pyramidal methodological approach. It will create a wide interactive society that builds new knowledge with a wide geographical scope. As a result, ThinkNature will provide the necessary policy and regulatory tools to solve significant societal challenges such as human well-being, tackling energy poverty, impacts of climate change, etc. through continuous dialogue and interaction.

2.8 The Zurich Flood Resilience Measurement Tool

The aim of the Zurich Flood Resilience Alliance, a multi-year initiative, is to advance knowledge, develop expertise, and design strategies to help communities improve their ability to deal with recurring floods. The Alliance seeks to strengthen flood resilience by enabling communities to understand their potential sources of resilience. To do this, it has established a framework that can meet the challenge of measuring resilience, and also does it in an empirically verifiable way (Campbell et al 2019). The tool also adopts a systems thinking approach, which takes into account the assets, interactions and interconnections at the community level, and provides consistency when it comes to identifying and testing potential sources of resilience.

Overview of the framework

The Flood Resilience Measurement Tool (FRMT) combined two existing models: the 5Cs16 and the 4Rs17 models (Figure 11). The 5Cs model developed as part of DFID's sustainable livelihoods framework, refers to complementary capitals that can help people on their development path, while also providing capacity to withstand and respond to shocks. The 5Cs are human, social, physical, financial and natural capitals. On the other hand, the 4Rs model refers to four properties of a resilient system, developed by MCEER: robustness (ability to withstand a shock); redundancy (functional diversity); resourcefulness (ability to mobilise when threatened); and rapidity (ability to contain losses and recover in a timely manner). The framework uses indicators referred to "88 Sources of Resilience" based on these models.

The FRMT identifies natural capital as a significant source of resilience, as it can provide a cost-efficient flood risk reduction solution that can be managed using local knowledge and capacities. Natural capital in the FRMT has 6 sources: river basin health, habitat connectivity, natural habitats maintained for flood resilience services, sustainable use of natural resources, conservation management plan, and national legislation that recognises habitat restoration. Practical Action, one of the alliance members, has tested the FRMT by engaging with communities in the Piura and Rimac river basins in Peru, and also the Karnali river basin in Nepal. Additionally, by working with partners the tool has been piloted in over 100 communities so far.

How is the framework different from others

While many theories and frameworks about resilience exist, most of them are difficult to operationalize and/or only apply to specific cases. Furthermore, measuring at the scale of the community level, where latent resilience is often most needed, poses its own difficulties. This holistic framework implemented in a web and mobile based tool for measuring community flood resilience in developing and developed countries. The approach bridges the resilience measurement gap by developing a comprehensive set of pre-event characteristics across five overarching capitals which are based on the Sustainable Livelihood Framework and comparing them to post-event outcomes. In brief, the approach for measuring community flood resilience is to measure the pre-event characteristics called baseline 'sources of resilience', such as household savings, level of flood risk awareness and whether the community has a flood recovery plan, that contribute to a community's capacity to avoid risk creation, reduce existing risk, prepare for and recover better from a flood event. The FRMT also measures actual or revealed flood resilience in the event of a flood. That is, should a flood event occur, the level of losses and recovery is measured across a holistic set of variables. This measurement process provides the missing empirical data to allow for large scale, systematic testing over time of the sources of community flood resilience for ultimately achieving resilient outcomes. It is the first study which presents results on such a scale across the globe.

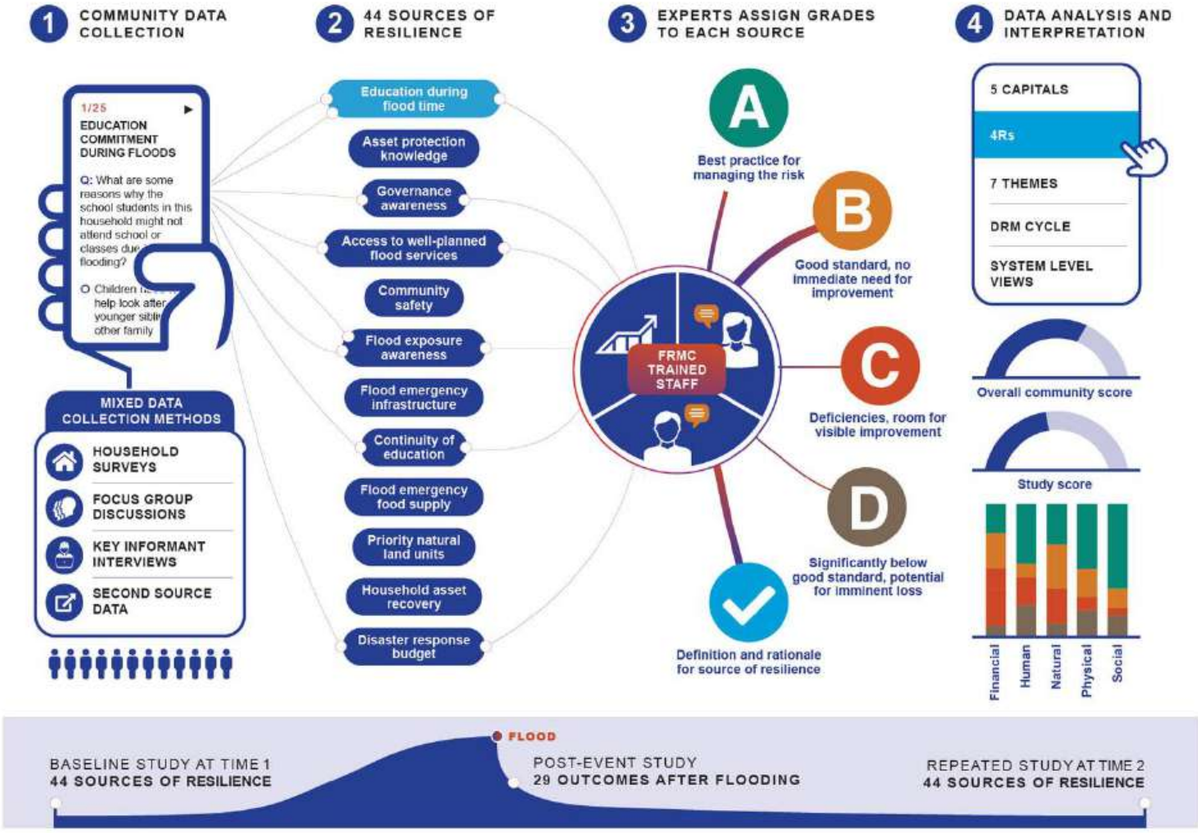


Figure 12 Diagram showing the different stages of the Zurich Flood Resilience Measurement Tool. (Image from floodresilience.net)

Critique of the framework

Training is required to use the tool, which takes time and investment but would help with the tool's adoption. The ultimate test of the tool is its usefulness for understanding and prioritizing evidence-based flood resilience investments. This validation process will take time and funding, which increases the risks of a fully scaled tool that operationalizes flood resilience measurement.

2.9 The World Bank: Implementing Nature Based Flood Protection

The objective of this guide is to provide principles and implementation guidance for planning, such as evaluation, design, and implementation of nature-based solutions for flood risk management as an alternative to or complementary to conventional engineering measures. The potential users of these principles and implementation steps are professionals in risk management and climate adaptation, NGOs, donors, and international organizations. This guidance was developed in cooperation with a large and diverse group of international funding agencies, research institutes, NGOs, governmental organizations, and engineering firms.

Overview of the framework

This framework gives guidance on the steps needed for the planning, assessment, design, implementation, monitoring, management, and evaluation of nature-based solutions for flood risk management (Figure 12; World Banker, 2017). It follows the general cycle of a flood risk management project and therefore are also applicable for grey measures. However, it provides more information and detail on specific aspects that need further attention when implementing nature-based solutions. These guidelines build and expand upon existing guidance developed by other organizations, including NOAA, USACE, and Ecoshape.

Projects that aim to implement nature-based solutions must consider biophysical and socio-economic processes on different scales in space and time. This calls for the engagement of experts from different disciplines such as hydrology, engineering, ecology, economics, and social sciences. As with other risk management projects, the design and implementation of nature-based solutions should be done in a participatory manner with full engagement of all relevant stakeholders. This is particularly important as nature-based solutions present an opportunity to address flood risks by aligning conservation, development, and poverty alleviation objectives. This can create new synergies and collaborations between governments, local communities, and NGOs, but also relevant private sector stakeholders.

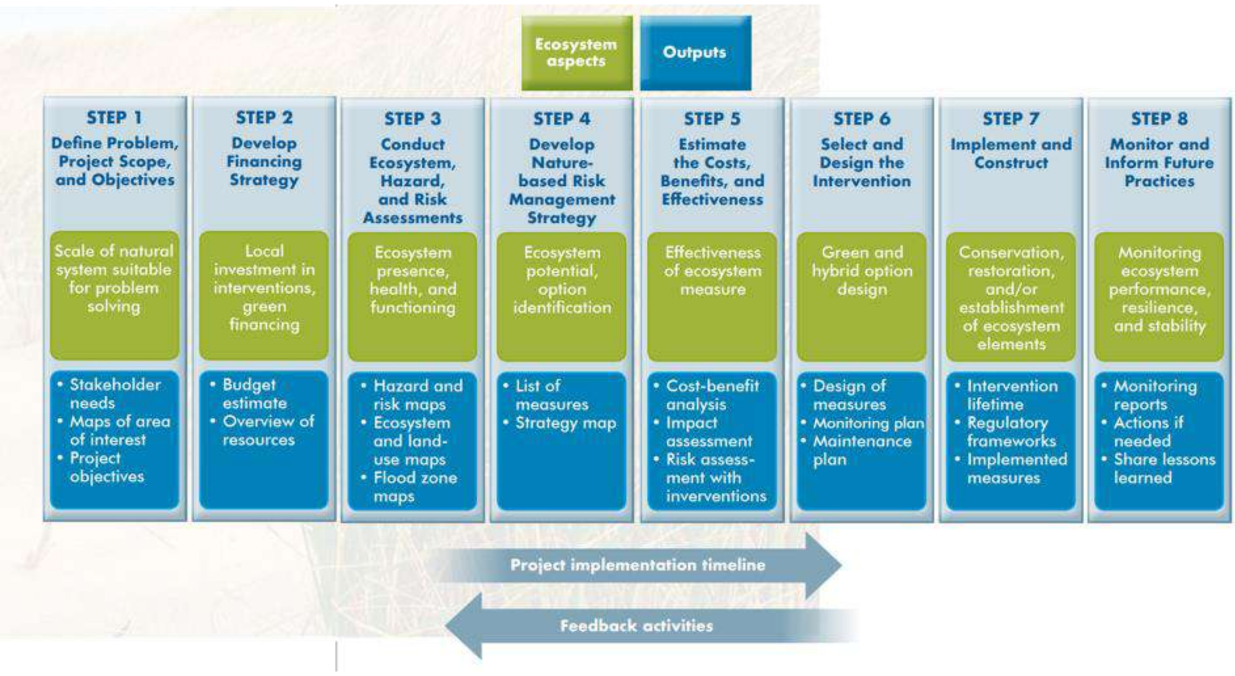


Figure 13 Diagram showing the implementation guidance (Image from WordBank.org)

How is the framework different from others

It creates a structured approach to the planning, evaluation, design, and implementation of nature-based solutions for flood risk management. It supports disaster risk management and climate adaptation professionals who plan flood risk management interventions, NGOs that implement nature-based solutions, as well as staff of donor and international agencies who design, review, or fund such projects. There is a growing momentum for the use of nature-based solutions as part of resilience-building strategies and disaster risk reduction, this framework and guidelines offer a step-by-step approach for implementing successful nature-based solutions for flood risk management.

Critique of the framework

This framework is for nature-based flood management, and forms an addition to other more specific initiatives such as detailed guidance on implementation (e.g. the WWF Flood Green Guide26; and USACE design guidelines that are currently in preparation), training programs (e.g. the NOAA Green Infrastructure for Coastal Resilience course27), and international networks (such as the Partnership for Environment and Disaster Risk Reduction, PEDRR28). It is encouraged that it is used as a starting point to build from, rather than a standalone framework.

2.10 The Green Framework

The Green framework is described as a 'dynamic' assessment framework that explicitly accounts for the impact of climate change on the effectiveness of the proposed NBS (Calliari, 2019). The framework goal is to make it possible to assess NBS suitability across most societal challenges identified in the EU Research and Innovation (R&I) agenda on the environment. It is based on an approach that integrates system analysis and backcasting. It is argued that backcasting is well-suited to the transformational character of NBS, as it encourages 'breakthrough' leaps rather than incremental improvements.

Overview of the framework

The framework factors in the multifunctional character of NBS and the aim is to capture associated direct benefits/ costs and co-benefits/costs. It is designed to be applied before any event in order to support the choice between innovative and traditional NBS options. Systems analysis supports decision makers when facing complex choices under uncertainty. Systems are defined by a problem situation, typically involving nature, man and his artefacts (including technology, law and social customs) and are characterised by many variables, feedback loops and interactions. System analysis helps to structure complex policy choices by identifying a set of logical stages that the analysis should follow. While there are many variations, the stages it suggests can be grouped into a sequence of steps:

The first three are so called "visioning" steps listed above seek to transform a commonly perceived unsatisfactory situation through to defining by the stakeholders of a shared vision for the future:

- Step 1 Baseline Definition, the starting point, is a description and analysis of the unsatisfactory situations that should be transformed.
- Step 2 Setting Objectives describe the desired situation and therefore the concrete goals that an action or a set of actions (i.e. a policy) aims to attain. The main objective is to overcome the problem identified in step 1 .
- Step 3 identification of enabling factors and constraints. The external factors that can enable and/or constrain the desired future situation are considered. This means drawing attention to wider political, economic, demographic and environmental trends that can affect the system of interest.

The backcasting stage works backwards to the present in order to determine how the objectives can be achieved This entails identifying the set of concrete actions that can lead to the desired situation. Three steps are included in this stage:

- Step 4 Definition of alternative courses of actions include different actions through which the main objective and sub-objectives identified in the visioning stage can be reached.

- Step 5 climate-proofing of alternatives. Are identified and designed, their climate resilience needs to be tested. This allows for considering nature-based or traditional investments options in a medium to long-term perspective and with respect to the hazard they are designed to tackle.

- Step 6 Map expected direct effects of alternatives. Is a preparatory step to the quantitative assessment, a mapping of the expected ‘performance’ of climate-proof alternatives.

The last stage Quantifying and Selecting is devoted to a quantitative evaluation of the effectiveness of alternatives in responding to the main and sub-objectives and to the selection of the final preferred option:

- Step 7 Set the criteria to evaluate alternatives. Qualify and quantify using indicators the impacts of each alternative on the system. These indicators are selected on the basis of costs and benefits listed in the mapping phase. They aim to provide comparable measures for the subsequent assessment.

- Step 8 Analyse the Alternatives; are evaluated through the indicators selected, usually by employing a model or models of the system. Tools are employed for the analysis such as hydrological models in the case of flood.

- Step 9 Evaluate the Alternatives. This is the “putting-everything-together” step which is carried out by employing analytical tools (e.g. Cost-benefit analysis, MCA). The suggested approach is to translate into monetary terms which allows having the same metric against which the choice of the preferred alternative can be made.

How is the framework different from others

Previously proposed frameworks have not considered the impacts of future environmental changes on the performance of NBS solutions. However, NBS are ‘living’ solutions whose effectiveness is determined both by the magnitude of the threats which they help to respond to, as well as their genuine ability to endure the rising (climate and other) environmental and anthropogenic pressures to which they are exposed. The dynamic nature of NBS is explicitly accounted for in this framework within the ‘climate proofing’ stage. It is important to consider how climate change will affect the future flow of ecosystem services, and to what extent the future flow of ecosystem service will satisfy the societal demand for which the green solutions were initially designed.

Critique of the framework

There are several factors that can inhibit the full operationalization of the framework, among them data accessibility/ availability and uncertainties permeating all aspects of the decision-making process. Effective involvement of experts and stakeholders in the knowledge co-production process on which the design, implementation and evaluation are based on, can prove challenging. The application of the framework requires transdisciplinary and multi-sectoral knowledge and tools, and a close engagement of multiple stakeholders.

2.11 ECO-DRR (Disaster Risk Reduction)

The IUCN’s Ecosystem based approach to disaster risk reduction (Eco-DRR) is the sustainable management, conservation and restoration of ecosystems to reduce disaster risk. It aimed to achieve sustainable and resilient development. Well-managed ecosystems, such as wetlands, forests and coastal systems, act as natural infrastructure, reducing physical exposure to many hazards and increasing socio-economic resilience of people and communities by sustaining local livelihoods and providing essential natural resources such as food, water and building materials. Ecosystem management not only offers an opportunity to strengthen natural infrastructure and human resilience against hazard impacts, but also generates a range of other social, economic and environmental benefits for multiple stakeholders, which in turn feed back into reduced risk.

Overview of the framework

Eco-DRR activities at the global level were coordinated by the IUCN Ecosystem Management (CEM) Programme, and supported by the expertise of CEM members. These activities included coordination and communications about Eco-DRR across IUCN, collecting and disseminating lessons learned about projects and processes that integrate ecosystem management, sustainable livelihoods and disaster risk reduction at the regional level. CEM actively worked in partnership with interested and qualified CEM members and especially with the Partnership for Environment and Disaster Risk Reduction (PEDRR), a global alliance of 22 international organisations, academic institutions and NGOs. Collaborative efforts involving CEM members included a growing "community of practice" for educational and scientific exchanges in the field of ecosystem-based disaster risk reduction, participation in publications, periodic PEDRR workshops on Eco-DRR and periodic technical inputs to IUCN on specific requests for feedback.

CEM members contributed directly or indirectly to the first Massive Open Online Course (MOOC) on Eco-DRR, "Disasters and Ecosystems: Resilience in a Changing Climate", which was launched in January 2015 and relaunched on the Asian Development Preparedness Center (ADPC) platform in 2017/18. Overall the MOOC attracted over 17,000 participants.

How is the framework different from others

The Eco-DRR/CCA case study booklet is designed as a guided learning resource and supports a problem-based learning approach. The basic idea is that master's students of the Eco-DRR course can work independently on the provided case studies and exercises, but the booklet can also be used as a free standing publication. The case study exercises are recommended to make the students apply the knowledge gained throughout lectures and to get to know ecosystem-based adaptation in different geographical regions and ecozones. They also recommend to include the case studies and respective exercises throughout teaching the Eco-DRR module, preferably after having taught the first block or more to equip the students with some applied knowledge on the topic.

Critique of the framework

This framework is used as a learning resource rather than one for research purposes.

2.12 Post-2020 Global Biodiversity Framework

Despite the commitments made by governments in 2010 to take effective and urgent action to halt the loss of biodiversity to ensure resilient ecosystems by 2020, much remains to be done still. As the United Nations Decade on Biodiversity 2011-2020 comes to an end, the development of what needs to be an ambitious new global biodiversity framework is in the process of being developed.

The process adopted by Parties to develop the post-2020 global biodiversity framework contains a set of principles to guide its implementation, an organization of work and sets out a comprehensive consultation process, including provisions for global, regional and thematic consultation meetings.

The post-2020 global biodiversity framework aims to do the following:

- Avoid duplication and enhance complementarity with existing frameworks, in particular the 2030 Agenda for Sustainable Development. It is essential that the biodiversity framework focusses on effectively addressing threats to biodiversity as well as gaps that might exist in the SDGs – for instance on the interlinkages of biodiversity and human health.
- Be structured to reflect the pathway from where we are now to the changes we'd like to see in 2050. Action targets must be underpinned by a theory of change reflecting a clear line-of-sight from now until attainment of the Vision.
- Have focused, concrete and measurable Action Targets, so that their implementation and impacts can be monitored and assessed.
- Reflect the objectives of the Convention on Biological Diversity as well as the three components of biodiversity (species, ecosystems and genes) in coherent specific outcome goals.
- Be a truly global framework, clearly speaking to the other Rio and biodiversity-related conventions as well as to those agreements that cover issues related to biodiversity. Synergies are essential.
- Integrate Nature-based Solutions to safeguard and maintain ecosystems. These are vital for food and water supply, protection against natural disasters and provision of goods and services which are essential for human well-being.
- Embrace all voices: indigenous peoples and local communities, regional and city governments, the private sector, NGOs, women, youth and society at large must be not only invited to the debate but the framework should also incentivise their explicit contributions towards the global goals.

Critique of the framework
It will be important for the RECONECT project to monitor and review the development of the GBD framework to avoid any duplication.

2.13 NBS for Europe's Sustainable Development

Pursuing economic targets of job creation, growth, and innovation while tackling global environmental challenges, has long been seen as impossible. However, any long-term economic competitiveness and security depends on the extent to which natural resources are used sustainably. Therefore, the European Union is investing in nature-based solutions to achieve this double goal. The difference between the prevailing economic model and a sustainable resource use has long seemed insurmountable. While many debates are paralyzed or radicalized, nature-based solutions could offer a transition path with realistic, incremental steps toward a sustainable economy as envisaged by the EU Horizon 2020 vision.

The EU intends to invest substantially in nature-based solutions to tackle the socioeconomic challenges we face in the 21st century. The Horizon 2020 program foresees large-scale pilots and demonstration projects of tangible nature-based solutions, which should maintain or increase production of well-being and welfare at lower costs, and offer potential for job-rich innovation. Concrete application of nature-based solutions in a research and innovation agenda requires a sharper definition of nature-based solutions, capitalizing on the accumulated knowledge on ecosystem services. In that sense, we define nature-based solutions as any transition to a use of ecosystem services with decreased input of non-renewable natural capital and increased investment in renewable natural processes.

Opportunities to promote nature-based solutions already exist for numerous ecosystem service applications (Figure 14). For the example of food production, nature-based use can be realized by (partial) replacement of fossil fuel and fertilizer input by natural processes and jobs. Innovations in agroecology and ecological intensification could increase productivity while delivering opportunities for skilled labour.

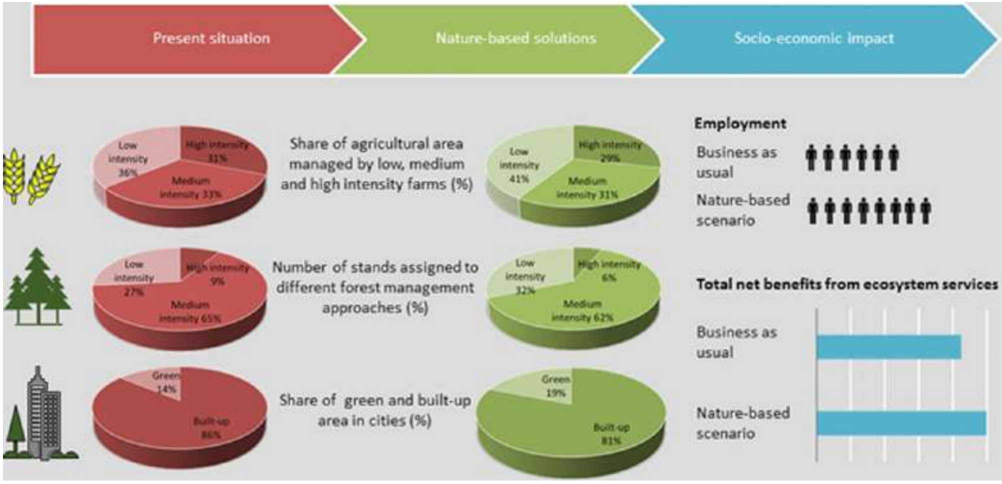


Figure 14 Potential of a nature-based economic scenario, increasing the nature-based use of farmland, forests, and urban areas creates additional jobs and increases total socioeconomic benefits of ecosystem services

Current conditions for the development, implementation, and evaluation of nature-based solutions seem favourable: the number of EU Member States which initiated a national ecosystem service assessment under Action 5 of the EU's Biodiversity Strategy to 2020 is growing, scientific knowledge is accumulating and societal awareness on ecosystem services and sustainability issues are rising. However, the seemingly insurmountable difference between the prevailing economic model and a strongly sustainable economy paralyzes and radicalizes debates. Here, nature-based solutions could realize a resource use transition in realistic incremental steps, if guided by a clear vision and permanent evaluation. Development and evaluation of nature-based solutions therefore spans three requirements: (1) decrease of fossil fuel input per produced unit, (2) lowering of systemic trade-offs and increasing synergies, and (3) increasing labour input and jobs.

Critique of the framework
Although this is not a framework, it will be important for the RECONECT project to monitor and review the development of NBS for Europe to ensure it will enhanced and address gaps.

2.14 Evaluation of the existing frameworks

This chapter has gathered the state-of-the-art frameworks regarding NBS to give an overview of what is currently on the market and the gaps of how they can be improved. Table 2 gives a synopsis and shows the research gap that the RECONECT framework will fill in. The main difference between RECONECT and other projects is that it works in the context of multiple hydro-meteorological risk reduction including floods, storm surges, landslides and droughts, and integrates monitoring and evaluation which is essential for developing the evidence base for NBS. A coordinated and common strategy is considered, which will strengthen the adoption of the approach at both a national and international scale.

Table 2 Evaluation of the existing frameworks & the positives of RECONECT

Framework	Evaluation/ Critique	How RECONECT is different
CORFU	- Scale problems arise in the development and application of DPSIR frameworks - Theoretical challenge: discretizing the different elements of the framework - Uses Flood Resilience Index (FRI) as a semi-quantitative measure of flood impact	- RECONECT will enables replication and up-scaling of NBS in different contexts - It will take into account the market dynamics, knowledge creation, institutional entrepreneurship and brokerage
PEARL	- Focuses on urban coastal areas - Flood Resilience Index (FRI) model & calculus has been developed into a useful tool - assigning of FRI values is dependent on assumptions and judgement	- The framework will advance the knowledge of NBS in the context of hydro-meteorological risk reduction focusing on floods, storm surges, landslides and droughts.
OPERAs/OPPLA	- As the framework is based on knowledge transfer between practical projects it will be challenging to apply in cases where that somehow differs in a way that makes it difficult to match it to previously explored cases	- RECONECT framework will enable cross-sectoral/ transdisciplinary analyses and evaluation to advance the knowledge of NBS
EU-CIRCLE	- Not an interactive & realtime framework	- RECONECT framework is “ready to use” and interactive - It provides realtime information
Safe & SuRe	- It is a diagram/concept. In order for the framework to be more useful to practitioners, it needs to be translated it into an interactive tool	- It will be an interactive & flexible tool, more than just a conceptual framework
EKLIPSE	- Requires further tailoring to a specific geographical and institutional context to ensure successful implementation	- It can be used at different scales and contexts
ThinkNature	- ThinkNature is a platform to help steer dialogue & interaction rather than a framework	- RECONECT is an interactive tool to integrate monitoring and evaluation that is essential for developing the evidence base for NBS.
Zurich Flood Resilience Measurement Tool	- Training is required to use the tool, which takes time and investment - Validation process takes time	- RECONECT will be intuative therefore easier to use wihout training

	and funding	
The World Bank	- It is starting point to build from, rather than a standalone framework	- RECONECT is a standalone framework that can be used at different scales and contexts
The Green Framework	- Several factors that can inhibit the full operationalization of the framework, among them data accessibility/ availability and uncertainties permeating all aspects of the decision-making process.	- The application of RECONECT does not require involvement of experts and stakeholders
ECO-DRR	- This framework is used as a learning resource rather than one that will be helpful for research purposes.	- RECONECT framework will enable cross-sectoral/ transdisciplinary analyses and research
Post-2020 Global Biodiversity Framework	- THE CBD is a set of guiding principles rather than a framework	- It will be important for the RECONECT project to monitor and review the development of the GBD framework to avoid any duplication
NBS for Europe's Sustainable Development	- This is the EU's overarching plan rather than a framework	- RECONECT needs to monitor the EU's plans for NBS to ensure the framework will be of use

3 RECONECT Eco-system-based approach

3.1 Introduction

The last chapter gave a strong overview of past NBS frameworks, information that will feed into RECONECT's ecosystem-based approach. The Framework developed within the FP7 Project PEARL (Pearl, 2016) has been taken as a basis and is currently further enhanced to address a range of large scale NBS (**Error! Reference source not found.**). As described above, the Pearl framework was focusing in the assessment of risk and impacts from floods and by doing that it was also assessment solutions which included NBS at urban scale. Therefore, the framework is taken as a basis but needs to be enhanced to accommodate more NBS solutions (i.e. large scale) and to accommodate and account for the benefits. This is where we see the potential for innovation and integration with other frameworks such the one developed in EKLIPSE.

RECONECT's holistic ecosystem-based framework expands the existing EKLIPSE impact evaluation framework for evaluation of large scale NBS in rural and natural areas. This has been done by grouping challenges into three categories being WATER, NATURE and PEOPLE and evaluating them in relation to spatial and temporal dimensions for the cases with and without consideration and deployment of NBS. Spatial dimension concerns evaluation in relation to the space required for ecosystem regeneration and hydro-meteorological risk reduction. Similarly, the temporal dimension concerns evaluation in relation to time required for ecosystem regeneration and hydro-meteorological risk reduction.

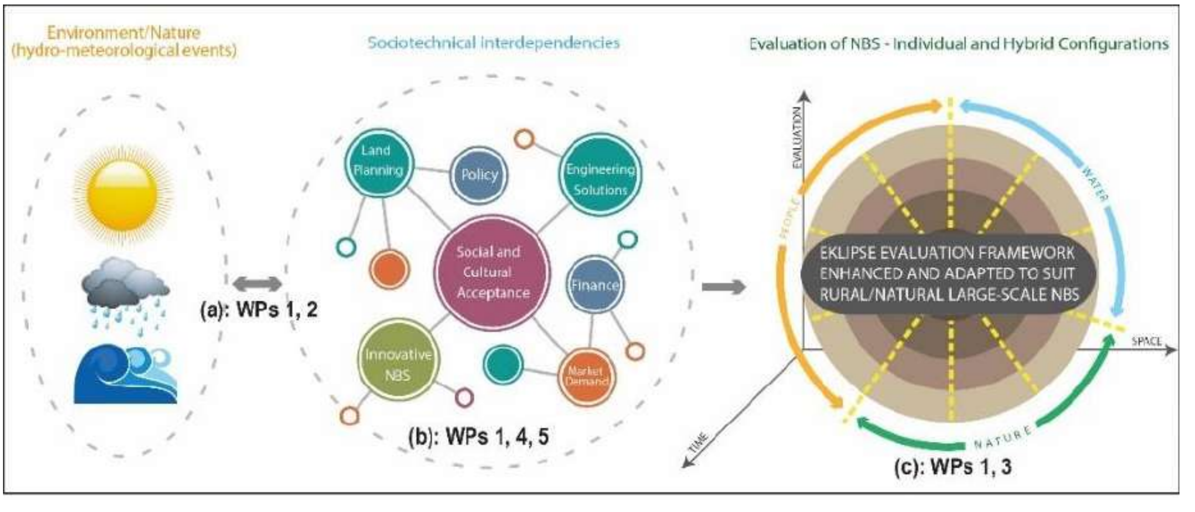
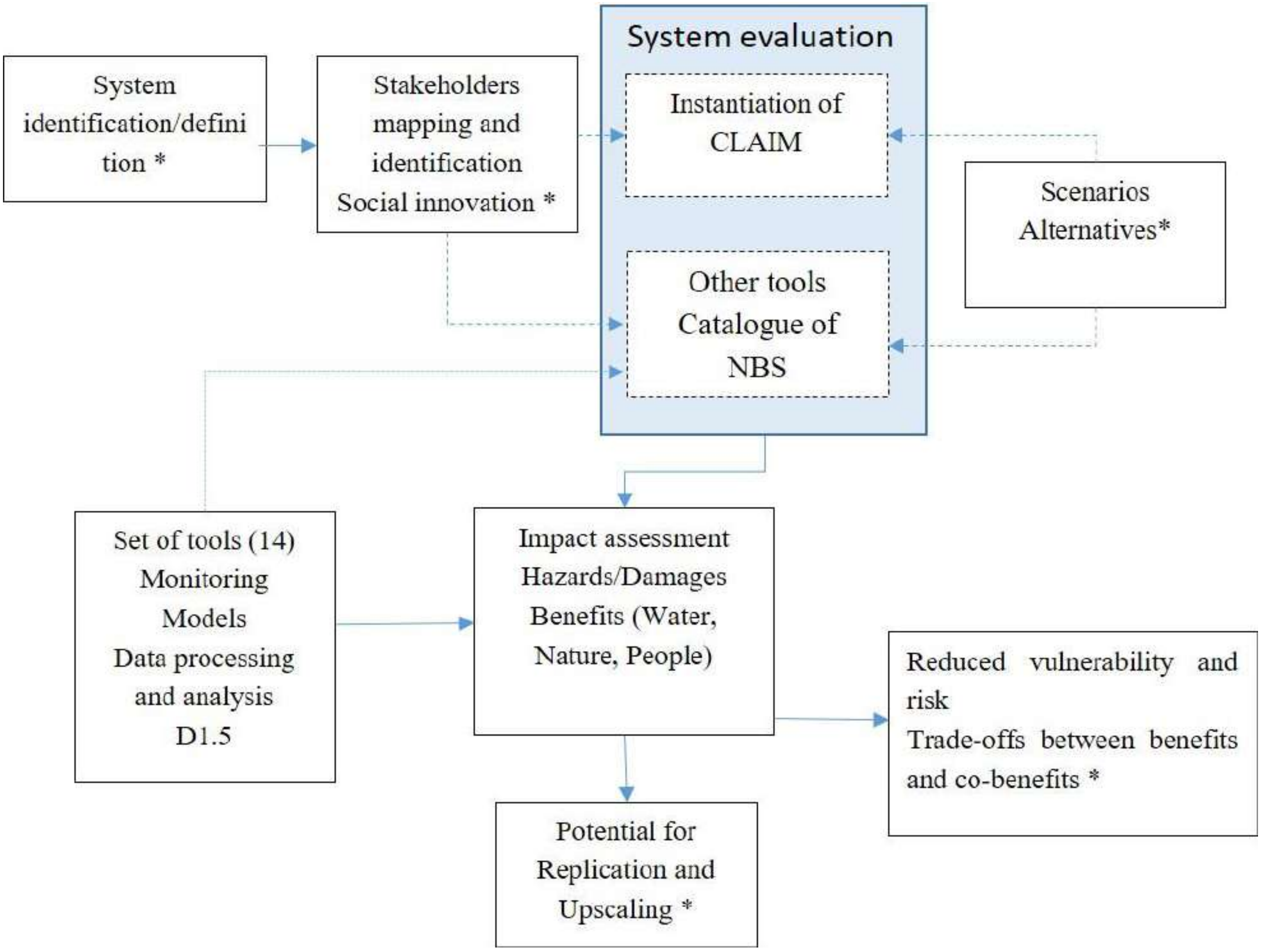


Figure 15 RECONECT Ecosystem-based framework

3.2 The RECONECT ecosystem-based framework

While the holistic risk assessment framework developed in PEARL was looking to the past flood incidents (using the FORIN approach) to understand the drivers and actors that contributed to formation and propagation of flood risk, RECONECT is looking at the present to identify barriers and opportunities for replication and upscaling of NBS systems. NBS systems which aim at increasing resilience and adaptation capacity to climate change. Moreover, PEARL did not consider Nature or the Environment directly in the analysis of risk as it was centered in the quantification of impacts or damages (direct and indirect) from flood events. RECONECT goes beyond this by explicitly considering Nature in the analysis and the quantification of benefits not only from nature to people (ecosystem services, livelihoods and human well-being) but for Nature itself (negative environmental impacts and habitat(s) vulnerability). NBS are measures or human interventions with good intentions. However, due to several factors they can also generate undesired effects that propagate in the system at different scales (i.e. negative impacts for the environment) – some of them not well understood and need to be further researched.

For the assessment of benefits, RECONECT goes beyond PEARL by incorporating the EKLIPSE categorization of benefit assessment. Benefits are classified for WATER, NATURE and PEOPLE. The evaluation of benefits is done in relation to spatial and temporal dimensions for the cases with and without consideration and deployment of NBS (Demonstrators and Collaborators).



* inputs from stakeholders as part of the Co-creation process

Figure 16 RECONECT ecosystem-based framework

System identification

From the PEARL holistic risk assessment framework, the framework starts from the view that risk emerges (or co-evolves) from actions and interactions within and between human systems and the natural environment. The framework also considers that human systems are socio-technical systems that consist of a social system (actors, behaviour, institutional structures) and a technical system (urban infrastructure, drainage, flood defences, industrial networks, agricultural systems, nature-based solutions, etc.). These two co-evolve through decisions about the use of the natural and human system and its development, changing infrastructure, policy and regulation through strategic management and governance. This implies that risk (floods, landslides, others) but also benefits and co-benefits emerges from actions and interactions within and between human systems and the natural environment as it is conceptually presented in figure 16.

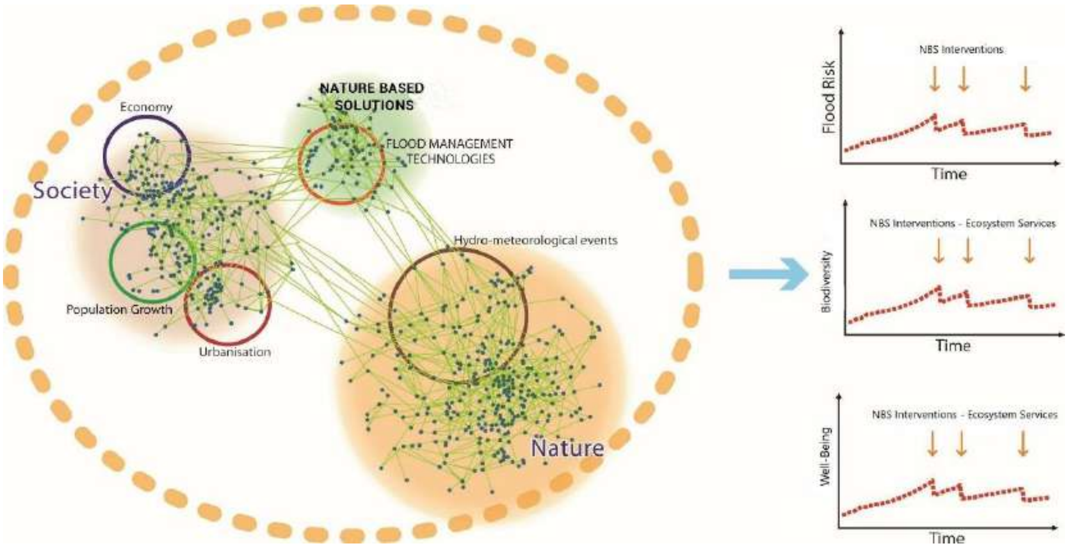


Figure 17. Formation and propagation of risk and benefits as a result of the coevolutionary nonlinear process between the ever changing social, technical and natural processes (dots illustrate sub-processes and activities, whereas lines illustrate their interactions) (source: adapted from Vojinovic, 2015)

It is becoming more evident nowadays that the traditional engineering approach for flood risk mitigation is far from optimal as it offers one main service or goal. While nature-based solutions can offer the same primary function (store or retain water, dampen flow peaks, infiltration, etc) and at the same time provide other functions that are important for water management and for the regulation of the water cycle. Therefore, the combination of measures at different scales is important to achieve several benefits.

As the current condition of any system is the outcome of complex interactions it is important to define the system and its scale. While the physical/natural system is relatively easy to define (by following the water movement) the social system boundaries are more challenging as there are complex relations and feedback mechanisms that are difficult to capture. The awareness of the system and its boundaries is important as it is the starting point of the holistic ecosystem framework.

Stakeholders mapping identification

The framework continues with the identification of key stakeholders using the methodology of social innovation proposed and developed in WP4. In RECONECT the local municipality where the NBS will take place is also a partner and therefore the identification and analysis of stakeholder's role is done with their input. The use of participatory methods plays a role to guide the local partners and stakeholders to identify existing barriers and mechanisms to overcome them (enablers). As it has been presented in figure 15, social innovation is essential in the application of the framework as it informs or provide inputs in several steps.

System Evaluation

In RECONECT mapping the stakeholder's, their roles and interactions can provide the input to the formalization of the MAIA meta-model. The MAIA framework generates the rules and behaviour for the agent-based model that was developed as part of PEARL which is called CLAIM. CLAIM is described in more detail in deliverable 1.6.

CLAIM provides the backbone to define the Agent attributes, relations among the Agents and Agent actions and interactions, thus the agent-based model can be formalised. After that, different initial conditions and/or scenarios can be assessed to quantify Impacts and benefits. As CLAIM was developed as part of PEARL it needs to be enhanced to incorporate the assessment of benefits, co-benefits and ecosystem services.

In case there is not enough information, data or resources to instantiate CLAIM, the evaluation of the system can be done with other tools (modelling tools, monitoring information, catalogue of NBS, etc) as well. Several WPs are developing or enhancing tools that can contribute to this step. Those tools will be described in deliverable 1.5 and annex A presents a brief summary.

Scenarios

Scenario analysis is performed to study the effect of possible changes to climate, land use and population dynamics which cannot be controlled by local planning entities. On the other hand, alternatives analysis will be carried out to identify desired and undesired implications of directives (for example EU Floods Directive), regional or country wise policies, plans and decisions made in the case study areas, and their amendments before testing and implementing them on the actual system, which is mainly the case for the collaborators.

The differences and variety of the case study areas in terms geographical position, climate, cultural and socio-economic conditions, highly affect the dynamics of the urban development, hence, how benefits are perceived and prioritized by local authorities and local citizens will be different. In RECONECT the scenarios are define by the local partners in each study area.

3.3 Toolbox

The assessment of impacts and benefits in each case study depends on the information available and which tools can be applied in each of them. In RECONECT, there are several tools being developed. Tools being developed as part of RECONECT that support the ecosystem based framework in several steps and in the ecosystem services analysis and assessment of benefits and co-benefits. These can be listed in Annex A and the set of tools are described in Deliverable 1.5.

Impact Assessment, Benefits and Co-Benefits

For the assessment of benefits RECONECT has different categories of case studies. The demonstration cases aim to provide the evidence of the effectiveness of the NBS for the three categories (Water, Nature, People). Here the monitoring plans in each case study, the smart online platform and the deployment of different sensors plays a central role in documenting what is happening once an NBS is introduce on the physical/natural environment. A set of tools is being developed or upgraded in reconnect to support this task such as: Indicators catalogue, etc

The collaborators provide the scene for replication and upscaling of NBS. The framework considers the use of tools to estimate the benefits or develop methodologies to help transfer the quantification of benefits (Models) from demo cases. This with the aim of aid decision making and understanding of the multi functionality and maximization of benefits in the collaborators study areas.

3.4 The Framework Output

Once the application of the framework has been done in the case studies, we foresee the output of the framework in two different ways. On one side, the assessment of NBS implementation can be realised or visualize by a map depicting the spatial position of the measure and the spatial distribution of benefits and co-benefits. The other output can display the replicability potential of NBS in the study area.

1. *Reduced vulnerability and risk*

   Visualization map depicting the spatial position of the measure and the spatial distribution of benefits and co-benefits. For example, a residual flood risk map, flood protected/enhanced area map, etc.

2. *Replicability*

   A map showing the potential to extend the NBS approach to other areas in the basin of the study area. The map with NBS measures to resolve similar issues in the catchment area or regional area can guide the scalability of the NBS approach and the development of business models being done in wp5.

4 Conclusions

RECONECT aims to rapidly enhance the European reference framework on NBS for hydro-meteorological risk reduction by demonstrating, referencing, upscaling and exploiting large-scale NBS in rural and natural areas. In an era of Europe’s natural capital being under increased cumulative pressure, RECONECT will stimulate a new culture of co-creation of ‘land use planning’ that links the reduction of hydro-meteorological risk with local and regional development objectives in a sustainable and financially viable way.

Through this review, we demonstrate how RECONECT combines the strength of existing conceptual frameworks in multiple ways to enable cross-sectoral/ transdisciplinary analyses at different scales and contexts. RECONECT will build upon the PEARL framework which has been successfully applied in several case studies in Europe and outside, while the evaluation part of the framework will integrate the EKLIPSE approach to suit large-scale NBS for rural and natural areas.

RECONECT is an ecosystem-based framework. In addition to PEARL, RECONECT is looking at present flood incidents to identify barriers and opportunities for replication and upscaling of NBS systems. NBS systems which aim at increasing resilience and adaptation capacity to climate change. RECONECT will consider Nature in the analysis and the quantification of benefits not only from nature to people (ecosystem services, livelihoods and human well-being) but for Nature itself (negative environmental impacts and habitat(s) vulnerability). Further, RECONECT goes beyond PEARL by incorporating the EKLIPSE categorization of benefit assessment. Benefits are classified for Water, Nature and People. The evaluation of benefits is done in relation to spatial and temporal dimensions for the cases with and without consideration and deployment of NBS (Demonstrators and Collaborators).

The RECONECT frameworks starts from the view that risk emerges (or co-evolves) from actions and interactions within and between human systems and the natural environment. The framework also considers that human systems are socio-technical systems that consist of a social system (actors, behaviour, institutional structures) and a technical system (urban infrastructure, drainage, flood defences, industrial networks, agricultural systems, nature-based solutions, etc.). These two co-evolve through decisions about the use of the natural and human system and its development, changing infrastructure, policy and regulation through strategic management and governance.

As the current condition of any system is the outcome of complex interactions it is important to define the system and its scale. While the physical/natural system is relatively easy to define (by following the water movement) the social system boundaries are more challenging as there are complex relations and feedback mechanisms that are difficult to capture. The awareness of the system and its boundaries is important as it is the starting point of the holistic ecosystem framework.

The differences and variety of the case study areas in terms geographical position, climate, cultural and socio-economic conditions, highly affect the dynamics of the urban development, hence, how benefits are perceived and prioritized by local authorities and local citizens will be different. In RECONECT the scenarios are defined by the local partners in each study area. Once the application of the framework has been done in the case studies, we foresee the output of the framework in two different ways. On one side, the assessment of NBS implementation can be realised or visualize by a map depicting the spatial position of the measure and the spatial distribution of benefits and co-benefits

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Annex A. Tool kit Impacts

Social and Economic impacts of tools

- NBS impact tool for screening (DTU) TRL 5 TRL 7: The tool will be expanded with social and economic indicators and will be enhanced with an API for integration with the ICT
- QuantiAmenity (DTU) TRL 5 TRL 7: Open source GIS-tool for quantitative (spatial) assessment of amenity / well-being / ecosystem services based on non-market valuation pricing methods
- Risk Evolution Tool (IHEDelft) TRL 4 TRL 6: ABM tool for policy impact analysis with some functionalities to explore land use policy changes over time and its impact on flood risk
- Risk Mapping Tool (IHEDelft) TRL 4 TRL 7: Mapping tool for risk visualization (direct and indirect impacts) and planning.

Biodiversity / Testing impact of solutions

- eDNA (e-DNA monitoring) (Amphi) TRL 5 TRL 7 Web based enhancements to support monitoring of species associated with inland water and monitoring of endangered freshwater biodiversity using environmental DNA. New DNA sequencing on target species and eDNA sampling will have been tested in operational environment.

- Data sensor combination TRL 7 TRL 9: The combination between spaceborne data sensors and LiDAR DTM that will be enhanced in RECONECT will allow a better classification of the water surface extracted from the radar image and is expected to be fully operational.
- INSAR (Ramboll) TRL 7 TRL 9: InSAR will be fully operational and technology will be tested before and after implementation of NBS to observe the influence of these NBS on the terrain subsidence and land movements in the demonstration area.
- KALYPSO modelling and planning tool (TUHH) TRL 6 TRL 8: Existing operational tool will be enhanced for NBS applications and linked to RECONECT platform for master planning

Mapping effects of Climate Change

- Tool (TAUW) TRL 6 TRP 8 The model is completed and tested on the Ijssel case.
- Vegetation scan and calibrated modelling tool (TAUW) TRL 5 TRL 7: Incorporate algorithms for new and improved nature based (infrared) scans with Normalized Difference Vegetation Index (NDVI) for a modelling processes calibrated with Interferometric synthetic aperture radar (InSAR).
- Climate Change Impact alignment tool (DTU) TRL 5 TRL 7: Development of open source code for provision of aligned climate data for present and future climate based on the CORDEX and CMIP5 databases

Hydroinformatics

- HydroNET tool – (Hydrologic HR) TRL 5 TRL 7: HydroNET catalog of services will be enhanced with API communication toolset (time series and gridded data)
- HydroWatch tool – (Hydrologic HR) TRL 5 TRL 7: HydroWatch tool will be enhanced for multiple hydrologic variable monitoring to automatically detect, visualise and analyse hazardous events

Optimisation modelling tools

- CADDIES (UNEXE) TRL 8 TRL 9 A fast flood modelling tool, using an Artificial Intelligence technique (Cellular Automata). Heat Stress Modelling
- Model-based optimisation tools (UIHE and UNEXE) TRL 5 TRL 8: Existing functionalities to incorporate optimisation between green and grey infrastructure.
- Hydro-meteorological processing and dissemination platform (HYDS) TRL 7 TRL 9: Platform used for flood forecasting and Early Warning Systems applications. Will be enhanced to manage, process and disseminate other
- NBS-related information and data sources.
- Selection and positioning tool for NBS measures (IHE-Delft) TRL 4 TRL 7: DSS tool for selection and optimization of NBS measures at large scale.

Industrial cloud solutions for visualitzation of benefits and impacts.

- ICT platform (InterAct) TRL 8: TRL 9: Integration of different data streams and existing modelling services into the InterAct platform.

- TeleControlNet (InterAct) TRL 7 TRL 8: Managed services for monitoring and control of remote monitoring networks and measuring stations around the world
- Smart Sensor Kit (InterAct) TRL 6. TRL 9: Intelligent devices (add-ons) for connecting any type of sensor or technical installation to TeleControlNet using industrial Internet of Things
- Crowdsourcing mobile app WaterDetective – (Hydrologic HR) TRL 5 TRL 7: Existing operational app will be used to implement the RECONECT platform.