"NAture Insurance value: Assessment and Demonstration"

NAIAD

SC5-09-2016 Operationalising insurance value of ecosystems

Grant Agreement nº 730497

Deliverable 5.4

Integrative modelling framework and testing in the DEMOs: a global decision-aiding perspective – Executive summary

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0 Introduction : global objectives, contents and role in NAIAD

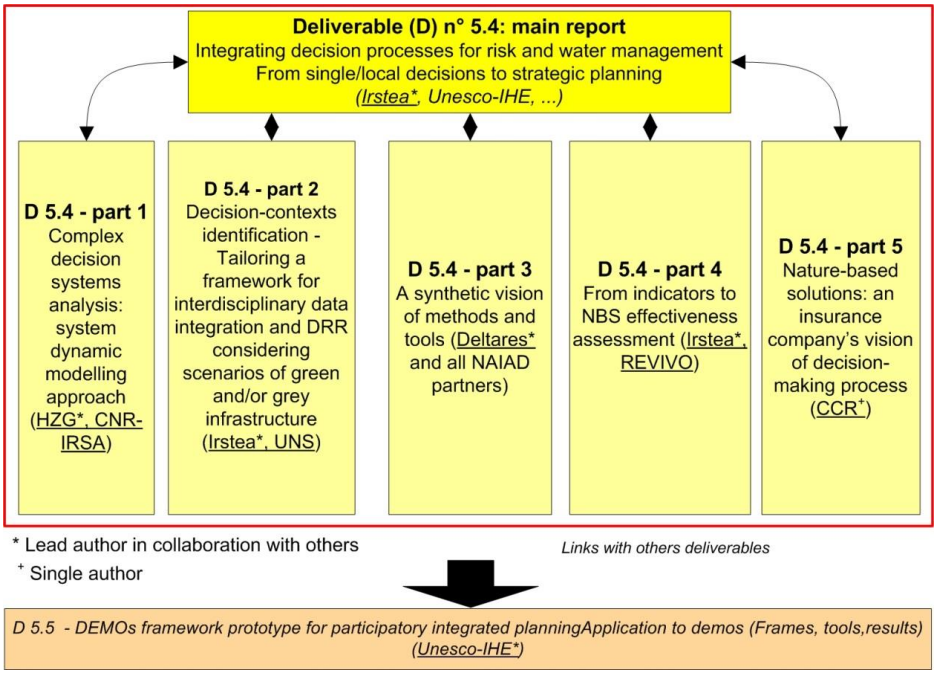
Considering Nature-Based solutions (NBS) within risk and water resource management involves taking complex decisions considering technical, economic, social and environmental issues. To help stakeholders decide which NBS to implement and how, there is a need for multi-disciplinary knowledge and choice procedures, combining expertise and value-understanding with context-relevant tools and methods for risk assessment, management and decision-making. The deliverable D5.4 of NAAID project presents approaches to move from more sectors driven and single-objective decisions to decisions that integrate multiple objectives, multiple stakeholders and multiple knowledge frames.

NAIAD's work package 5 (WP5) plays the role of integrator for methods and tools developed in WPs 2, 3, 4 in the context of DEMOs (WP6). Deliverable 5.4 (D 5.4) deals with *Integrative modelling framework and testing in DEMOS*. And corresponds to the the work carried out in the frame of Task 5.2. *Integrative participatory modelling approach* and Task 5.3. Integrated decision-making framework based on multi-criteria analysis.

D 5.4 aims to identify the whole decision and implementation contexts and to propose both approaches applied to some DEMOs and an extensive framework proposing a global vision for decision-making and planning. Deliverable 5.4 complements context-specific work done in WP6 by giving a global vision and examples of connecting approaches in relation with decision-making processes. This document is a synthesis of deliverable D5.4's main outputs and deliverables[1].

1 Structure of deliverable D 5.4

Deliverable D5.4 is composed of a main document (this report) introducing 5 parts which detail specific approaches (Figure 1).



[1] (wriiten by Jean-Marc Tacnet, see Authors and contributor in specific parts)

Figure 1 : Structure of deliverable 5.4: one main report introducing 5 specific reports

This deliverable complements sectorial work done in WP6 (corresponding to the implementation giving a global vision and examples of connecting approaches in relation with decision-making processes with those principal outputs:

- it describes differences and consistency between disaster risk reductions measures and water management plans;
- it clarifies how to build scenarios of risk reduction plan for water-related (cascading) hazards taking into account climate change, economic and social trends in order to assess a management strategy;
- it proposes a list of various, available kinds of modelling approaches.

Some parts of deliverable D5.4 (main documents, parts 1,2 and 4) have been gathered to produce a book to published at the end of year 2020 whose title is "Nature Based Solutions choice and efficacy assessment: integrative modelling and decision-aiding framework. They are therefore not fully public at this stage but will be delivered after publication.

2 D 5.4 – a global decision-aiding perspective - main report

This report[2] is the entry point to detailed contributions by introducing needs, objectives and then presenting integration principles. In recognition of the multiple fields of knowledge around NBS and with the objective to foster integration across disciplines, it first recalls differences and consistency between disaster risk reductions measures and water management plans. Local decisions and strategic planning principles are presented. Global framework and expectations about integration within NAIAD are then described.

The main report represents a general introduction to the five parts of the deliverable D5.4. It presents two decisions contexts related to Nature Based Solutions, namely risk management and water resource management contexts. It also presents general frameworks for planning in the two contexts by underlining the differences and similarities. Lastly, the different vision of integration in NAIAD is described.

NAIAD project proposes an extended vision of Nature Based Solutions implementation ranging from their physical effects to the analysis of others co-benefits such as economic, social, environmental aspects with an analysis of the financial issues through business cases proposals. Many spatial, temporal scales are addressed (e.g. figure 1) and several disciplines are involved.

[2] Tacnet, J.M. and Van Cauwenbergh, N. (2019): "Integrative modelling framework and testing in the DEMOs: a global decision-aiding perspective - main report ". Deliverable 5.4 of EU Horizon 2020 NAIAD Project Grant Agreement N°*730497*. April 2019.

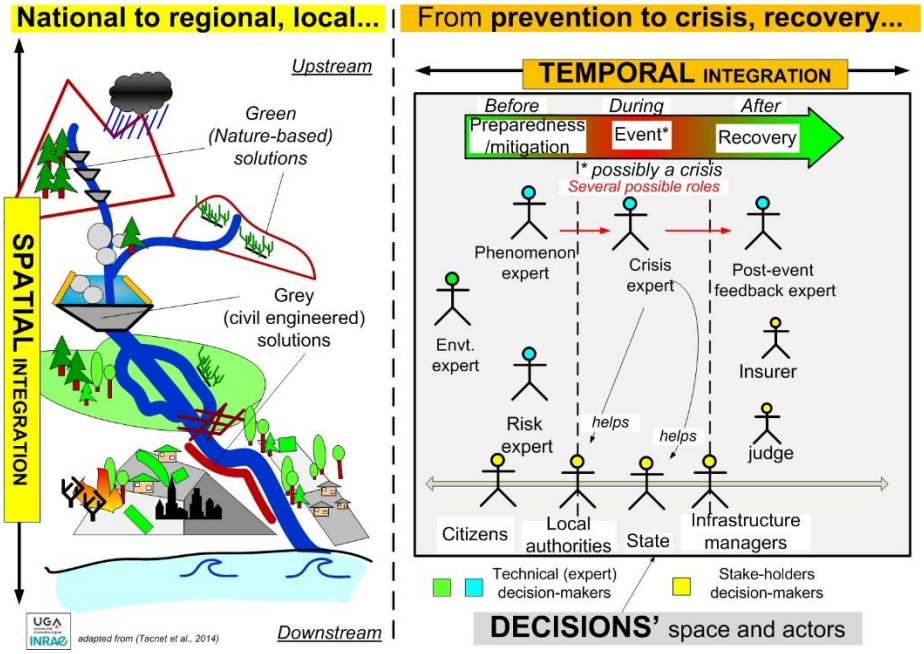


Figure 2 : Decision-making related to risk management requires integration of disciplines, methods according to the different spatial (local, global) and temporal visions (short, mid and long term, prevention, crisis, recovery steps) (adapted from (Tacnet et al, 2014) in Environment Systems and Decisions.

However, integration of multidisciplinary approaches linked to various objectives is not easy. An integrated vision is developed and addressed within NAIAD through the different work packages and application in demos. As shown on figure 2, Integration can correspond either to gathering of several approaches related to the same topic, concept or approach (e.g. Decision-aiding methods) or to the association of several different methods and disciplines to reach a multidisciplinary objective such as NBS' effectiveness assessment.

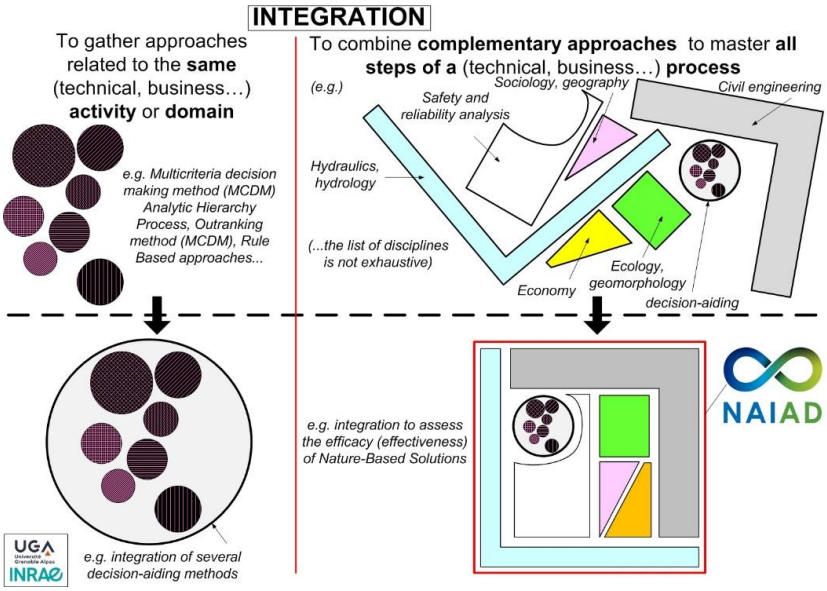


Figure 2. Two visions of integration are developped and implemented in NAIAD

The methodology of integration contains two steps. It starts with the identification of components and methods (figure 2) and is then followed by the description and formalization of pathways for integration showing the links between demos (figure 3) and approaches.

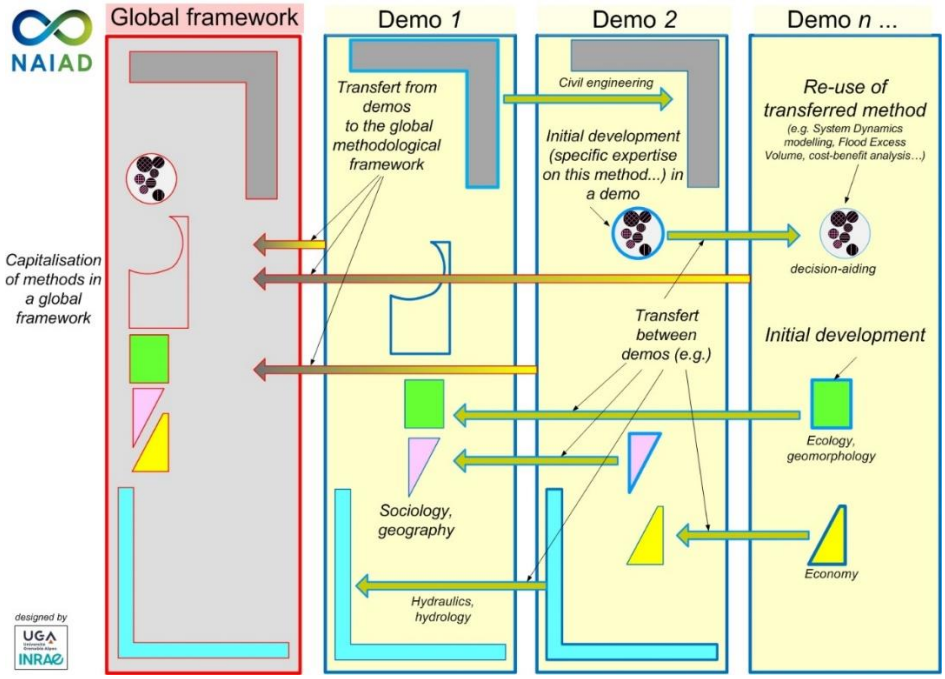


Figure 3 : Methods are developed in a Demo (application site) and then transferred to and used by others DEMOs (e.g. economic analysis, transfert of physical assessment techniques from La Brague Demo to Glinscisca river Demo)[3].

A generic graphical representation is proposed to show the links between methods, disciplines and applications (Figure 4).

This approach is a meta-analysis tool and framework to share and integrate multidisciplinary information between actors involved in NBS and risk management. It proposes an empirical structured vision of multidisciplinarity to make the actors aware of necessary linkage between domains, techniques and to help them to connect all approaches. This integrated vision is also somehow an overall and starting contribution to decision-aiding approaches and NBS effectiveness indicators assessment. It allows to connect methods and developments with practical risk management decision contexts.

[3] See Piton et al., deliverable D6.2 (both French and Slovenian application case).

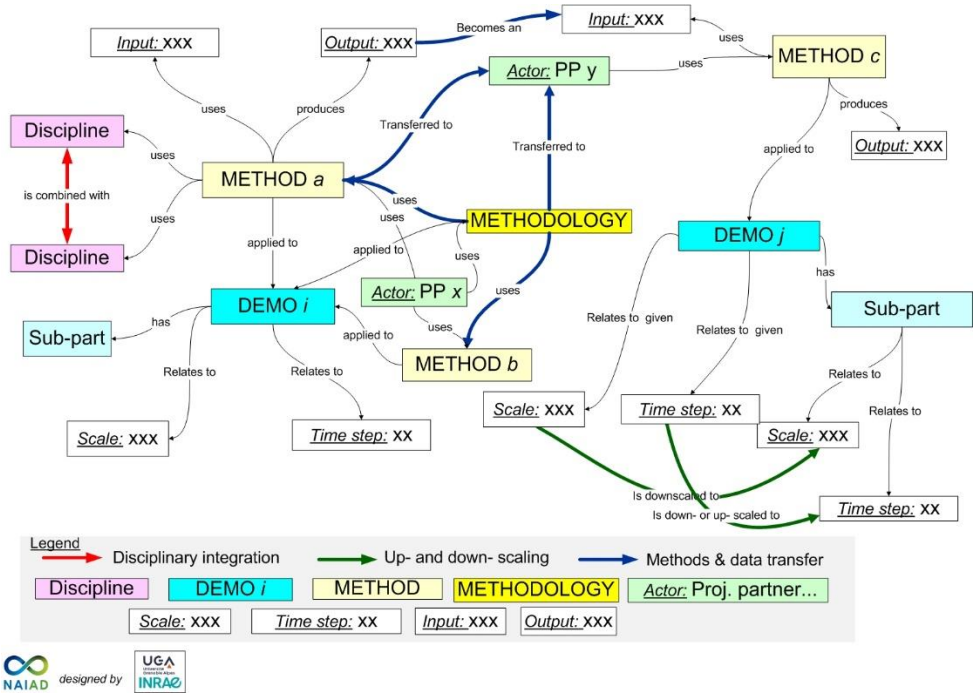


Figure 4 : Generic conceptual model is used and implemented to represent links between methods, disciplines, actors for all NAIAD's demos.

3 D 5.4 – part 1: Complex decision system analysis – dynamic modelling[4]

The participatory modelling framework used to support the assessment of NBS effectiveness is presented. The framework has been applied in 4 NAIAD DEMOS (Copenhagen, Medina del Campo, Lower Danube and Glinščica) to integrate different sources and forms of knowledge and to enhance general decision-making and policy-planning for environmental risk reduction. The participatory modelling approach is described as an innovative tool to capture local knowledge and to co-produce simulation system dynamic models along with stakeholders. The system dynamic models are used to perform an integrated analysis of the impact of NBS on flood risk and other water-related hazards.

[4] Eulalia GOMEZ; Alessandro PAGANO; Raffaele GIORDANO; Maria MAÑEZ (2019): "*DELIVERABLE 5.4 Integrative modelling framework and testing in the DEMOs. Part 1: Complex decision system analysis and system dynamics modelling approach"*. EU Horizon 2020 NAIAD Project, Grant Agreement N°*730497 (public report)*

4 D 5.4 – part 2: Decision context analysis – tailoring a framework for interdisciplinary data integration[5]

The methodology consists of an integration methodology that can facilitate participatory collaboration and decision-making between actors involved in NBS management and can promote the participation of local stakeholders. In addition, the methodology should facilitate the systematic choice of criteria for the formation of multi-criteria analysis and scenario generation.

It is based on the DPSIR (Drivers-Pressures-State-Impact-Response), a conceptual framework with widespread and global use in many domains since several decades.Modifications were made to serve the structural form of the project, that is to respect the initial division of tasks by domain of study i.e. bio-physical, social and economic (WP2-4), as well as its strategical goals and aims of forming a methodology that will serve the collaboration between socio-economic priorities expressed in the form of strategic choices made for investment in risk mitigation/protection structures and the respected bio-physical variables that generate hazard and subsequently risk.

The initial analysis is performed by domain of study (also named subsystem of study) and efforts are centred on constructing a causative chain of progression of each aspect of the disastrous event, from its formation to its impact. For each subsystem (biophysical, social and economic), driving forces as mechanisms of change are initially considered in order to account for a suitable future time window where non-negligible changes can occur to the system. This is necessary for including variables such as climate change, which can alter the hazardous event itself, but also variables of socio-economic interest such as unsustainable development trajectories that can increase exposure and vulnerability and thus risk and impact. For each subsystem, pressure points are defined, and state variables are chosen. Depending on the state variables, the impact on the system and its reaction is assessed. The interaction domain is conceptualised where interference occurs between the state variables of the biophysical, social and economic domain and where natural based solutions can possibly act beneficially.

For the validation of the methodology, efforts are directly concentrated on linking the proposed methodology with a DEMO site for its application and testing (WP6). The application site is the Brague DEMO for which questionnaires with key stakeholders where already available to analyse and extract information about locally established problems, risk management and risk perception. Basic tables of the causal chain of progression are established and subsequently enriched through the collaboration of partners of IRSTEA Aix-en-& Grenoble and UNS (IMREDD). The tables produced, include information not only of the process of consideration, but also about methods, tools and data necessary to perform the certain task/analysis. Finally, the results of the first stakeholder participatory workshop, organised in Nice, France on the 21st of March 2018 are seen to appear in their majority in

[5] YORDANOVA, Radina P.; CURT Corinne; PITON, Guillaume; DOUAI, Ali; GNONLONFIN, Amandine and TACNET, Jean-Marc (201),: "*DELIVERABLE 5.4 Integrative modelling framework and testing in the DEMOs. Part 2: Tailoring a framework for interdisciplinary data integration and DRR considering scenarios of green and/or grey infrastructure"*. EU Horizon 2020 NAIAD Project, Grant Agreement N°*730497 – to be included as a chapter of an incoming book*

the process tables as components – location specific issues that act on a finer scale were not examined at that point of the analysis.

Once the process tables for each domain are established, they can easily be transferred to the flowchart formation. This allows for refining the process of generation of scenarios as the variables of the tables are connected to form a logical progression and generate a specific scenario form. The explicit choices made at various steps of the flowchart form the final scenario form. Keeping that fixed and altering only the variables for "measures of protection" then gives a different impact level, which can be evaluated over several criteria to decide which are the measures that provide the best balance between risk protection, investment, well-being etc. The choice of protective measures can be formally represented by a multi-criteria process that is used not only in the evaluation of the base scenario (BAU scenario) but also will be projected to different future scenarios of adoption, or not, of NBS for flood protection, as well as for cost reduction.

5 D 5.4 – part 3: Overview of methods and tools

This part (report available)[6] briefly recalls and gathers methods which have been used through applications to different DEMOs sites (Figure 6). It complements the specific and extended description done in WP6 dedicated to DEMOs description. It also proposes general table highlighting pro and cons is provided in Appendix.

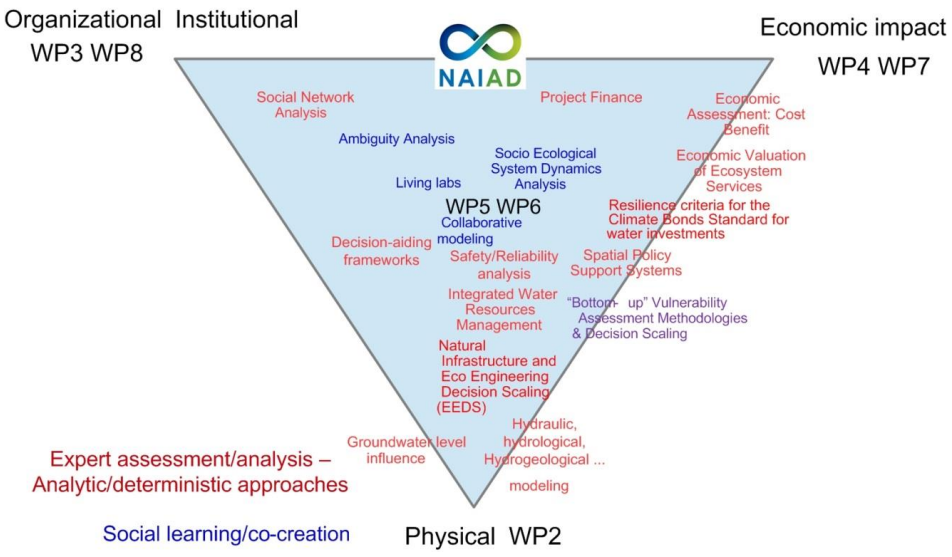


Figure 5 : Linking approaches in NAIAD (adapted from Deltares)

[6] Eskedar T. Gebremedhin; Laura Basco Carrera; Jean-Marc Tacnet, Guillaume Piton, Albert Scrieciu; Monica Altamirano; Nora Van Cauwenbergh; Peter Van Der Keur; Le Coent Philippe; Beatriz Mayor Rodriguez; Sophia Burke; Polona Pengal, Mark Mulligan; África De La Hera Portillo; Miguel Llorente Isidro; Sylvain Dupire; Kieran Dartée, Eulalia Gomez; Marta Faneca Sànchez; Roxane Marchal: (2019) "DELIVERABLE 5.4 Integrative modelling framework and testing in the DEMOs. Part 3: Methodology list". EU Horizon 2020 NAIAD Project, Grant Agreement N°730497. (public report)

Disaster risk reduction and water resource management involve several kinds of stakeholders, complex systems and require advanced methods to appraise a situation and its possible future trajectories, propose improvement of human actions and take decision.
Several modelling tools and approaches were applied in the NAIAD DEMOs. Some of these are more focused towards setting up and establishing a coherent common conceptual understanding of the integrated physical, social and economic systems in each DEMO. Others seek to accurately simulate the processes occurring in one of these constituent systems e.g., groundwater fluxes, flooding processes, while others still seek to integrate and synthesise the quantified outputs from each of the constituent system models and aid decision making e.g., cost-benefit or multi-criteria methods. A list of tools and approaches to be applied are provided in Table 5.1 below. These advanced methods are of different kinds shortly described throughout this deliverable

Table 5.1: Short list of tools and approaches

Tools	Approaches
Physical modelling	
Forest fire modelling	GIS index or full modelling
Hydrological models	Statistical distributed models, run-off models, models with a conceptual approach rather than physically based
Hydraulic models	1D, 2D modelling of streams / rivers (natural or engineered like canals), water+solid transport+woody debris
Groundwater models	conceptually and physically based models
Damage modelling	Empirical, physical (deterministic), Statistical modelling
CAT-models	Couple hazards and damage modelling
Participatory modelling	
System dynamics	Companion modelling (agent-based modelling + role-playing)
Bayesian networks	Group Model Building (causal loop diagrams, system dynamics)
	Concept of conditional probability and causal probabilistic networks to model uncertain and complex domains, like environmental management.
Fuzzy cognitive mapping	Collaborative development of complex simulation models using existing modelling tools (e.g. iMOD, DFlowFM)
Agent-based modelling	Interactive modelling using touch table applications
Social network analysis	Serious gaming
Decision-aid methods	
Cost-effectiveness	
Cost-benefit analysis	
Expected utility models	Economic based models (Decision Theory based)
Multi-criteria decision making	Total (AHP, MAUT-like) or partial aggregation models (Electre- like methods)

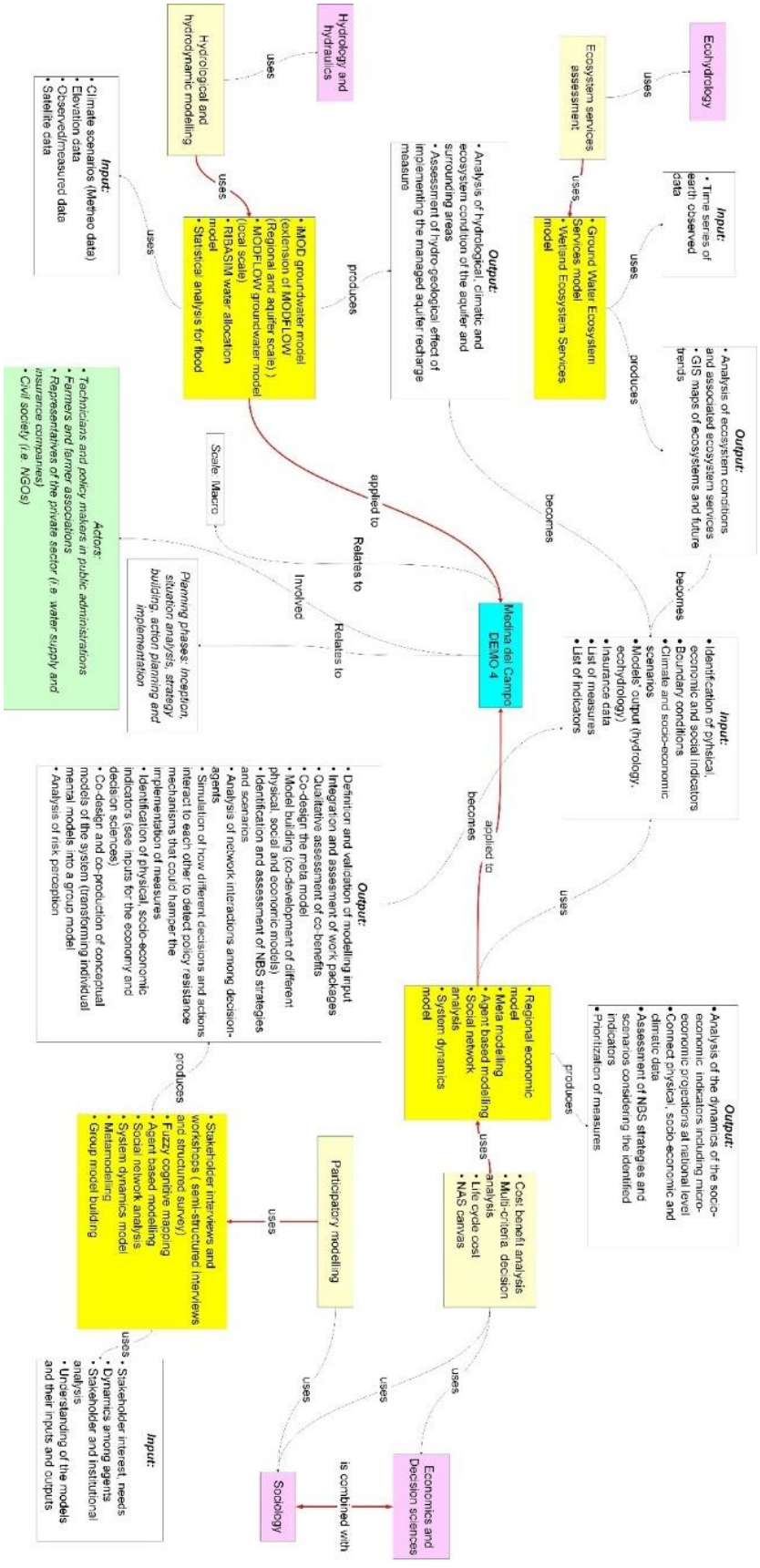


Figure 6 : Example of the implementation of the framework: disciplines, methods and methodologies used in Medina del Campo DEMO

6 D 5.4 – part 4: Indicators for NBS' effectiveness assessment[7]

This report is a part of deliverable 5.4 relative to production of an integrative modelling framework designed with a decision-making perspective. It proposes on one hand some advances in describing their capacities and, on the other hand, some pathways to help decision-making. NBS effectiveness assessment and related indicators identification are essential objectives of this report. It provides therefore an extended vision of an integrated framework coupling different disciplines and methods ranging from hydraulics, civil engineering to safety and reliability analysis, multicriteria decision-making.

6.1 A framework to identify and define indicators of the efficacy of NBS[8]

Objectives and concept

An important objective of this part consists in designing and using indicators to assess the efficacy (effectiveness) of Nature Based Solutions (NBS). Nature-Based Solutions (NBS) are indeed part of risk mitigation strategies and decision-makers (municipalities, basin agencies, state, risk managers…) are searching to assess their effectiveness and compare them with others more classical solutions in order to choose the best strategies and check that they contribute to risk reduction. Several typologies of NBS and related performance indicators exist (e.g. EKLIPSE framework) but indicators may sometimes appear as difficult to be chosen or used. One output of NAIAD consists in a generic approach to define, use and assess effectiveness indicators. The idea is to allow stakeholders to be able to have a critical view on existing indicators and better choose those which corresponds to their needs.

As a starting point, NAIAD project emphasizes that the concept of effectiveness (or efficacy) is not something obvious and it can be very relative. To assess effectiveness in practice, NAIAD develops and uses functional and systemic approach. This approach is derived from safety and reliability engineering, classically used for technological systems. It also allows to describe some possible, often neglected, drawbacks or specific vulnerabilities of NBS such a woody debris caused by erosion of riparian forest or wildfires destroying protection forests.

[7] TACNET, Jean-Marc, PITON, Guillaume, FAVIER, Philomène, PENGAL, Polona (2019): "DELIVERABLE 5.4 Integrative modelling framework and testing in the DEMOs. Part 4: From indicators definition to NBS choice and effectiveness assessment". EU Horizon 2020 NAIAD Project, Grant Agreement N°730497 (*to be published as part of a book*)

[8] A synthetic presentation is available in the the NAIAD e-guide.

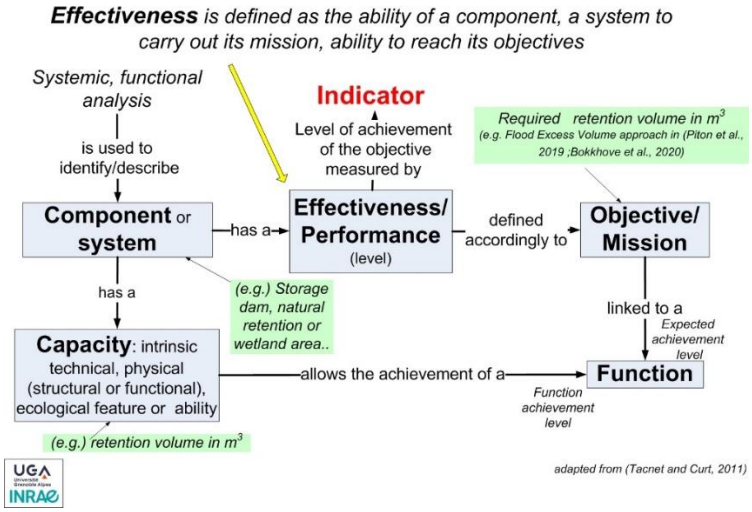


Figure 7 : Definition of the concept of indicator linking a capacity, an objective linked to a component or system and ist function (submitted in EU NBS Handbook, chapter 2)

Within NAIAD context, the approach considers NBS as a system (composed of several components) which aims to achieve a function with a given objective. To reach this objective, NBS have capacities. The level of achievement of the function compared with the objective defines the effectiveness. For example, a natural retention area will have a **capacity** measured by its volume. The **objective** associated to the **storage function** can be determined by simple physical models (see Flood Excess Volume method, FEV[9]). The comparison between achieved, observed and expected levels defines the effectiveness (Figure 1). This may look trivial but it is indeed a powerful way to structure the approach in a pragmatic way and to select or even invent the most relevant indicators.

Four main categories of indicators are proposed and gathered under a so-called **TOPHEE** approach which offers a way to structure the analysis of effectiveness. It includes 1) **T**echnical or Physical effectiveness (will the NBS resist to flooding, will it reduce water depth? Etc…), 2) **E**conomic effectiveness (Are the costs lower than the monetary benefits, what are the avoided damage costs?),3) **E**nvironmental effectiveness (How does it preserve, improve quality of environment, habitats, geomorphologic equilibriums) and finally 4) social, **H**uman, cultural effectiveness (how does it improve quality of life, landscape etc.). Another organisational aspect is proposed but not developed in NAIAD.

[9] Flood Excess Volume (FEV): an easy-to-use and understand method to determine the hydraulic requirements and compare them with NBS capacities http://naiad2020.eu/about-the-e-guide/tools/estimating-rapidly-cost-effectiveness-of-nature-based-flood-mitigation-schemes-using-the-fev-flood-excess-volume/

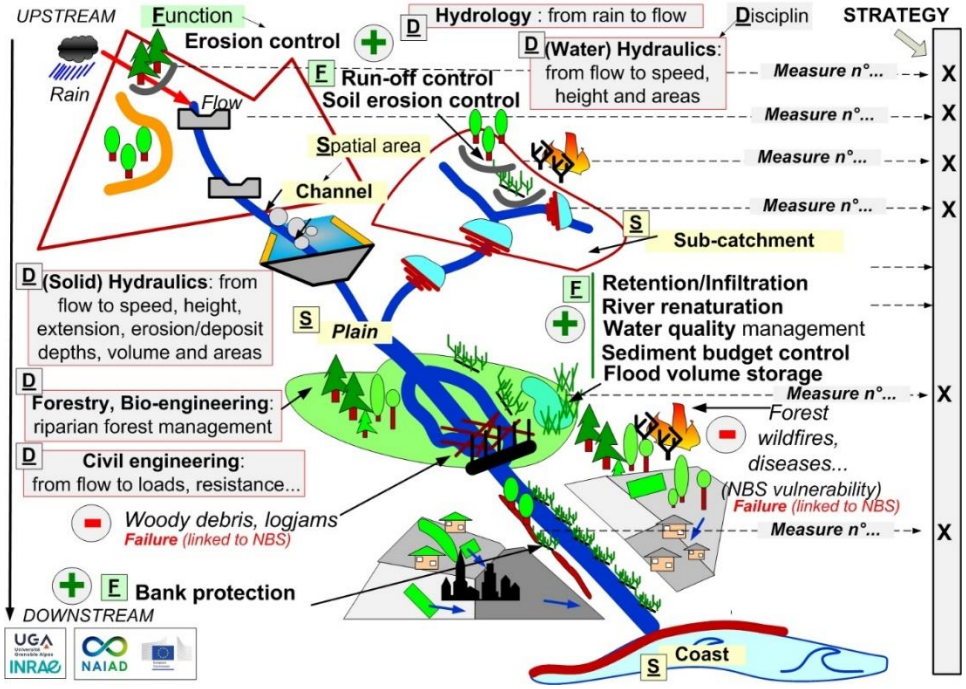


Figure 8. The concept of functional analysis: functions and capacities of NBS have first to be clearly identified and described and then secondly assessed (in the most objective, quantitative or qualitative ways) to assess their effectiveness (Tacnet et al., 2019. NAIAD D5.4 part. 4)

An example of application is proposed on figure 2. It describes the physical functions of different categories of NBS in the context of flood risk management. This chart describes the process to organize and structure the assessment of NBS' effectiveness. First step is to analyse the spatial areas and scales where measures will be implemented. Each measure is described according to its functions. Indicators can then be chosen and assessed using inputs from different disciplinary thematic, technical approaches.

(Potential) applications to decision making in the insurance and risk management sector :

The approach applies functional and systemic analysis to NBS thematic domain even if it can be applied to assess the effectiveness of any risk management measure or solution including grey, green and hybrid strategies. This pragmatic framework is compliant with multidisciplinary approach and allow decision-makers and stakeholders to stay or become critical about existing indicators and innovative when new indicators are needed.

Identification and use of usable indicators is of higher interest for risk managers, decision-makers, public funding bodies and generally any actors involved in decision-making processes linked to NBS effectiveness assessment and risk management. This framework allow those actors of decision to be able to check the relevance of proposed indicators and also, if needed to design and add new ones. Different categories of potential users can be identified including regional and local authorities**,** river basin authorities**,** land use planners**,** public bodies and agencies**,** State, Administration, experts but also citizens**,** non-governmental organizations and insurance companies.

It is an essential step in the new hybrid design framework (see next section) to link thematic approaches and decision-aiding approaches.

6.2 New hybrid design methodology and framework of practical tools for decision-aiding and assessment of NBS' efficacy[10]

Choosing Nature Based Solutions (NBS) among other protection strategies or assessing their efficacy (effectiveness) levels are two examples of key decisions that stakeholders have to take to manage risk. A new hybrid design methodology and operational tools to use them are proposed to help decision-making. A structured approach of the decision-making process is proposed (figure 1). The first steps to help decision-making is to describe the decision context which is addressed (step 1 to 3, figure 1).

Using an example among the numerous existing multi-criteria decision-making, (step 4), we have designed a multi-criteria decision-making framework, easy to design and implement, to assess main NBS' features, following the TOPHEE (Technical, Physical, Economic, Environmental, Human/Social, Organisational) approach (see also factsheet in this e-guide about Designing and using indicators to assess the efficacy (effectiveness) of Nature Based Solutions).

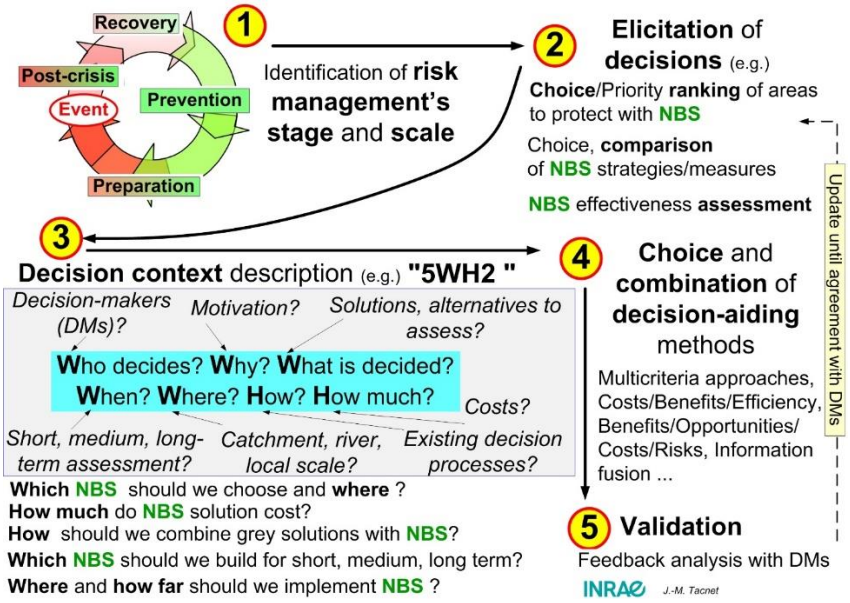


Figure 9. A decision-aiding model is always linked to a specific decision context: a whole methodology is proposed from problem identification to decision-aiding (including and using several methods). A simple 5WH2 approach is used to describe decision contexts as a starting point of decision-aiding process.

A decision model is proposed to assess NBS solutions and strategies according four main NBS' features corresponding to technical/physical (1), economic (2), social/human/cultural (3) and environmental (4) aspects (figure 2).

[10]http://naiad2020.eu/about-the-e-guide/tools/new-hybrid-design-methodology-and-framework-of-practical-tools-for-decision-aiding-and-assessment-of-nbs-efficacy/

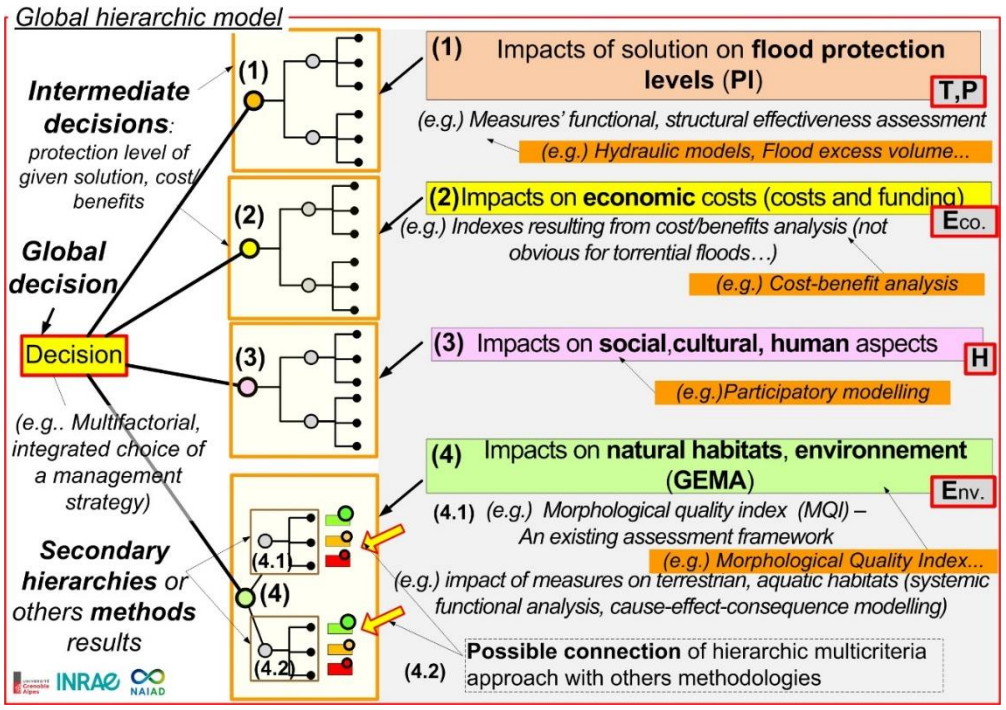


Figure 2. A new hybrid design approach is proposed : a (multicriteria) decision-aiding framework is coupled with thematic, disciplinary, expert approaches to analyse Technical, Physical (T,P), Economic (Eco), Social/Cultural,Human (H) and Environmental (Env) NBS' features and effectiveness (+ option Organisational (O) – not represented). (adapted from Tacnet et al., 2018) DOI : 10.14758/SET-REVUE.2018.26.09.

For each of these items, the indicators are assessed according to thematic, disciplinary approaches such as hydraulic modelling for protection against floods. This combination constitutes the so-called hybrid design methodology bridging the gap between decision-making and more classical expert, engineering approaches (figure 3).

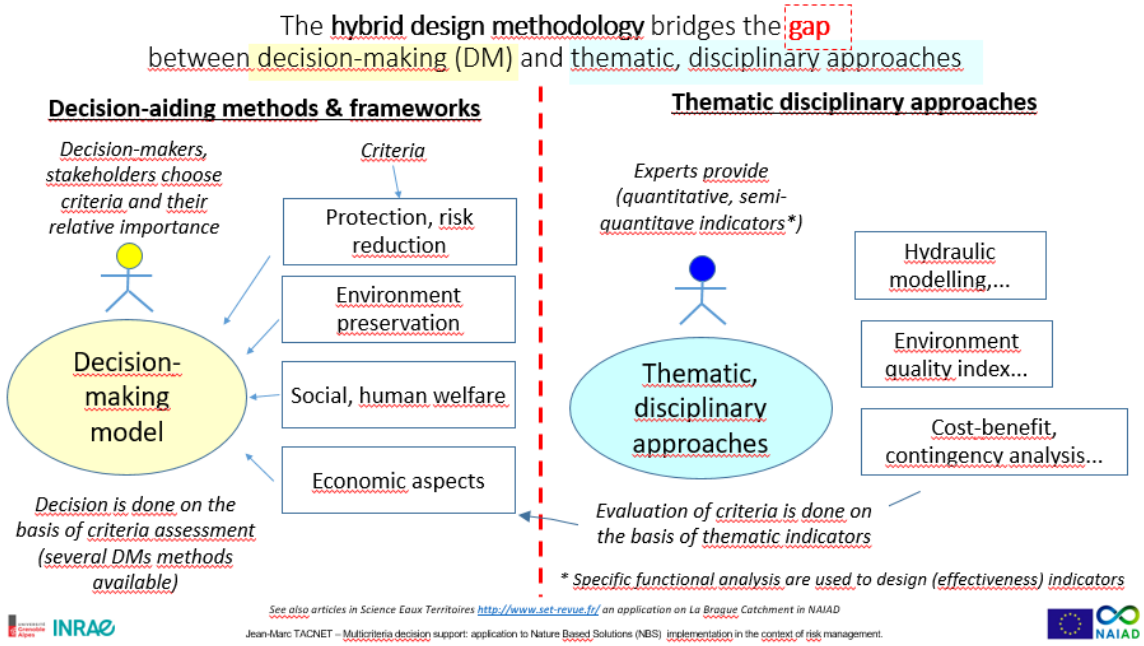


Figure 3. The new hybrid design methodology combines decision-aiding methods and thematic approaches (hydraulic engineering, economic analysis, bioengineering…) to assess NBS' effectiveness and/or choose the best strategies.

To be implemented and used in practice, operational tools are proposed to demonstrate, explain the principle of the multicriteria decision model. Users can assess interactively the score of protection strategies (e.g. Grey –Scenario 1 , Hybrid (Grey and Green solutions) – Scenario 2 and Green –Scenario 3). Based on relative preferences between the four main criteria and preferences between solutions for each of them, it is therefore possible to calculate the overall aggregated score of each solution. This (excel microsoft) spreadsheet exists in French and English and is available for free.

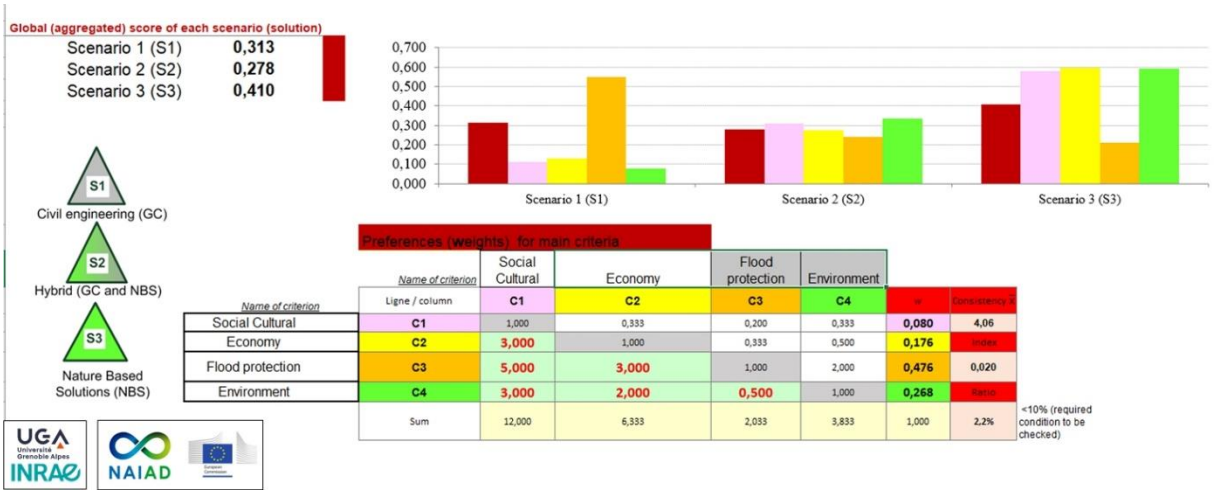


Figure 3. An easy to use calcultation tool (excel spreadsheet) is delivered (in French and English) to illustrate the implementation of the multicriteria decision-aiding approach and as a support for transfert to stakeholders and practitionners.

Once the principle of building a multicriteria decision model is understood, it is possible to design any model and evaluate it easily. One key step the process is to calculate preferences. A series of spreadsheets is proposed to calculate weights given relative preferences matrix.

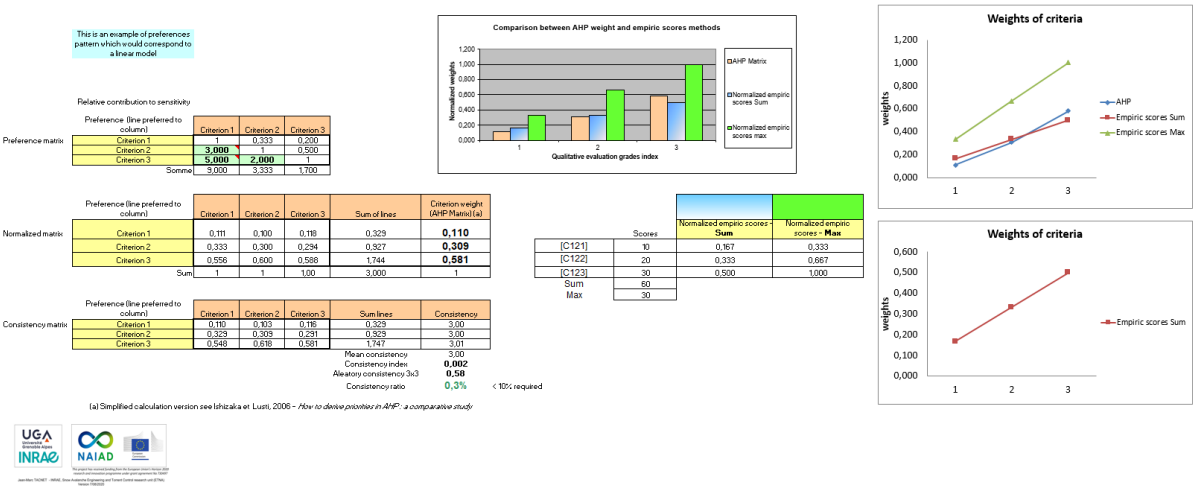


Figure 4. A more advanced versatile spreadsheet is proposed to calculate weights given preferences matrix (AHP framework). It allows to easily build, adapt any multicriteria decision-aiding model.

The approach and the tools offer a traceable, explicit description of decision processes and helps decision-makers to discuss and make choices according to their own priorities (instead of applying and being somewhere obliged to follow technical conclusions and outputs). The approach merges thematic, engineering and decision-aiding approaches. It bridges different

worlds and communities. Decision-makers can use information provided by experts and introduce their own vision, preferences about the benefits of each solution to take their proper decision. A practical and educational framework allows them to see interactively the influence of their choice. It can be applied to any decisions about choosing the best protection or solutions including NBS and assessment of NBS' effectiveness can be addressed. It offers a new perspective in comparison with existing methods (risk analysis, monetary cost-benefit analysis).

7 D 5.4 – part 5: Nature-Based Solutions: an insurance company's vision of decision-making process[11]

This report describes the vision a (re)insurance industry company (CCR) in natural risk assessment and highlights the challenges and needs for local decision makers. There is an increasing concern about climate change and building of resilience in the (re)insurance sector. An interpretation of the perception of both local stakeholders and the (re)insurance industry, on NBS and risk is proposed. It also present tools for supporting decision making mainly based on a risk modelling chain. It finally provides a business lens on knowledge integration to inform decision makers. It complements the large perspective of the effectiveness of NBS in risk reduction developed in the part 4 of the D5.4

Water-related hazards (floods and droughts) are increasing from climate change, in addition to growing communities and concentrations of wealth in high-risk areas. There is a growing interest in the protective role of nature-based solutions can play in adapting these risks. However, there is a lack of data on their effectiveness on hazards, in terms of costs and co-benefits which can limit their implementation. Here, we study local decision-makers' challenges and needs for risk assessment of their communities. Decision–makers concerned with risk management, require both relevant information and expertise based on multidisciplinary approaches to make decisions. It is based on how the insurance industry' risk modelling framework to assess risk, in a broaden horizon, can be used to assess the effectiveness of preventive measures. These include nature-based (e.g., wetlands, bioswales, giving room to the river etc.) and grey ones (e.g, dikes). We do not include policy measures (e.g. home elevation, sand bags etc.). We first find that risk culture will be critical driver of nature-based prevention. This report presents cat loss risk model structure (used by CCR) based on hazard, vulnerability and damage units. It advocates that (re)insurance industry' risk modelling chain – taking into account uncertainties is useful to integrate nature-based solutions throughout the chain. This is the part of avoided damage analysis to be combined with co-benefits analysis performed by other actors. This report describes the use of insurance tools to compare nature-based and grey measures and to inform decision-makers on the most effective solutions meeting issues of risk reduction, environmental protection and urban growth. It also stressed investments and financing issues as possibility for the insurance sector to foster nature-based solutions implementation.

[11] Roxane MARCHAL; David MONCOULON (2019): "*DELIVERABLE 5.4 Integrative modelling framework and testing in the DEMOs. Part 5: Nature-Based Solutions: an insurance company's vision of decision-making process."*. EU Horizon 2020 NAIAD Project, Grant Agreement N°*730497 – (public document)*