# Natural assurance schemes: moving earlier in the risk management cycle with nature based solutions and strategies

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## Introduction

In Greek mythology, the Naiads (Naϊαδες) are the spirits of small brooks, fountains, wells, springs, and other freshwater bodies. Different to the river gods, the naiads were smaller, more adaptable in different forms. The NAIAD project presented in this article takes inspiration from this freshwater ancient wisdom to look at disasters. Particularly, considering the prevention and reduction part of the disaster risk management cycle by looking at nature, not just as part of the problem but as part of the solution.

The ancient Greeks thought of the world's waters as all one system, which percolated in from the sea in deep cavernous spaces within the earth, to the sea. This systemic view on risks is very much at the heart of NAIAD. The approach is also focused on this versatility afforded by nature and the interest in understanding the protective role of nature-based solutions (NBS) in buffering risks posed by natural hazards through the development of natural assurance schemes.

The main objective of the EU funded NAIAD project is to develop a better conceptual framing and understanding on the insurance and assurance value of nature to help address and prevent damages from natural hazards by bringing nature into the equation not just as a problem but as a solution. NAIAD is a project funded by the European Commission under the program Horizon 2020 running over 3 and a half years (2017-2020) with a budget of 5 million euros. This short article will present the main results from developing this conceptual frame and the operationalisation of the assurance value of ecosystems in disaster risk management, putting a special emphasis on prevention and avoided damages through nature investments.

Flood events have huge impacts worldwide. In Europe, numerous examples can be found from the past decade, that cause extensive damages (e.g., cloudburst in Copenhagen, the Elbe floods in 2002, 2013, Danube floods in 2006, Alpes Maritimes floods in 2015, Lez floods in 2014, Seine floods in 2016 and 2018, etc.). Around 90 % of natural hazards are water-related and these are likely to become more frequent and more severe due to climate change. For example, climate change is projected to increase damages up to 50 % by 2050 in France (Moncoulon et al.

2018). The *Caisse Centrale de Réassurance* (CCR) has estimated that mean annual insured of flood hazards will be up to 38 %, respectively 50 % related to runoff hazard and 34 % to river flooding.

Climate change is already resulting in rising levels of risk posed by natural disasters and the related costs these create (Lawrynuik 2019). The total reported losses caused by natural disasters over the period 1980-2014 reached approximatively 453 billion euros in Europe, with only 45 % of these economic losses insured (EEA, 2019). Therefore the (re)insurance industry is a critical actor to engage and to understand its current and potential contributions to the assessment of what we have called Natural Assurance Schemes (NAS). The insurance sector has the opportunity to play different roles to engage loss prevention through NBS (Marchal et al. 2019). The use of catastrophe models developed by or for (re)insurance companies are tailored to assess the quantification of the avoided damage provided by preventive measures. It could be performed in addition of co-benefits assessment supported by both research institutions and specialist organisations with knowledge on the role of green infrastructure in delivering resilience dividends.

# 1. The main aim and strategic goals

The main objective of the EU funded NAIAD project[1] is to develop a better conceptual framing and understanding on the insurance and assurance value of nature to help address and prevent damages from natural hazards by bringing nature into the equation not just as a problem but as a solution. NAIAD is a project funded by the European Commission under the program Horizon 2020 running over 3 and a half years (2017-2020) with a budget of 5 million euros. This short article will present the main results from developing this conceptual frame and the operationalisation of the assurance value of ecosystems in disaster risk management, putting a special emphasis on prevention and avoided damages through nature investments.

The project is coordinated by the Duero River Basin Authority. It has brought together a consortium of 23 partners from 11 European countries including 3 universities and education research institutes, 8 research centres, 4 small/medium size enterprises, 3 public bodies with competences in applied research, 2 public bodies with key competencies in management (the city of Copenhagen and the Duero Basin Authority), 2 NGOs, and the French public reinsurance company CCR.

The project´s purpose is fully aligned with the upcoming draft EU adaptation strategy “Adapting to climate change”[2] and EU Taxonomy on Sustainable finance including 68 activities on climate change adaptation[3] published in March 2020, contributing to make our societies (and our activities) more climate resilient. NAIAD starts from the assumption that healthy and fully functioning ecosystems can significantly contribute to mitigate extreme water risks and increase the resilience of society in a context of climate change.

To demonstrate the role ecosystems can play in reducing water related risks (e.g. frequent and extreme events) the project has developed what we have termed “Natural Assurance Schemes” (NAS). The project included 9 demonstration sites across Europe spanning different scales: from large scale like the Thames basin (UK), the Lower Danube (Rumania) or the Medina aquifer (Spain), to middle scale like the Lez, Brague (France) and Glinščica (Slovenia) catchments, to city scale of Copenhagen (Denmark), Rotterdam (Netherlands) and Lodz (Poland). These sites face different hazards, the majority focused on floods both pluvial and fluvial (Danube, Glinščica, Lez and Brague), whereas the Medina aquifer in Spain focused on droughts. These different sizes range from the smallest, a neighbourhood in the city of Rotterdam, to the largest one, the lower Danube, with a stretch 250 kilometres long. These cover urban,

(1) www.naiad2020.eu
(2) An open public consultation is open until 20 August to gather stakeholder views and feedback for the design of the new strategy. A blueprint accompanies the consultation in order to provide context, indicate possible directions of development and stimulate the debate.
(3) https://ec.europa.eu/knowledge4policy/publication/sustainable-finance-teg-final-report-eu-taxonomy_en

peri-urban and rural environments, including cities, basins and aquifers as units of analysis. Most importantly, in relation to the design of natural assurance schemes, our demos also cover cases that started from scratch like in Romania or Slovenia, to cases that were fully implemented and where attention was given, instead to developing robust monitoring and evaluation frameworks, to monitor the effectiveness of measures taken for e.g. natural flood management in the Lower Thames.

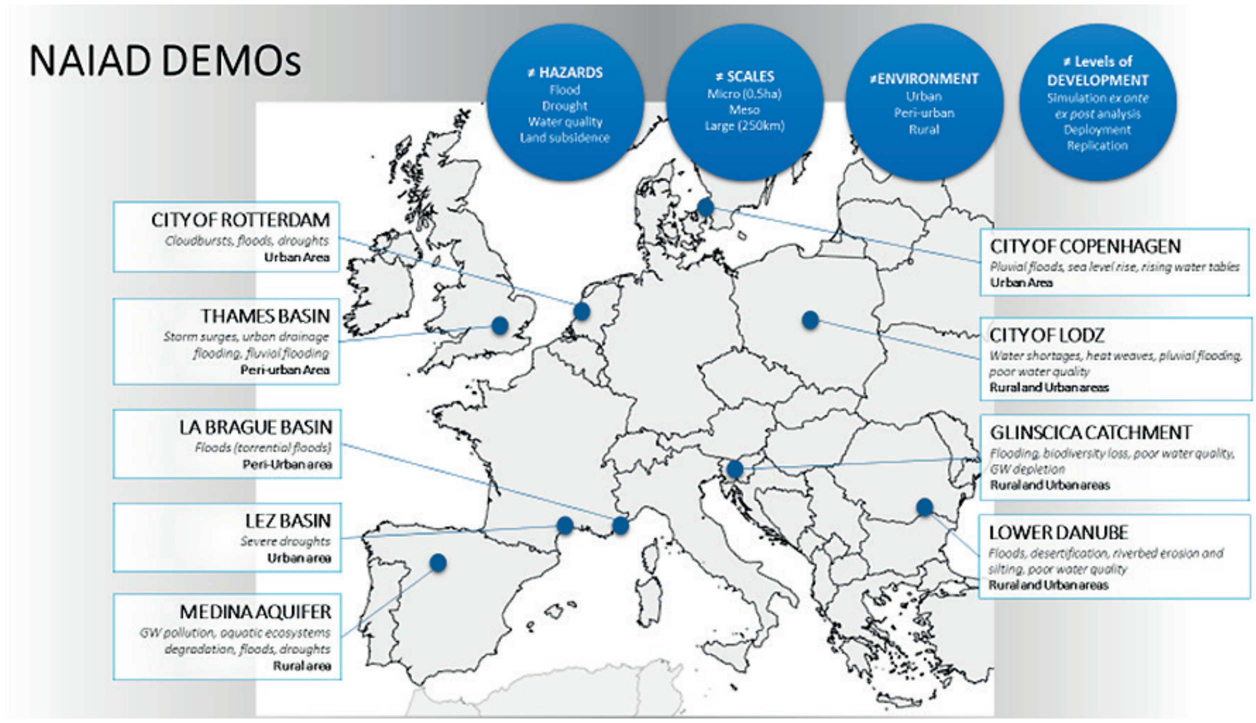


Figure 1: NAIAD Demo location and main focus.

With this, the project aims to propose new concepts and approaches to enlarge the portfolio of available solutions. Conventional infrastructural measures are expensive - the investment needed in water infrastructure over the next fifteen years has been estimated at 22 trillion dollars, which is more than half of the total expected infrastructure investment demand (USD 41 trillion) (WEF, 2019).

To achieve the central aim of demonstrating the assurance value of ecosystems, three strategic goals were identified:

- To develop biophysical, social, and economic assessment tools and methods to provide relevant decision and planning support frameworks for identifying, co-designing and simulating NBS strategies for specific locations.
- Testing these tools and methods at the 9 demonstration sites/real environments, providing evidence on the value of ecosystems for DRR and Ecosystem based adaptation.
- Policy uptake and exploitation of the results of the project, by engaging different decision makers and policy makers at different levels. This will help to validate the results and identify next steps towards further implementation, as well as knowledge gaps that merit further research and development.

The paper -after a brief discussion on the main conceptual frame- will now present in sequence over the coming sections the results for these three strategic goals.

# 2. The conceptual frame: natural assurance schemes for the uptake of NBS for ecoDRR and ecosystem-based adaptation

There is a realisation on the relevance to move earlier into the risk management cycle while helping to adapt to climate change and Disaster Risk Reduction (DRR). Here the role of mainstreaming and normalizing NBS as an alternative or complement to conventional grey solutions to prevent or reduce risks. Thus, increase resilience and response capacity to water related hazards.

The interest in Nature-based Solutions (NBS) has significantly increased over recent years. The European Commission (2015) defines nature-based solutions as solutions that are inspired and supported by nature, which are cost-effective, and simultaneously provide environmental, social and economic benefits and help build resilience. NAIAD focused particularly on how NBS can help society become better prepared and more resilient to natural hazards, looking at the value from prevention in terms of avoided damages and other benefits, what we have termed "the assurance value". NBS offer different functions, from conserving or rehabilitating natural ecosystems, the enhancement or creation of natural processes in modified or artificial ecosystems, and can be applied from the micro- (e.g. a small wetland) or macro- (e.g. flood plain restoration) scales (WWAP/UN-Water, 2018).

We have made a conceptual difference starting from the fact that the insurance value can have several interpretations or components depending on the value dimension considered, and more specifically who/what is insured: the ecosystem or the humans? and the risk considered. Thus the difference between nature insurance, when e.g. a mangrove is itself insured for the protective value as a financial product for risk transfer versus the "assurance value of nature", i.e. the protective functions from nature itself, whether insured or not[4]. Theoretical aspects of the insurance value of ecosystems have already been covered in the literature (Pascual et al., 2010; Baümgartner & Strunz, 2014), yet there is a lack of operational methods building on these theories that enable cities or basins to assess strategies including NBS against grey strategies or status quo.

A series of the tools and method has been developed and will be briefly presented in this paper[5]. These schemes are designed to capture the natural Assurance Value in the reduction of risks that natural systems can secure (Denjean et al., 2018, Marchal et al. 2019[6]). This includes the full range of economic, financial, regulatory, institutional and stakeholder mechanisms that regulate a sustainable and equitable flow of primary and co-benefits between NBS and society. What has developed is a structured, modular approach with the development of (1) methodologies to assess and value NBS biophysically, socially and economically, (2) the notion of risk perception and (3) experiences with implementation of NBS in the NAIAD case studies have furthered this definition of NAS to operationalize all elements of the enabling environment.

# 3. Biophysical, social, and economic assessment tools and methods

The starting point for all of our demos was the biophysical assessment of their risks. Several tools and methods have been developed that can do this and that are suitable for the different scales.

## 3.1. Biophysical tools and methods at different scales- the Eco:Actuary tool kit and the FEV tool

For example, the Eco:Actuary Toolkit was developed for the larger scale demos. This toolkit consists of three elements. First, the Eco:Actuary Decision Support Tool is a global spatial catastrophe model which maps flood risk and exposure

(4) Please check our infograms on the different natural hazard insurance business models at
http://naiad2020.eu/wp-content/uploads/2019/03/Newsletter05.pdf
(5) For more details into these tools and methods please visit http://naiad2020.eu/media-center/resources/
(6) http://naiad2020.eu/wp-content/uploads/2018/10/Newsletter02.pdf

under current climate and Intergovernmental Panel on Climate Change scenarios as well as loss mitigation and avoided losses by use of natural flood management (NFM) interventions. Second, the //Smart:River Freestations (see Fig 2) which links real time low cost DIY IoT-linked monitoring (FreeStations) to understand NFM contribution to flood risk reduction. Finally the Eco:Actuary Investment Planner, a simple, online spreadsheet based tool that allows assessment of the scale and approximate cost of different types of interventions required to achieve a specified flood reduction goal. The relevance to the insurance industry is that natural catastrophe models are commonly used tools in the insurance industry. They help insurers assess the severity of risk and thus set appropriate insurance premiums. The Eco:Actuary Toolkit includes a catastrophe model with a range of scenario options to explore the effects of climate change and flood mitigation options such as changes to land use, land management practices and natural flood management interventions.


Figure 2: Image of a //Smart:River FreeStation: using IoT for flood prevention.

In some countries the insurance industry and national government are closely aligned with increased awareness in the insurance industry to help reduce flood risk. That is how insurance and mitigation interact. By investing in mitigation interventions, insurance companies could save on compensation in the long term. //Smart uses networks of low cost IoT connected water level loggers can be used for (a) understanding the effectiveness of flood mitigation measures, (b) monitoring peak flows during flood events as either an early warning system or a real time data feed for the development of parametric insurance, in which pay-out is made with a loss adjuster i.e. on the basis of flood depth.

Other tools and methods suitable for smaller scales were also developed like the «Flood-Excess-Volume» method and tool (FEV), which provides a rapid assessment on the cost-efficacy of flood-mitigation strategies: In order to optimise the tailoring of generic flood-mitigation strategies to specific river-catchment scenarios, an algorithmic protocol, or «tool», is required that can assess a wide range of measures in a clear, quantifiable, educational and user-friendly fashion that is accessible to a wide audience. Through a collaboration between the University of Leeds, UK, and the EU-funded NAIAD project, precisely such a tool has been developed and tested on data accrued from real flood events occurring in the UK, France and Slovenia (for more details please see: Bokhove et al., 2019, 2020) (for further details see the insert about the Flood-Excess-Volume tool).

**THE “FLOOD-EXCESS-VOLUME” TOOL**

By Piton, G., Tacnet, J.M., Bohove, O. y Kelmanson, L.A.

Optimally, the tool should overcome two main obstacles. First, it should identify and utilise indicators of flood severity that are quantifiable, easy to understand and to measure; this makes the tool objective, transparent to scrutiny and user-friendly; crucially, it also admits repeatability and flexibility. Second, it should be capable of rapidly verifying whether a given ensemble of protection measures are sufficient to mitigate against an *a priori*-specified degree of flood severity.

The input data required by the tool are the project-flood hydrograph (i.e. the water-discharge time series), the water stage-discharge curve (i.e. the channel capacity) and the threshold level (i.e. the discharge above which severe flooding occurs).Using this information, the tool first computes the Flood-Excess-Volume (FEV), i.e., the amount of water that cannot be contained by existing flood defences for a given flood (see Figure Ia). Second, it computes the size of a virtual lake, 2m deep and square in shape, that could retain the computed FEV (see Figure Ib). This visualisation –of a virtual square lake of human-scale depth– helps stakeholders to assimilate in a meaningful way the excess of water that must be contained to offer flood protection. Importantly, it is to be contrasted with the somewhat less-intuitive visualisation of the actual catchment topography. The simplified visualisation deliberately allows, and hence empowers, a wide and non-expert audience to comprehend the magnitude of the amount of water that needs to be contained to mitigate against flooding.

The last step is to split the lake into constituent components, each of which is associated with a specific flood-protection measure (see Figure Ic) such as restored wetlands, leaky dams, flood-plain reconnection, flood-retention dams and giving-room-to-the-river, etc.

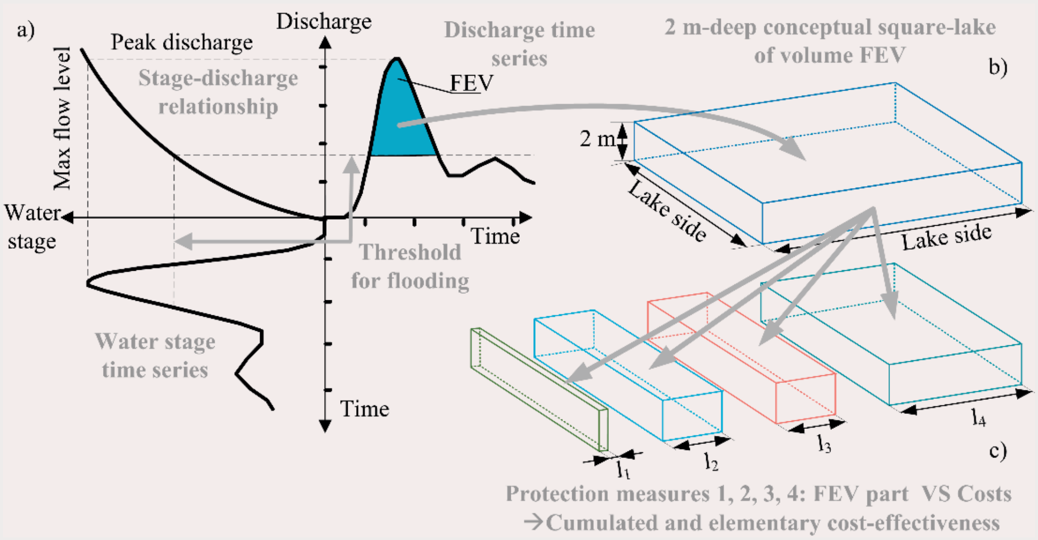


Figure I: The three stages of a FEV analysis.
(a) Three-panel graph highlighting FEV: (bottom-left) river-level time series, (top-left) stage-discharge relationship and (top-right) discharge data, in which FEV is the blue area, i.e., the peak volume above a chosen threshold discharge. (b) FEV square-lake representation as a 2m-deep square lake facilitates visualisation of FEV magnitude, or severity. (c) FEV-effectiveness assessment computed for each measure, of various colour, as equivalent FEV fraction (adapted from Bokhove et al., 2019).

## 3.2. Participatory modelling- turning barriers into opportunities for collaboration and collective action

The second type of method focused on the social assessment based on a participatory modelling tool for NBS co-design. The method aimed at handling ambiguity in risk perception though inclusive and equitable engagement of the different stakeholders. The tool was mainly based on system thinking approach. That is, the developed model aimed at defining and analyzing the complex and non-linear causal connections, affecting the behavior of the system to be managed. The tool is based on the sequential implementation of different phases: i) individual risk perception elicitation and analysis; ii) development of the System Thinking-based model; iii) detection of the main barriers to NBS co-design and implementation; iv) trade-off analysis and conflicts identification. Specifically, the analysis carried out in phases i) and iii) allowed NAIAD to bring stakeholders and decision-makers in a participatory process which main scope is to co-design effective interventions for reducing the water-related risks and producing the expected co-benefits. The methods implemented in phase iv) were meant to enhance the equity of the NBS implementation process. Stakeholders were capable of recognizing their contributions in the model, developing a sense of ownership in the obtained results. The effectiveness of this approach to also develop indicators which are placed specific has now been developed for the Glinščica catchment (Santoro et al., 2019; Pagano et al. 2019), the Lower Danube (Giordano et al., 2020) and the Medina Aquifer (Giordano et al, 2020).

The Participatory Modelling approach adopted in many NAIAD demo sites contributed to engage different stakeholders in a NAS design process that was inclusive, legitimate and cooperative. This, in turn, contributes to enhance the NBS social acceptance. Specifically, the adopted method and accompanying modelling tool contributed to the inclusiveness and legitimacy of the participatory process by giving voice to the different point of views concerning the management of water-related risks. The tool aimed at enhancing the potential richness, diversity, and complexity of the collected knowledge, rather than searching consensus among participants. To this aim, the tool was based on individual cognitive models, representing the individual perceptions of the water-related risks to be dealt with, the main impacts at local level, and the main social issues that need to be addressed. The integration of the knowledge of the different stakeholders and the scientific knowledge allowed developing a model that was perceived as legitimate by the participants. They could recognize their contributions in the model, developing a sense of ownership toward it and the obtained results.

Concerning the cooperation issue, two key benefits were produced during the participatory modelling process. Firstly, the stakeholders' engagement for the model development contributed to build relationships among the stakeholders, and between them, the scientists, and the decision-makers. Secondly, the participatory modelling tool allowed unravelling the complex network of interactions taking place between the decision-actors involved in the NBS design and implementation. The results obtained in different demo sites showed that ineffective interaction networks represent a barrier to NBS implementation. Therefore, measures and actions are needed to enhance the cooperation among different institutional and non-institutional actors to effectively implement NBS.

Thus in parallel to the physical and socioeconomic evaluation carried out by the technical partners of the project, meetings were organized at the local level in the 9 demonstration sites. During these meetings, in addition to informing local stakeholders about the project's objectives, public participation sessions were held where the participants (project stakeholders) took part in the achievement of various NAIAD tasks in collaboration with the technical partners (see Fig 3).

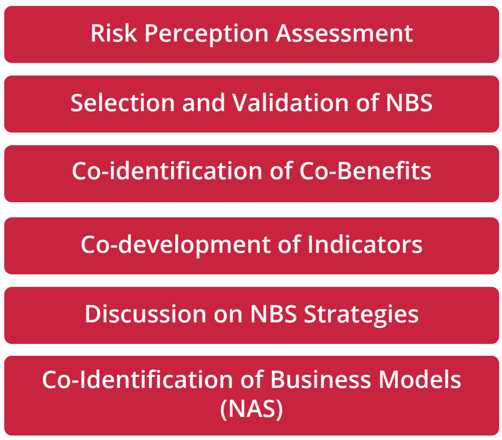


Figure 3: Co-design process.

## 3.3. Integrated cost-benefit analysis of Nature based strategies

The economic assessment framework, which is one of the pivotal elements in the development of natural assurance schemes, was developed with accompanying detailed guidelines aiming to compare the main costs and benefits generated by NBS for water related risks. We particularly developed methods for the monetary assessment of different costs and benefits:

- Costs of implementation: those that are necessary for the implementation and maintenance of the NBS included in the NBS strategies.

- Opportunity costs: related to the loss of benefits of areas that are taken out of production, or land that is used for NBS and that cannot be used for other profitable purposes such as the construction of building. These are the indirect costs of the NBS strategies.
- Avoided damages: the damages avoided due to the reduction of water risks generated by NBS strategies. Avoided costs are the primary benefit generated by NBS strategies aiming at reducing water risks.
- Co-benefits: the additional environmental, economic, and social benefits generated by NBS. utilizados para albergar SBN y que no pueden utilizarse para otros fines económicos como la edificación. Son costes indirectos de las estrategias de SBN.

The economic assessment subsequently compares these costs and benefits over the life-time of alternative projects, grey, hybrid and NBS, with a Cost-Benefit Analysis. Our results reveal that the cost of implementation of NBS is lower than the cost of grey solutions for the same level of reduction of water risks. This reinforces claims about the cost-effectiveness advantage of NBS and would urge decision makers to consider more systematically these solutions to address water risks. However, the economic benefits related to the reduction of flood damages are not sufficient to fully cover investment and maintenance costs. This problem may be a challenge to have these solutions funded by sectorial financing mechanisms focused on the reduction of water risks. Instead more comprehensive projects would tap into all the benefits.

Co-benefits (reduced air pollution, reduction of heat in cities, improved landscape, climate change mitigation…) and these represent the largest share of the value generated by NBS strategies. The co-benefits are needed for these solutions to be economically beneficial, while initially designed to reduce water risks. This multiplicity of benefits therefore requires project developers to look for and blend multiple sources of funding and financing. Enabling policies for NBS development would therefore require facilitating this process.

For the case of avoided damages, we relied on the expertise of CCR with their CAT Model. Modelling of overflow and runoff hazards is performed in the first unit; insured contracts geolocalized at the address level with information on the type of risk and insured value are available in the second unit; the last unit merges hazard to vulnerability with damage curves linking water height/water flow to destruction rate. Finally, it is possible to estimate the insured losses as consequences of a natural disaster (see the insert about CAT Models).

## LOSS DAMAGE ASSESSMENT AND USE OF CAT MODELS: LOSS PREVENTION THROUGH NBS

By Marchal, R. and Moncoulon, D.

The (re)insurance industry has an increased interest in assessing the effectiveness of preventive measures by using its expertise in modelling hazard and in loss damage assessment. Such a tool has been used and replicated in France within a collaboration between the French partners involved in the EU-funded NAIAD project.

Interest in understanding the protective role of nature-based solutions (NBS) in buffering risks posed by natural hazards is growing within the (re)insurance industry. The sector has different roles to engage loss prevention through NBS (Marchal et al. 2019). The use of catastrophe models developed by (re)insurance companies is tailored to assess the quantification of the avoided damage provided by preventive measures.

Caisse Centrale de Réassurance (CCR) French public reinsurance industry, along with French researchers from INRAE, BRGM and University of Nice implemented this framework during the NAIAD project, in order to increase knowledge on the role of NBS in loss prevention and support local decision-making process. The following paragraphs will focus on the methodology applied by CCR for modelling flood events by using its CAT model for assessing hazards and the avoided damage. The loss projections in a context of climate change has also been studied, based on a global climatic model linked with flood impact model (Moncoulon et al. 2018).

CCR is modelling some direct and tangible damage and hazards (floods, earthquakes, marine submersions etc.) within the frame of the French Natural Catastrophes Compensation Scheme. A CAT model is composed of a hazard, vulnerability, and damage units (Figure II). Modelling of overflow and runoff hazards is performed in the first unit; insured contracts geolocalized at the address level with information on the type of risk and insured value are available in the second unit; the last unit merges hazard to vulnerability with damage curves linking water height/water flow to destruction rate. Finally, it is possible to estimate the insured losses as consequences of a naturel disaster.

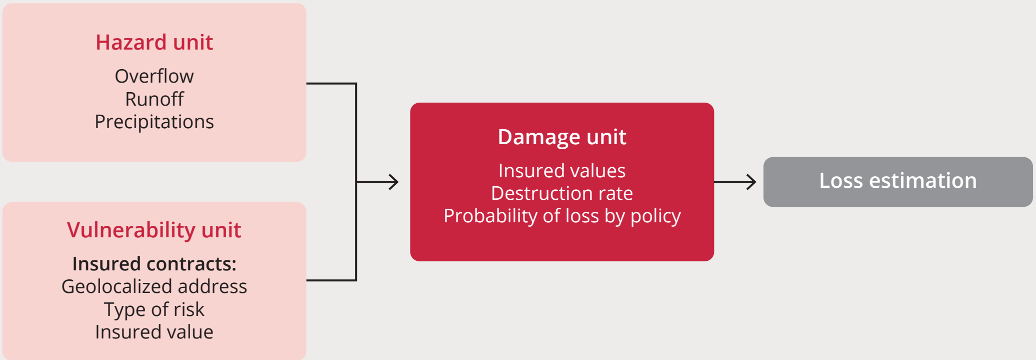


Figure II: Catastrophe model structure.

The first step in a Cat model is to run the hazard unit. The CCR overflow/runoff model is a 2-D distributed model at 25m-resolution calibrated at the watershed scale for the entire French territory (Moncoulon et al. 2014).

The model has been adapted to the French demonstrations sites at catchment scales and to the selected past flood events: a) Collecting local information especially on the land-use occupation; b) Adapting the digital terrain model slopes calculation to be tuned to take into account water height on each mesh in order to sprawls water along short watercourses. At catchment scale calculation duration are shorten than at the country scale.

Then, flood hazard modelling is validated by comparison with the local information collected during the disaster events (i.e., flood marks, flood extent). In parallel, information on the insured damage (claims) for the selected events are extracted from the insurance portfolio at the street center or address resolution level. The calibration of insured damage functions relies on the hazard and vulnerability units' outputs. Often there is no damage curves specifically representing runoff or overflow damages in the studied area. Such curves are used to obtain costs and probability of losses.

The damage unit is based on the damage function which is the correlation between hazard characteristics and observed damages. The observed damages are defined by the destruction rate (DR). The DR is obtained by dividing the number of claims by the insured value.

$$DR = \frac{Amount\ of\ claims}{Insured\ value}$$

The damage function is then: 〖DR〗 r= f($m^3$/s o m). The damage function could be fitted for different types of risks such as residential homeowners, commercial, industrial, or agricultural businesses.

Two curves are then calibrated: damage rate curve which is the average destruction rate per water flow/water height class, integrating the probability of losses; damage curve which is the average destruction rate per water flow/water height class with claims only.

The curves validation is done by comparing the real costs to the simulated ones at the flood event scale on the studied area. The damage functions calibrated on the studied disaster events and at the catchment scales are then used to estimate the avoided damage of NBS. Within the damage unit, a reduction rate of hazard intensity has been applied on the model to estimate the avoided damage. These hazard reduction scenarios have been chosen to estimate the avoided damages on a 10 to 50 % reduction range. The impact of NBS on the hazard reduction is depending on the NBS nature and flood event intensity. It will be estimated by experts on the hydrologic modelling within the project and afterwards.

An x % of hazard reduction provides an estimate of avoided damage in euros. For example, on the Lez catchment, based on the 2014 flood Cevenol events for residential homeowners, a reduction of 50 % of runoff hazard will reduce the damage to ~1.9 €M or by 40.45 %.

These damage functions can also be integrated to assess the insured losses on probabilistic hazard at current and future climate. The annual average insured losses in the catchment are based on the stochastic simulation of 400 years of climatic hourly rainfall from ARPEGE-Climat at current and 2050 conditions (Moncoulon et al. 2018). It provides an overview of the future amount of damage per return periods and an estimate of the increased losses. Following this step, it is possible to calculate the requisite percentage of hazard reduction to reduce the effect of climate change to the current business-as-usual losses. For example, on the Lez catchment, the hazard has to be reduced by 35 % using NBS to limit the effect of climate change to the current losses.

# 4. Knowledge integration: adaptive planning, new business models and innovative sustainable financing

The knowledge obtained in each demo case resulting from the biophysical, social and economic analysis is integrated into a global framework that can be applied in environments with different technical, biophysical, social and economic challenges. To facilitate the integration and use of the multidisciplinary knowledge, support methodologies have been designed for decision-making.

A series of additional methods and tools were created to integrate the different elements in the assessment like the development of a stakeholder engagement protocol that supported the whole process of problem identification, potential solutions and favoured strategy (see Annex 1), which translated into a strong process of co-design with local stakeholders. This was then linked to the adaptive planning cycle and the use of a specific natural assurance business canvas to identify potential revenue flows and the financing framework on how to fund these NAS schemes focused on identifying finance options available (particularly around blended finance, impact investment and performance based contracts). We now explain each of the integrative methods in more detail.

## 4.1. The Adaptive planning cycle

First, through its strong framing under the adaptive planning as introduced by Basco et al. (2020) and analyzed and discussed by van Cauwenbergh et al. (2020), adaptive planning is a structured, iterative process of robust yet flexible decision making in the face of uncertainty, with the aim to manage uncertainty over time through system monitoring and learning from what is experienced, as the future unfolds. Using some of the models developed specifically for many of our case studies, it is possible to potentially develop Dynamic Adaptive Policy Pathways (DAPP), which is an iterative policy analysis process for adaptive planning that allows adjusting future action when events, that are presently unknown, unfold in the future. The DAPP approach combines "Adaptive Policymaking" with "Adaptation Pathways", and the developed plans include a strategic vision of the future, commit to short-term actions, and establish a framework to guide future actions. This was not implemented in our case studies, but it could be integrated into the current frame.

## 4.2. The Natural assurance Business Canvas

Second, through the natural assessment business canvas that is explained in Mayor et al. (2020). A business model is a conceptual tool containing a set of concepts and their relationship to each other, to fully develop the value proposition of a specific product or service. It allows for a simplified description and representation of what value is provided to customers, how this is done and with which funding sources and its financial consequences (Ostenwalder et al., 2010). The NAS Canvas is different on two accounts; first, because it is structured based on a logic of supply and demand of ecosystem services, and because it is based on a pluralistic understanding of value (Sanders et al, 2016) and relational values (Mouraca, B. & Himes, 2018) which are now part of the IPBES Framework and defined as "… imbedded in desirable relationships (sought after), included those between nature and people" (Diaz et al. 2016). Therefore the Natural assurance canvas captures not just the fully private values, but also the collective and public values, preparing the ground therefore for the collective alignment of a number of interested parties and their collective benefits, and willingness to pay for different services provided by multifunctional solutions like nature based strategies that deliver, often simultaneously, a bundle of services (collective benefits), i.e. the various benefits that can be provided by a NBS simultaneously over a certain period. (Jiang et al. (2016).

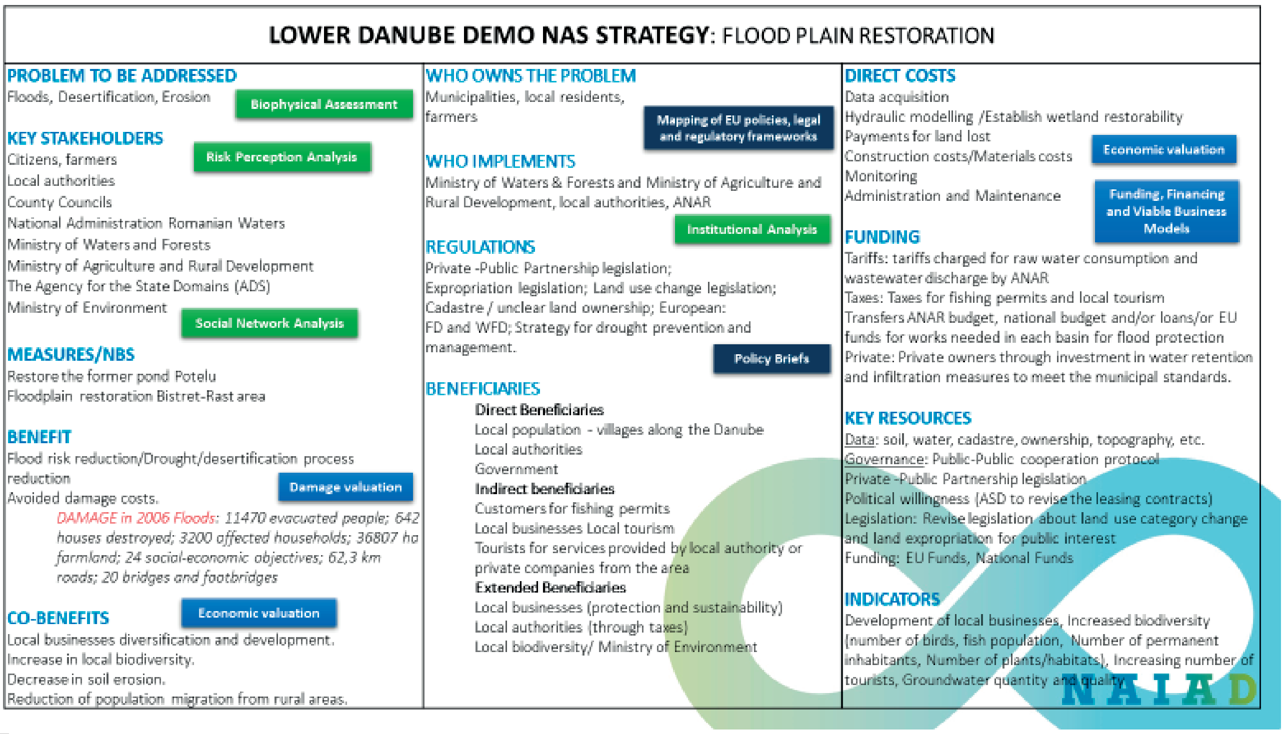


Figure 4: Example of the NAS Business Canvas applied to the Lower Danube.

## 4.3. A financing framework for water security

Third, through the financing framework for water security, as described by Altamirano et al. (2020). This financing framework further develops and tests for natural assurance schemes the "Better Business Case approach" (Smith and

Flanagan, 2001). This includes 5 elements of analysis a) the "strategic case" to demonstrates that the proposed nature based solutions (or strategies) are strategically aligned and are supported by a compelling case for change, b) the "economic case" ensures that a wide range of investment options, which in our case will compare green, hybrid and grey options, have been evaluated and that the preferred option optimises value for money, c) the "commercial case" ensures that any proposed procurement is commercially attractive and viable, which in relation to nature based solutions offers specific challenges, d) the "financial case" demonstrates that the preferred solution is affordable and can be funded, e) the "management case" provides assurance where processes and capabilities are in place to ensure that the preferred solution can be successfully delivered in our case, quite often as will be seen below, by public authorities since these are often the problem owners and most exposed directly (or indirectly through their citizens and businesses) to natural hazards.

NBS are facing several specific barriers for scaling up, including the difficulty to access funding and financing schemes from the lack of real examples providing evidence on their capacity and viability, and thus provide investor confidence and lower investment risks. Furthermore, making this type of projects attractive for private and impact investors requires a clear identification and quantification of the value proposition provided by these solutions, as well as a strong business case that ensures return of investment, particularly in the mid to long term. Most NBS projects fail to develop such a business case partly due to the limited data and evidence on the range of benefits provided by NBS, and their respective value. These projects also need to assess how the value generated – in our case by natural assurance services converted into viable schemes – through risk reduction and additional co-benefits can be captured and generate a series of revenue streams that makes them financially viable, similar to the business models developed for private projects providing goods and services. Identifying the "business model" for an NBS project – including a quantified value proposition, the elements required to deliver this value (resources and stakeholders), the costs of delivering this value, the range of beneficiaries and potential pool of clients and the associated possible revenue streams – will be an essential step to build a convincing business case that reduces the perceived risk by investors, also identifying the possible mix of funding sources to cover the whole range of lifecycle costs and also consider the opportunity costs.

## 5. Some case study results: what did we learn and do?

This section summarises some of the results from some our case studies. For reasons of space we only reflect on a number of them, namely the smallest and the largest case studies: the case of the Spangen neighbourhood in Rotterdam, which is being replicated in the Spanish city of Valladolid, the Thames, Lower Danube and the Medina del Campo case studies.

### 5.1. A CO-DESIGN PROCESS: PROBLEM OWNERSHIP AND LEGITIMACY: Example from the Lower Danube (Romania)

The Lower Danube case study covers an area of 250 km of the river. The strategy selected by stakeholders was flood plain restoration. Based on a structured process from the Stakeholder engagement protocol (see Annex 1), the main priority was to reduce the risk of floods and drought in the region. Stakeholders of the project (local and regional authorities, insurers, farmers, Watershed Management Authority, etc.) met with those responsible for the NAIAD project to discuss the most appropriate solutions to tackle the problems of the region, the direct benefits and co-benefits associated with these solutions. For this region based e.g. on the participatory modelling explained earlier, stakeholders identified the Nature Based Solutions preferred to reduce the risk, in this case the restoration of the Potelu pond and the restoration of the flood plains of the Bisret area were selected as a strategy. The direct benefits in this case are the flood risk reduction and the avoided damage costs, where the CAT Tool was implemented. Then, the associated benefits from the implementation of these solutions and the co-benefits associated to these solutions.

Local development, increased biodiversity, decreased soil erosion and reduced population migration to urban areas were identified as the key co-benefits. Then, in a facilitated process of co-creation, stakeholders identified who owns the problem, who implements the solutions and the regulations that would regulate the implementation of the solutions (direct, indirect and extended beneficiaries that will be benefited, based on the use of the NAS Canvas), as well as qualitative estimates on the direct costs of the implementation, as the planning, construction, maintenance, monitoring among others. The direct costs of the execution of the work, of the planning, construction, maintenance and monitoring of the solution and possible funding instruments, revenue flows and / or financing options were also identified and analysed. Data, governance, and revision of legislation regarding land use change were identified as key resources. Finally, a series of monitoring indicators were defined to evaluate the effectiveness of the solutions and the provision of co-benefits.

## 5.2. EFFECTIVENESS OF NBS: comparing options for flood and drought at large scale in Lower Thames (UK)

The Eco:Actuary toolkit was co-developed with the insurance industry and implemented in the UK Thames region with local authorities and land owners. During NAIAD we have held "Dragons' Den" type pitches with investors keen to develop green investment opportunities. These include investing in large scale NFM and drought friendly farming practices, such as regenerative agriculture, and using the //Smart: system to quantify the contribution of those investments to mitigate flooding and drought. We are also working with actuaries associations have also expressed an interest in a global climate risk index based on the Eco:Actuary global model. Finally a UK water supply company has invested in using the //Smart: technology developed during NAIAD to help advice farmers on best practices for reducing leachate using tillage and cover crops in drought-prone and nitrate-sensitive chalk aquifer areas.

The results of the monitoring and evaluation frame have shown that investment in Regenerative Agriculture is the most cost effective way of mitigating flood; if water stays on the land and is able to infiltrate, this very effectively reduces flood risk downstream. By improving infiltration, water remains available during seasonal droughts. Regenerative agriculture has significant co-benefits including reducing carbon emissions from ploughing and increasing soil biodiversity and organic matter. Increasing rainfall infiltration will reduce runoff and erosion, and thus preserve soil fertility and prevent pollution of the waterways from agricultural runoff.

## 5.3. POLICY FRAMING: Policy drivers to address water security in Medina del Campo (Spain)

In the case of Medina del Campo, both droughts and floods were analysed. The Groundwater Directive 2006/118/EC and the Water Framework Directive 2000/60/EC impose the obligation for the Duero River Basin Authority (DRBA) to assess the impact and damages from existing pressures and to take measures to restore the good quality status by 2027. In the case of the Medina del Campo Groundwater body, the main threats identified include lowering piezometric levels, diffuse agricultural pollution ($NO_3$), and elevated arsenic contents of lithological origin. A first measure established by the DRBA to address these pressures was a water transfer from the neighbouring Adaja River and the Cogotas reservoir to substitute groundwater by surface water for irrigation in the Adaja irrigation district (6,000 ha). As a result, a localised recovery on piezometric levels was detected in the surrounding area due to the double effect of stopping groundwater extractions and increased replenishment from surface water losses.

The NAIAD framework aimed to contribute to these challenges in the Medina case study. The study pursued to identify and assess possible Natural Assurance Schemes (NAS) that could help reduce water related risks while restoring the aquifers system status and functions. With this objective, a series of NAS strategies were co-designed with local stakeholders combining NBS and soft measures. The process followed the iterative steps set by the NAIAD stakeholder engagement protocol (Annex 1). The collaborative approach was combined with an analysis of their legal and technical feasibility by the river basin authority.

Two NAS strategies were considered for reducing vulnerability against drought risk while restoring the aquifers system status and functions in the Medina del Campo Groundwater Body:

1. Crop change towards drought resilient species, soil and water conservation practices, establishment of water user associations, abstractions monitoring and control and environmental awareness rising.
2. Aquifer recharge, establishment of water user associations, abstractions monitoring and control and environmental awareness rising.

The groundwater flow was simulated for three different climate scenarios and three different groundwater management scenarios: 1) Business as usual (BAU); 2) a reduction of Exploitation Index to 0.85 by year 2050 and beyond, and 3) a reduction of EI to 0.8 by 2050 (DRBA goal) and beyond. The last two models aimed to provide sensibility on the impact of small groundwater management changes. The main results were that groundwater management (through reducing the EI) has a much larger impact on piezometric recovery than climate change (through modified recharge of the aquifer).

The two NAS strategies proposed for coping with drought hazard risks in the Medina del Campo groundwater body were also economically evaluated under different scenarios following the economic cost-benefit analysis framework presented in Le Coent et al. (2020).

The climatic and socio-economic/regulatory scenarios considered were selected using a combination of expert-based and participatory co-development approaches. The evolution of the EU Common Agricultural Policy (CAP) subsidies was identified by stakeholders as a critical driver of land use change. Consequently, both a current CAP scenario and a more environmentally oriented CAP scenario were considered. Regarding climatic scenarios, a preliminary assessment of trends in average and maximum precipitation using the RPC 4.5 and RPC 8.5 IPCC projections (CEDEX, 2012) showed that no significant trends existed in any of the rainfall series to the project time horizon (2050), in line with the risk assessment results (Llorente et al., 2018). Consequently, only one climate scenario, based on the historical trends, was simulated (Calatrava et al., 2019).

The economic impacts of the NAS strategies in terms of reducing drought risk have been assessed using an agro-economic model calibrated to the technical, economic, and hydrological characteristics of the study area. This model simulates land and water allocation among cropping alternatives to improve the aquifer's conditions and to reduce drought risk in irrigated agriculture, under the different climatic and socio-economic scenarios considered, and computes several economic, social and resources use indicators. The method and results of the economic assessment of the impact of NAS strategies on the avoided damages is detailed in Calatrava et al. (2019).

Although the strategies' co-benefits have not been monetarily evaluated, the combination of the different analysis performed allowed for the qualitative and/or quantitative assessment of major expected co-benefits.

Identified co-benefits include an increase in water productivity, job generation and the profitability of agricultural employments, suggesting a greater potential for higher agricultural wages. Regarding the environmental co-benefits, both strategies would have similar impacts on the improvement of the aquifer's quantitative and qualitative status, although the artificial recharge in strategy 2 would accelerate the aquifer's improvement and would positively impact on some riverine ecosystems. Lastly, strategy 1 implies a less intensive farming than strategy 2, as crop rotations and less water-demanding crops are fostered, resulting in an environmental improvement of agricultural systems.

The results of the economic assessment show that the second strategy does not reduce drought risks but improves local riverine ecosystems, while the benefits of strategy 1 largely outweigh its costs, with a 3.17 benefit/cost ratio, even if the existing co-benefits were not considered (see Calatrava et al., 2019). However, strategies 1 and 2 are not conflictive but highly complementary and should be ideally combined to accelerate the aquifer's recovery and increase other environmental co-benefits. Our results also indicate the importance of considering an integrated value frame (Lopez-Gunn, et al., 2020).

## 5.4. REPLICATION: Football stadiums for climate with nature-based solutions: NAIAD flood mitigation in Rotterdam and drought resilience in Valladolid

Finally our smallest demo developed within the H2020 NAIAD project concerned flood mitigation in a neighbourhood of Rotterdam, Spangen. Here, an NBS was implemented which increases rainwater retention while reducing rainwater discharge to the sewage system. The neighbourhood did not have sufficient rainwater retention capacity, which is problematic during extreme rainfall events that are expected to become more frequent in the coming years. At the same time, the neighbourhood had been vulnerable in relation to drought (e.g. heat stress or degradation of foundations of buildings). As such, the municipality of Rotterdam concluded that the area required an additional 53,000 $m^3$ of water retention capacity.

To meet the need for the retention capacity, the municipality prepared a water plan for the neighbourhood. Part of this plan was the realisation of a pilot project 'Urban Water Buffer' (UWB) around a Sparta football stadium. The UWB relies on subsurface storage in which water is collected and stored during heavy rainfall events. Also, rainwater runoff from the roof of the stadium and from surrounding areas is collected, treated and recovered for irrigation. The project results in an increase of neighbourhood retention capacity of 1,500 m3 every 48 hours, which can contribute to flood as well as drought mitigation.

In addition to the empirical study of the implementation and decision-making process evolving around the implementation of the UWB, the NAIAD project assessed the economic impact of three strategies for flood mitigation in relation to the entire neighbourhood of Spangen Rotterdam:

- Grey, being a separated sewer system and permeable pavement.
- Hybrid, being a separate sewer system with natural retention and infiltration at public squares, including aquifer storage.
- Green, being only green infrastructure for retention and infiltration.

Critically, the analysis considered not just direct financial costs and benefits relating to the primary purpose of flood mitigation (which were designed to be equivalent in each option), but also considered a range of co-benefits that the NBS options produced. These co-benefits included health impacts, impacts on property values, heat mitigation, roof lifespan extension (for green roofs) and potable water system savings from water reuse.

The analysis found that the cost of implementation of grey solutions was higher (by 15 %) than that of NBS for the same level of risk management – therefore NBS are likely to be more cost-effective than grey solutions. Additionally, the co-benefits of the green option were estimated to be far higher than the flood mitigation benefits, making an attractive case for investment.

The solution is now in the process of being replicated in the city of Valladolid and the José Zorrilla Football Stadium, joining forces with the H2020 UrbangreenUp project in the same site, together with funding provided by the Partners for Water Dutch innovation fund and co-funding by the city of Valladolid, with the technical support of Aquavall, the local water company, the Real Valladolid Football club and the Duero River Basin Authority. This shows how nature-based solutions can mitigate flood and drought risks which are more likely under climate change scenarios while generating important co-benefits, made possible through the collaboration of cities, football clubs, local water companies and basin agencies, supporting innovations from European start-ups backed by the best scientific institutions.

# 6. Policy uptake and explotation

The NAIAD Project has focused on the potential that nature-based solutions and green infrastructure offer for future proof investment for climate change adaptation, to increase the resilience at both territorial and city scale to floods and droughts. This increased resilience is built on the bundle of avoided damages and co-benefits that nature can provide. We have introduced the concept of a Natural Assurance Schemes (NAS) that cities and regions can develop, by sharing a range of NAS tools and methods: tools like Eco:Actuary or the FEV for biophysical assessments, a participatory modelling frame to capture stakeholders values and perceptions, an integrated cost benefit analysis, the framing into the adaptive cycle, a business model canvas for natural assurance schemes and a financing framework for water security, which are all part of the NAS Methodological Assessment frame. We have also presented some of the results of their application to four of our nine demos located across Europe spanning different scales: from large scale like the Thames basin (UK), the Lower Danube (Rumania) or the Medina aquifer (Spain), and Rotterdam (Netherlands), including its replication to Valladolid (Spain).

At the end of the project experience a first NBS Dragons' Den and NBS Pitches, were held with our demos, with a "mock" exercise with real private and public investors in our final demo meeting in Copenhagen (Jan 2020), and what elements would be needed to turn this knowledge into lessons learnt and bankable natural assurance scheme viable projects.

Equally a series of policy briefs and guidelines have been developed. In the final months, a series of national roundtables have been organised in different EU countries (Spain, France, Romania, Sweden and Slovakia) to directly present some of our results but even more important, validate these results and frame them into the wider policy discussions currently under way on the draft EU adaptation strategy, the new draft Law on Climate Change and the EU Taxonomy on Sustainable finance. Here the focus has been to include in the conversation the role of NBS and potential natural assurance schemes in three gaps identified in conversations with DG Clima: the protection gap, the investment gap and the information sharing gap.

Ultimately NAIAD has provided a conceptual framework, a set of tools and methods and means for integration to have a better understanding on the role that nature based solutions can play for risk reduction and prevention, capitalizing on the assurance value of nature for both avoided damages and co-benefits, testing it in 9 demo cases at different scales and locations, and at different stages in the implementation cycle. As has been seen these frameworks and tools aim to support the integration of NAS into planning and implementation (gathering evidence of the effectiveness of the measures implemented) at different environments. The possibility to evaluate NBS will facilitate the incorporation of these solutions in, for example, river restoration plans, and therefore, funding for its implementation to convert them into real projects. Another key output of the project is a set of training materials on NAS implementation and assessment, through a MOOC (massive online Open course), that will be now complemented through an edited book with Springer currently in preparation.

# 7. Conclusions

In conclusion, the project started asking some questions, and now, after more than 3 years, we can respond to some of them:

First, in a context of climate change and land use change plus and increase of asset values and distributions, the level of losses is increasing significantly, posing a challenge to governments, cities, the insurance sector and citizens. Are NBS the solution? Can the design of natural assurance schemes better prepare and avoid potential costs? On the evidence from our results, all these questions have a positive answer.

Second, NAIAD demonstrates that NBS are an important part of the portfolio of risk reduction, increasing the resilience of the system while providing additional societal co-benefits. However equally NBS are not a silver bullet, sometimes a combination of NBS with other measures, including grey solutions could be the best option. Therefore, the answer to how we best develop locally adapted solutions in catchments and urban areas is through real evidence and by revisiting existing evidence. What is clear is a revised paradigm benefits from bringing in multi-disciplinarity, to better understand the nature of what are inherently complex problems. Here the correct integration of knowledge (and disciplines) is key, which is ideally suited to the properties of nature-based solutions that are inherently multifunctional. Our simulations also seem to indicate that NBS will be particularly well suited to frequent events, rather than the most extreme, thus increasing the overall resilience of the system. In prevention, we saw that NBS display their highest insurance value at the prevention stage against extreme events but also against more frequent events related to water risks.

Third, the possibility of evaluating NBS and NAS will facilitate the incorporation of these solutions in River Basin Management, River Restoration Plans, flood and drought risk planning and, therefore, the mobilization of resources for their financing, moving towards an adaptive management cycle that shifts the focus earlier into the risk management cycle into prevention.

Finally, one important insight learnt in the process was to identify that what normally is seen as a barrier, namely the different risk perceptions and ambiguity between the different stakeholders is in fact a latent opportunity for their uptake if these different perceptions are aligned. The mobilization of collective action to deliver risk prevention and reduction will be central and what until now were bundled as “transaction costs” need instead to be “unbundled” and understood for their enormous potential to help deliver collective action for risk reduction tapping in the value of nature for increased resilience and prevention.

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# Annex 1: The Stakeholder engagement protocol - co-designing natural assurance schemes

In parallel to the technical work, the DEMOs organized several workshops with the local stakeholders where NAIAD partners co-developed with them same steps of the process for the effective implementation of NBS in their area.

The results obtained in these workshops were:

- The assessment of the risk perception in the area.
- Selection and validation of the solutions more suitable (including hybrids, grey...).
- The identification of the co-benefits associated to these solutions.
- The co-identification of indicators to monitor these solutions along the time and see if they are being effective in reduce the risk, provide co-benefits...
- Additional discussion on possible NBS-Strategies, the most effective combination of different solutions.
- And in the final workshop, co-identification of potential business models derived from the solution selected.

## Box 1: The Stakeholder Engagement Protocol developed in NAIAD

A core operating principle of NAIAD is to proactively engage with stakeholders in the case studies throughout the application of its conceptual and assessment methodologies for Natural Assurance Schemes. The interdisciplinary nature of the whole approach fundamentally makes it relevant to a wide range of stakeholders, including decision makers, practitioners, scientists, end users and communities. Each stakeholder will have their own knowledge and perspectives of the integrated physical, social, cultural and economic systems in which the case study is situated, with all these needing to be shared and synthesised during the assessments. In addition, the stakeholders served an important function in terms of "road testing" and validating the tools and methods developed and presented in this article.

To fulfil this principle, various participatory modelling techniques and approaches were applied. The selection of the relevant approaches for each case study depended upon the contextual realities and the specific problems being addressed. However, a general set of guidelines compiled into a "stakeholder engagement protocol" were developed to serve as a practical source of guidance for case study practitioners, while ensuring some standardization and coherence/comparativeness of the process across the case studies.

The Stakeholder engagement protocol was composed of ten iterative and sequential steps which set the framework, objectives and proposed the range of methodologies that could be applied to advance through the participatory data collection, co-design, modelling and validation activities. (Click here to see more about The Stakeholder Engagement Protocol).

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