The Natural Assurance Schemes Methodological Approach – From Assessment to Implementation

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Highlights

- We demonstrate that most case studies achieved high levels of technology readiness, given the large amount of data-driven and physical modelling driven approaches combining engineering and natural sciences expertise.
- A transdisciplinary approach to NBS planning and design further increased technology readiness, by generating understanding of NBS performance across stakeholders.
- Most multifaceted tailoring was needed to assess and generate institutional readiness and investment readiness.
- To cope with the inherent uncertainty of NBS and their implementation, we propose an adaptive planning and management approach to provide sufficient flexibility on the risk-benefit transfers while providing needed investment security.

This chapter is based on Van Cauwenbergh, N., Dourojeanni, P., Mayor, B., Altamirano, M., Dartee, K., Basco-Carrera, L., Piton, G., Tacnet, JM., Manez, M., Lopez-Gunn, E. (2020). *Guidelines for the definition of implementation and investment plans for adaptation*. EU Horizon 2020 NAIAD Project, Grant Agreement N°730497.

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19.1 Introduction: NBS and NAS Implementation Readiness

The previous chapters of this book have provided an overview of the concept and role of nature-based solutions (NBS) aimed at disaster risk reduction in view of the limitations of grey infrastructure. They illustrate how NBS deal with societal challenges and mitigate water related natural hazards while at the same time being cost effective and providing environmental, social and economic benefits to society.

Lopez-Gunn et al. (2020) developed the novel concept of Natural Assurance Schemes (NAS), defined as "ecosystem-based risk reduction measures that reduce the level of risk in one area". The central idea of NAS is that nature can ensure some assets in real monetary terms while also assuring (restoring or protecting) the ecosystems in a context of anthropogenic pressure. The question then is, how can we build NAS?

In this chapter, we aim to answer that question by discussing how NAS are set up to operationalize the assurance value of NBS, i.e. their ability to reduce the flood and drought risk while generating a series of co-benefits. Operationalizing NBS and NAS requires a context-specific understanding of drivers and barriers that exist.

To manage uncertainty, overcome barriers and capitalize on existing drivers, we propose an improved planning process for NBS and NAS that explicitly leads to implementation and investment planning. Rather than framing the process as one of overcoming barriers, we present it as a process to increase readiness for the implementation of NBS as described in detail by van der Keur et al. (2022, Chap. 1 – this volume). Following this, we further divide the readiness into three types:

- Technology readiness (TR) – linked to barriers on knowledge and absence of clear evaluation of NBS performance and uncertainties in the natural and technical system (generation of evidence) + inclusion of certain benefits such as aesthetic appeal in the design– related to setting up an appropriate level of experimentation in a context of trust. Levels run from 1 to 9 and an NBS is considered to be ready for implementation at large scale (or aggregated smaller scale) at TRL 8–9.
- Institutional readiness (IR) – linked to barriers on acceptance, trust, handling uncertainty and ambiguity, multi-functional solutions and coordination, as well as innovative regulatory frameworks to deal with the inherent uncertainty of NBS and potential liabilities. IR is positioned on the crossroads of the natural/technical and social system and is constituted by 8 categories (e.g demand for NBS, sustainability) that exist in parallel and each have to achieve sufficient maturity for the overall institutional readiness to be achieved.
- Investment readiness (IvR) – linked to capturing multiple values and valorising the multiple benefits in public-private-people partnerships and related to funding/finance barriers and economic/financial uncertainties in the social system. IVR is related to the building of innovative business models such as the NAS canvas. In analogy to TRL, IVRL consists of 9 levels and an NBS is considered to be ready for funding/financing at IVRL 8–9.

This chapter aims to document the experiences of increasing readiness in different contexts, scales and starting conditions. We present an ex-post analysis of readiness levels before and after the application of NAS methods and tools and discuss the key lessons learned.

The insights from case studies aim to help practitioners from different disciplines to design NAS with methods and tools appropriate for the context they encounter themselves in. Key messages are (1) importance of self-check to choose the right tools/methods, (2) guidance to tailoring tools and methods to specific context. Our findings also contribute to further developments in the science-policy arena on NAS/NBS approaches and methods that are explicitly considering investment and institutional readiness, in addition to the already widespread TRL.

19.2 NAS Approach: From Assessment to Implementation

The NAS approach consists of the participatory step-wise creation of NAS with NBS targeting flood and drought risks. It is based on a quantitative and qualitative assessment of NBS and their implementation schemes. The approach includes a detailed assessment of risks, costs and co-benefits and formulates adaptive implementation plans that provide a blueprint for the fair distribution of investment, risks and benefits of NBS in a context of uncertainty.

19.2.1 Participatory Adaptive Planning Framework and Readiness Levels

To increase readiness for NAS and the integration of NBS in climate adaptation and water security plans, this handbook proposes a participatory and adaptive planning (PAP) and implementation process. The framework outlining this process is shown in Fig. 19.1 and discussed in detail in by Basco & Van Cauwenbergh et al. 2022 (Chap. 7, this volume).

At the core of the PAP approach is the recognition that for NBS to be integrated in water security and climate adaptation plans, the planning and implementation process needs to address not only technology readiness, but institutional and investment readiness as well. To increase the readiness level of innovative technology such as NBS, uncertainty needs to be managed. A number of methods and tools are used at different stages of the planning process to increase knowledge and thereby reduce uncertainty related to the process and address variability. Given that the uncertainty is not only related to variability (irreducible) and incomplete knowledge (reducible), but also to ambiguity reflected by diverse stakeholders involved, management of an agreement on information transfer between parties is key.

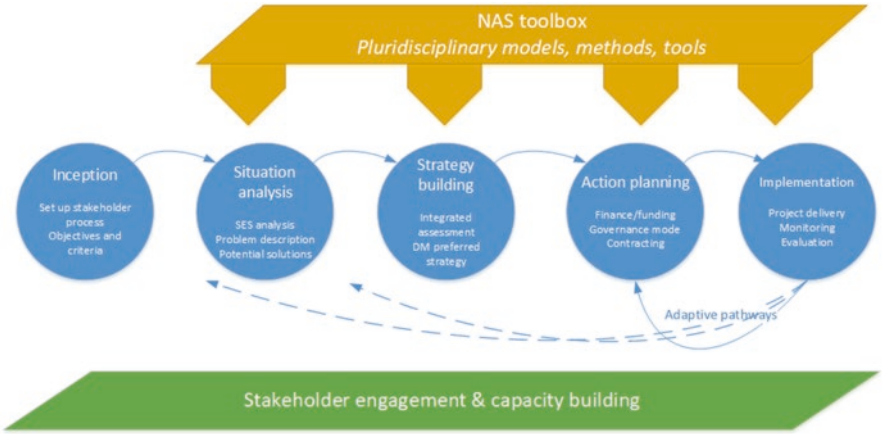

Fig. 19.1 Participatory adaptive planning process. (Adapted from Van Cauwenbergh et al. 2020)

Those elements are structurally addressed in all the different steps of the process as to assure the level of readiness is high enough to formulate implementation and investment plans. Uncertainty management is not limited to the steps of adaptive action planning and implementation using adaptive pathways, it starts in the early phases of the planning by recognizing ambiguity in problem framing, design of scenarios and potential measures, but also in the interpretation of evidence (either from models or empirical evidence) in the integrated assessment.

19.2.2 NAS Framework and Selection of Methods/Tools

To generate the needed readiness to implement NBS, a suite of methods and tools have been developed and optimised for the different case studies discussed in previous chapters. As introduced in Chaps. 4, 5, 6, 7, 8 and 9, the design of NAS involves a myriad of assessments, methods and tools in an interdisciplinary and transdisciplinary approach. At the basis of NAS design, lies a structured analysis of the system, aiming to (1) identify and formulate feasible management actions; and (2) generate and present quantitative information to enable better decisions on proposed actions targeting natural assurance. The NAS toolbox combines a number of disciplines and approaches to deal with the complexity of NBS and its multiple benefits in a risk-based context. Indeed, to address this complexity, pluri-disciplinary methods and tools are needed. Apart from methods, models and tools facilitating quantitative assessment of biophysical system behaviour, economic impacts and social risk perceptions (see Chaps. 4, 5, 6 and 7), a number of semi-quantitative and qualitative methods are used to incorporate the less tangible values of stakeholders.

As for the quantitative models, the effect of NBS in the case studies (Chaps. 10, 11, 12, 13, 14, 15, 16 and 17) has been assessed using integrated hydrological modelling, including surface- and groundwater models as well as hydraulic models. Each of these models are associated with uncertainty with respect to the availability and quality of data to set up the model, run, calibrate and validate it, but also to structural uncertainty, i.e. incomplete understanding of the representation of physical processes (Refsgaard et al. 2006) and uncertainty guidelines have been developed in e.g. van der Keur et al. (2010, 2016). Policy and decision makers within disaster risk reduction and climate adaptation need transparency and guidance on the, often long-term (deep) (e.g. Herman et al. 2020), uncertainties to make informed decisions and to consider measures that could reduce uncertainty where it matters most.

Whereas some of the methods follow a more technology heavy and data demanding top-down approach, using remote sensed data or data and process intensive hydrological modelling, several of the methods are grounded in the stakeholder reality in often local environments and where results heavily depend on the quality of the stakeholder engagement process that is described below.

The use of models, methods and tools is channeled through the planning process. Understanding of complex issues is mainly aided through the use of data and modelling in the situation analysis and strategy building steps. Different models are used in this step to cover the socioeconomic, political and bio-physical dynamics of the water system to be managed and planned. These dynamics are captured in indicators that provide comparable metrics between alternative options. As different indicators are expressed in different units, and not all indicators can be monetized toward a cost-benefit assessment, multi-criteria analysis is proposed to generate integrated assessment of alternative strategies.

19.2.3 Stakeholder Engagement at the Core of the NAS Approach

For the models and tools to be useful in the process and generate the readiness that is needed, participatory approaches with sufficient attention to capacity building and fostering social learning are needed. Throughout the entire planning process, involvement of stakeholders is key to a number of issues. First of all it helps to assure a good understanding of the often complex issues and to handle trade-offs in a societal acceptable way. But stakeholder involvement is also necessary to anticipate and adapt to a number of implementation issues to avoid producing results that those potentially impacted will not support. Indeed, choices about managing water-related risks and other natural resources trade-offs involve more than hydrology and economics. They involve people's values, ethics, and priorities that have evolved and been embedded in societies over thousands of years (Priscoli et al. 2004). Finally, as mentioned earlier, uncertainty is not only related to variability and incomplete knowledge, but also to ambiguity in the diverse stakeholders involved.

Therefore the transfer of information between stakeholders needs to be well understood, managed and agreed upon. Stakeholder involvement brings both knowledge and preferences to the planning process—a process that typically will need to find suitable compromises among all decision-makers and stakeholders if a consensus is to be reached.

By hypothesising NBS design and implementation as a collaborative decision-making process, we assume three premises: (i) NBS design and implementation need to be based on inclusive and equitable participatory processes, capable to ensure the active involvement of all different categories of stakeholders and decision-makers; (ii) collaborative decision-making for NBS implementation requires a clear understanding of the ambiguity among different decision-makers in perceiving and valuing NBS co-benefits (Giordano et al. 2020); (iii) decision-makers do not take decisions in a vacuum, but social interactions can alter preferences, choices and hence decisions (Kolleck 2013; Siegel 2009; Sueur et al. 2012).

Nevertheless, divergences in values, beliefs and problem frames may lead to collaboration structures that encourage stakeholders and decision-makers to avoid each other, turning the participatory process into a controversial and futile process (Brugnach and Ingram 2012; Giordano et al. 2017; Howe et al. 2014; Jacobs 2016; Shrestha and Dhakal 2019), resulting in a barrier to NBS (Eisenack et al. 2014; Therrien et al. 2019).

Most of the approaches described in the literature concerning conflicts analysis and resolution assume that conflicts among decision-actors derive from ambiguity in problem framing and non-conformity in their individual objectives and preferences towards alternatives. However, through effective interaction mechanisms, different decision-actors tend to align their problem frames, overcoming the barriers caused by ambiguity in problem framing. Conflicts may not occur between decision-makers with a rather different problem frame and good relationships (Liu et al. 2019).

19.3 Methods: Ex-post Analysis of NAS Using an Integrated Readiness Framework

We tested the above described NAS approach for readiness creation in a number of European case studies, ranging from small scale NBS for flood and drought management (e.g. hybrid UBW, the Netherlands), to large scale projects with focus on either drought (e.g. Medina, Spain and Danube, Romania) or floods (e.g. Lez, France and Glinščica, Slovenia, Copenhagen, Denmark). Details of these case studies are described in Chaps. 10, 11, 12, 13, 14, 15, 16 and 17 of this book.

For a number of selected case studies, we performed an ex-post self-assessment of NBS readiness both before and after implementing a series of methods and tools to support NAS design. The self-assessment uses the definition of readiness levels provided in Sect. 19.1 and attributes LOW, MEDIUM or HIGH readiness for each of the levels.

We then discuss the changes in readiness achieved in relation to the case studies' (1) varying biophysical conditions, spatial scale and vulnerability to water related natural hazards that require diverse NAS approaches, but also to (2) varying starting levels of technology (TRL), institutional (IRL) and business (IVRL) readiness for implementation of nature based solutions in NAS.

19.3.1 Selected Case Studies

Below, we briefly describe the context and projected NBS for the case studies that were selected for an in-depth analysis of readiness generation.

- Urban water buffer in the Spangen area, Rotterdam, the Netherlands: this case study is discussed in detail by Dartee et al., 2022 (Chap. 16 – this volume) and concerns a hybrid NBS at urban neighbourhood scale targeting flood and drought risk. It consists of an innovative grey underground water storage for buffering storm-water runoff with controlled release into a natural filtration system which creates a green space for the benefit of the community. The treated water is then stored subsurface in an aquifer bubble and pumped up when needed for use in the neighboring football stadium. The local water operator, municipality and regional water authority all manage part of the NBS.
- Copenhagen restored urban river scenario, Denmark: this case study is discussed in detail by Jørgensen et al., 2022 (Chap. 17 – this volume) and concerns a restored urban river stretch scenario to lessen the risk for urban groundwater flooding which result from high and rising groundwater levels due to changed patterns in water use, sewage system management and climate change. Key stakeholders involved are the city of Copenhagen (and adjacent Frederiksberg), Copenhagen Water Utility (HOFOR), an insurance and pension umbrella organization, national and regional authorities, environmental NGOs, legal advisors and urban planners.
- Lez watershed (including the city of Montpellier), France: this case study at medium basin and (peri-) urban scale discussed by LeCoent et al. 2022 (Chap. 14 – this volume) explored whether different scenarios of green infrastructure (water retention basins, bioswales, green roofs…) and conservation of peri-urban natural and agricultural land, considered as NBS scenarios may reduce runoff flood risks and address climate adaptation challenges. Key stakeholders involved are Montpellier city, the Lez river basin authority, CCR (French reinsurer), local communities, environmental associations, and local and national government.
- Glinščica, Slovenia: this case study at medium scale discussed by Pengal et al., 2022 (Chap. 15 – this volume) explores NBS river restoration and management to reduce flood risk in the Glinščica Stream, upstream of Slovenia's capital, Ljubljana. The torrential character of this river, together with advancing urbanization, climate change (less frequent, but higher intensity rainfall) and hard regulations, results in regular flooding of the Vič and Rožna dolina districts of Ljubljana.

- Medina del Campo aquifer recharge, Spain: in this large scale case study discussed by Mayor et al., 2022 (Chap. 11 – this volume) a number of different NBS were considered to deal with increased flood and drought risk; Managed Aquifer Recharge (MAR), change of crops, agricultural soil conservation, and water reuse. Stakeholders involved are the Duero river basin authority, regional and provincial government as well as associations in the environmental and agricultural sectors, local cultural associations, municipal councils, universities, private companies and civil protection.
- Lower Danube basin, Romania: in this large scale case study discussed by Scrieciu et al., 2022 (Chap. 10 – this volume), the focus was on identifying NBS to reduce natural hazards, mainly focusing on flood management, but also on reducing drought and desertification aggravated by climate change. Involved stakeholders are the ministries of environment, water, agriculture and rural development as well as the national administration of Romanian waters, General Inspectorate for Emergency Situations, the National Association of Insurance and Reinsurance Companies, the Lower Danube River Administration and Local authorities & NGOs.

19.3.2 Checklist of Questions

To assess how readiness was created (or not) in the selected case studies, we performed a readiness assessment before and after the NAS approach and analysed how the NAS toolbox and the larger (changes in) context contributed in the creation of readiness. Findings are qualitative and based on a self-assessment by the leading researcher of each case study, using the checklist of questions in Table 19.1.

19.4 Results: Assessment of Readiness and Its Increase Using the NAS Approach

Using the checklist above, key experts of each of the case studies assessed the technology, institutional and investment readiness before and after the interventions of the NAS approach. Table 19.2 summarizes the assessment and lists the key methods and tools used. In continuation, we discuss how the NAS approach in general and the specific methods/tools mobilized have contributed to the increase in readiness.

19.4.1 Urban Water Buffer, The Netherlands

This case study started at high readiness levels. The technology of water storage and bioremediation – infiltration had been tested at lab scale. Institutionally, there had been prior experience in the municipality with building green infrastructure as part

Table 19.1 Practitioners' checklist for participatory NBS implementation/investment planning and relation to readiness *(darker colors = higher contribution to readiness)*

Phases	Actions/Information to be gathered	Check list questions	Readiness		
Inception phase			T	IV	I
Set up the stakeholder process	Identify and characterize (key) stakeholders and their interlinkages Define core working group Agree level of involvement and modes of communication Assure continuity in the process	Support for adaptation guaranteed at high level A core team on adaptation in place Institutional cooperation set up All affected stakeholders involved Human and financial resources secured in the long term Target group-specific formats for awareness raising carried out			
Define Objectives, criteria	Based on prior assessment of risks and existing policies, what are key objectives of NBS in the hydro-social system (reduced risk as primary objective/benefit and increased socio-economic opportunities as co-benefits) Identification of criteria/yardsticks that allow you to evaluate whether the objectives are reached?	Appropriate indicators developed			
Situation analysis					
Assess baseline Situation analysis	Description of natural, socio-economic and institutional system Identification of problems and controversies Stakeholder analysis, DPSIR Assessment of ambiguity and risk perception	A first overview on climate-related impacts gained Ongoing activities with relevance for adaptation identified Common understanding on climate change adaptation gained A systematic overview on past weather events, their consequences and response actions in place Understanding of future climate change gained Non-climatic stress factors identified and considered Main concerns are identified that require an adaptation response Transboundary issues considered Knowledge gaps and uncertainties in climate change summarized and made explicit			

(continued)

Table 19.1 (continued)

Phases	Actions/Information to be gathered	Check list questions	Readiness		
Inception phase			T	IV	I
Identify indicators, methods and tools	Identification of quantitative and qualitative assessment needed to provide relevant information (related to policy objectives and stakeholder preferences) Checklist of available methods/tools	An approach on how to deal with uncertainties developed			
Scenarios	Storylines of possible futures (drivers of change, external to the system) List of drivers and translation into quantitative scenarios to be modelled				
Strategy building					
Formulate solutions (measures, alternatives)	Identification of interventions/measures/alternatives in collaboration with key stakeholders (Participatory) prioritization of promising measures that will be modelled	Gaps and barriers that hindered an adequate response in the past identified and understood A full portfolio of adaptation options considered Measures considered are aligned with existing regulations and policy priorities (SBC)			
Combine priority measures into strategies	Separation of interventions in short/medium/long term	Suitable adaptation options were described in detail Clear scope of preferred solution (SBC)			
Assess strategies under different scenarios, including capacity building	Quantification of indicators (including life cycle costs) Identification of no-regret interventions (based on scenarios) Definition of no-regret strategies	A prioritisation system of adaptation options developed in cooperation with stakeholders Reliable information on hydro-meteorological risk reduction by measures (SBC) Possible synergies and conflicts identified and taken into account			
Decision making (negotiation, choice and compensation): select preferred strategy	Communication of indicator results for different strategies Use of different decision-making methods (e.g. MCA, CBA, scorecard, voting, …) And (group) decision making aided by the assessment scores provided in previous step	Cost-benefits of options assessed Reliable evidence of positive cost-benefit considering direct and indirect costs (EBC) Preferred adaptation options selected for implementation Adaptation strategy developed and politically adopted Direct beneficiaries and willingness to pay identified (EBC) Compensation for losers identified (EBC)			

Action planning					
Enabling environment, develop business plan and distribute responsibilities Mobilize financing and funding	Discussion of role and responsibilities for the implementation of the preferred strategies Timeline of actions Identification of funding/finance Development of business plan Definition of service levels, performance indicators and contract negotiation Risks and liabilities Funding/Finance strategy	Action plan developed Steps for implementation set Timeline of actions and capital investment clearly defined (CBC) Risk and liabilities are clarified (CBC) Identification of life-cycle cost (FBC) Quantification of revenue streams considering tariffs, transfers and taxes (FBC) Access to funding or financial instruments to close funding or financing gaps (FBC) Responsibilities of organizations in procurement, construction and operation are clarified (MBC)			
Implementation					
Implement	Construction of green-grey infrastructure and enforcing regulatory arrangements	Contracts needed and procurement strategy are clear (MBC)			
Monitor and evaluate	Data collection on performance indicators Communication of monitoring results Check of evolution monitoring levels with initially established service levels and NBS objectives	Appropriate M & E provisions for both your adaptation policy's objectives and selected adaptation options developed Appropriate indicators from step 1 checked and operationalized in M & E plan			

Own elaboration after European Commission 2013; HMTreasury 2018; Altamirano et al. 2021
SBC Strategic business case, *EBC* economic business case, *CBC* Commercial business case, *FBC* financial business case, *MBC* management business case, *TRL* Technology readiness level, *IVRL* investment readiness level, *ISRL* intitutional readiness level

Table 19.2 Readiness level before and after the NAS approach

Readiness level	T	Iv	I	Methods/tools used	T	Iv	I
Urban water buffer, NL	6	5	6	Hydrological modelling, stakeholder workshops, willingness to pay surveys	8	9	8
Copenhagen city plan, DK	6	5	6	Hydro-geological modelling, economic assessment, system dynamics modelling and social risk perception	8	7	8
Lez basin, FR	6	5	5	Runoff flooding risk modelling, economic assessment suite of methodologies, economic valuation and perception of co-benefits	7	8	7
Glinščica, SL	5	4	4	Hydrologic and hydraulic modelling, implementation of Free Station monitoring, stakeholder involvement	8	7	8
Medina aquifer recharge, ES	4	4	4	Hydro-geological modelling, ecosystem services assessment, economic modelling, stakeholder workshops, integrated modelling (meta-model) and scenario analysis, social risk perception and system dynamics modelling, NAS canvas generation	5	7	7
Danube delta, RO	5	4	4	Hydro-geological modelling, ecosystem services assessment, economic assessment, NAS canvas generation and framework for funding and finance,	7	6	6

T Technology, *Iv* Investment, *I* Institutional

of climate adaptation plans and there was interest from the neighborhood organizations who wanted to increase green spaces in the area. Finally, the investment readiness started at a high level as well, with support from a technology and innovation fund (TKI) toward the design of the system and interest by the neighboring football stadium to buy the water once the system would be built. As a large water user, the football stadium was interested in reduced costs for irrigating its field. Through the NAS approach, the readiness was further increased through a series of workshops, interviews and co-design sessions that looped a number of key stakeholders into the conversation on detailed design and operation of the system and by doing so, furthered the confidence of the stakeholders that the proposed scheme would work. The conversation was championed by a local actor at the municipality, who contributed largely to overcoming the disconnects between municipal silos and highlighted the potential co-benefits of the project as it would be contributing to government programs around resilience and climate adaptation, while reducing the flood risk in a non-privileged area of the city. Investment in the building and implementation of the scheme was further secured by the connection between the football stadium as large water user and the water utility company Evides that joined the project triggered by the support of the regional water authority and supporting the incorporation in their network of the bioremediated water stored underground.

19.4.2 Copenhagen City Plan, Denmark

The case study identified the potential for river restoration, including an estimation of avoided costs of groundwater flooding induced damage for insurance companies, the city of Copenhagen and citizens. Also, barriers for NBS implementation were identified by stakeholder involvement and subsequently analysed by participatory modelling. The Copenhagen case study (Jørgensen et al., Chap. 17, this volume) contributed to increasing the technological readiness level (TRL) linked to advancing knowledge and performance with respect to developing a hydrological modelling approach for exploring the effect on rising groundwater level by reestablishing an urban river from a currently piped stream in Copenhagen. The developed integrated surface- and groundwater hydrological model can subsequently be (re) applied to evaluate additional and new scenarios including climate change and decisions by the municipality for climate adaptation measures. As the modelling tool is physical based it can be applied in other (urban) environments as well. The investment readiness level (IVRL) has been addressed by considering a simple damage function approach by combining hydrologically modelled effects on groundwater level as a result of the draining effect of the restored urban river NBS scenario with reported insured damage. Assumptions on how shallow groundwater levels relate to incurred damage makes it possible to value the avoided damage which affects the IVRL. The results show that by reopening the river, an economic benefit is obtained because the river now functions as a drainage channel which prevents flooding by groundwater of subterranean structures, notably housing cellars, and potentially as a recipient of stormwater events by connecting to cloudburst management measures. Valuation of co-benefits in addition to avoided damage is anticipated to contribute substantially to the IVRL. Finally, the institutional readiness (IRL) is explored by the integration of stakeholder's knowledge in the co-design and implementation process of NBS to support complex decision-making processes and was carried out by (1) participatory modelling activities to elicit and structure stakeholder's risk perception, (2) mapping the interaction among decision-makers and stakeholders, and by (3) deriving Fuzzy Cognitive Maps (FCM) from Group Model Building. The FCM simulation showed that NBS implementation requires effective cooperation among different decision-makers to define potential interventions and to reduce the level of conflicts and to facilitate collaborative decision-making.

19.4.3 Lez Basin, France

In the Lez study (Le Coënt et al., 2022 – Chap. 14 this volume), the Lez basin demonstration site at the at the watershed/city scale showed the potential of scenarios of NBS (green infrastructure and urban sprawl control) at the watershed scale to reduce urban flooding risks and address territorial challenged. The TRL was increased by designing spatially-explicit green infrastructure development scenarios and

modeling their impact on urban flood hazard. The economic assessment revealed that NBS could reduce flood damage cost by 14–20%. In addition, a survey with 400 citizens demonstrated the large value granted by residents to NBS co-benefits, notably climate change mitigation, landscape conservation and air quality improvement. Overall the cost-benefit analysis revealed the economic interest of a large NBS programme as well as the magnitude of revenue streams that should be mobilized to finance NBS (increased IVRL). The institutional readiness (IRL) was addressed and strengthened through the involvement of stakeholders to increase the knowledge on the potential of NBS to mitigate flood risk and other challenges and to help identifying potential strength and barriers for implementation. To increase IRL, the results of this study will need to be translated into strategies/programs led by municipalities of the watershed in which smaller scale projects at the neighborhood scale may be developed for concrete implementation. The leadership of municipalities is key to increase IRL and reach that new step of implementation.

19.4.4 Glinciska River Basin, Slovenia

The Slovenian demonstration site (Pengal et al., 2022 – Chap. 15, this volume) considered as NBS measures to mitigate flooding hazards: retention areas, re-meandering of the river and wetland restoration in the Glinščica catchment area. While none of NBS technologies are new or unproven, implementation and evaluation of NBS strategies were enhanced and supported by integrated HEC-HMS - HEC-RAS and FEV based hydrological/hydraulic rainfall-runoff modelling. The increased know-how for achieving this in combination with implementing FreeStation multifunctional monitoring of the effects of implemented NBS increased the TRL. In order to assess the investment readiness, an economic analysis was performed to compare business as usual (BAU) with NBS strategies over a 30-year timeframe. The cost of NBS strategies were approximately 60% lower that BAU, although large barriers for implementation remain. Institutional barriers include poorly coordinated institutions at several levels, in-effective regulatory and legislative frameworks, but stakeholder based consultation and demonstration of co-benefits increased awareness and may decrease uncertainty and ambiguity on NAS and NBS and contribute to increased institutional readiness (IRL) on the longer term.

19.4.5 Medina Aquifer, Spain

Technological readiness level has been increased substantially through a geo-hydrological and geophysical assessment of managed aquifer recharge (MAR) based ecosystem services as well as the role of groundwater sustained ecosystem services. Stakeholder workshops were then organized to co-create viable business options for the public/private financing of management measures that increase the Investment readiness level (IVRL) of groundwater related ecosystem services.

The demonstration site identified a number of feasible technical and institutionally supported NBS strategies to positively contribute to the institutional readiness level (IRL) and evaluated the acceptability of the NBS solutions. Apart from a series of structural NBS, stakeholders in this case study ranked "increase awareness and environmental education" as well as "Regulatory fees and improving users' organization" as most appropriate to deal with the increasing climate variability in this area.

19.4.6 Danube Floodplain, Romania

In the Danube case study, the NAIAD project aimed to create an efficient network of stakeholders trained to apply the methods and scenarios identified in the project, in order to promote sustainable development for extreme events mitigation by using the ecosystems services, ecological (re)construction and green solutions. The technical readiness level for Danube floodplain restoration NBS planning scenarios was substantially supported by integrating local stakeholder knowledge in hydraulic modelling (HEC-RAS) for assessing river flooding vulnerability. Stakeholder knowledge was incorporated by means of two workshops from which a causal loop diagram (Vensim model) was derived to explain and support expected impacts, benefits and co-benefits of planned NBS. This also supported the increase in institutional readiness. Finally, the investment readiness was supported by assessing the economic parameters related to damage as a consequence of flooding with and without the implementation of floodplain restoration NBS. The economic assessment was based on a GIS aided analysis and collected information from various sources on flood damage.

19.5 Discussion

In this section we discuss how the different elements of the NAS approach facilitate the increase in readiness for NBS/NAS to reduce flood and drought risk. We divide the discussion in reflections on the methods/models and tools used and on the participatory process. We then discuss some lessons learned and provide recommendations for the use of the approach in different contexts.

19.5.1 The NAS Toolbox and Contribution of Methods and Tools to Technology and Investment Readiness

Technology readiness is the first necessary step to ensure consideration by local decision makers of the relevance of NBS for water risk management. In the case of flood risk, the civil engineer culture remains dominant and the demonstration of the

effectiveness of NBS for flood risk management remains a challenge. In the case studies above, the modeling of the effectiveness of NBS as compared to grey solutions for the reduction of flood risk has been key in the pathway towards implementation, especially in those case studies initially strongly biased towards grey solutions, as for example in the Brague case (Chap. 13 – this volume). The assessment of the effectiveness of NBS also provides the basis for the economic evaluation of NBS.

The economic assessment compares elements to evaluate the magnitude of the costs and benefits generated by NAS. It is built on the preliminary assessment of the effectiveness of NBS using key indicators, whose monetary value is subsequently evaluated. The proposed Cost-Benefit analysis method (Chap. 6), helps (i) identifying whether a given NAS presents positive net benefits, (ii) determining among different NAS which one is preferable from an economic standpoint. The economic assessment also helps identifying the magnitude of the different benefits of the NAS, which is the basis to identify revenue flows and a viable business model, necessary to achieve investment readiness. Some indicators such as non-monetary impacts on water risks and co-benefits that can not or only partially be valued monetarily such as social and environmental indicators are fundamental in NBS assessment and the decision making process for the development of NBS. Economic assessments of NBS should therefore be complemented with other integrative approaches such as Multi-Criteria Decision Analysis (MCDA) described in Chap. 7.

Investment readiness can be pursued through the generation of the NAS business canvas (Mayor et al. 2021) and can be translated in investment plans built around the 5 business cases for water security proposed by (Altamirano et al., 2020), which are further discussed by Mayor et al. (2022 – Chap. 7, this volume). When analysing the different boxes of the business canvas, it becomes clear how investment readiness is generated in the planning process; from the start of the inception phase, throughout situation analysis, strategy building and action planning. A clear understanding of the monitoring and evaluation as well as how different parties of the public, private, and communities are related to it, is further increasing investment readiness.

19.5.2 Importance of Capacity Building and Stakeholder Engagement for Institutional Readiness

Experiences in the different case studies show that capacity and readiness building is key for the creation of an implementable NBS. Given the multitude of stakeholders involved project and their multiple objectives and interests as well as knowledge frameworks. Different levels of capacitation will relate to different targets for the readiness (individual, group and institutional). With the participatory process in PAP we are mainly aiming at capacity building at group level (the multi-stakeholder platform) and at the institutional level (which directly relates to institutional readiness).

The *ex-post* assessment of the activities in the selected case studies demonstrate to what extend the PAP process allowed pursuing the three key elements of a stakeholders' engagement process for NBS/NAS effective implementation, i.e. (i) equitable engagement of different stakeholders; (ii) based on a clear understanding of ambiguity in problem framing and risk perception; and (iii) enabling cooperation among different institutional actors. Pros and cons of the adopted approaches are discussed further in the text.

The elicitation and analysis of the different risk perceptions and problem understanding (for more details on the implemented methodologies, please, refer to Chap. 5 of this book) were at the basis of the stakeholders' activities in several demo sites. These activities contributed in enhancing the institutional readiness level. Specifically, the implementation of the PAP process contributed in making clear that different stakeholders' needs and concerns need to be accounted for during the NBS design phase. Contrary to most of the works mentioned in the scientific literature, in which NBS are mainly described as solutions for addressing different risks, the experiences carried out in the case studies demonstrated that the co-benefits are, in many cases, as important as the risk reduction itself. Therefore, accounting for the stakeholders' co-benefits perceptions and valuation since the NBS design phase is of utmost importance. NAS activities demonstrated the suitability of disciplined methods and tools that facilitate stakeholders' dialogue and help reflecting on the different sources of ambiguity in co-benefits definition and valuation.

Among the different enabling elements supporting institutions in dealing with a complex issue such as NBS implementation, the institutional cooperation demonstrated to play a key role in different case studies. NBS implementation requires effective flow of information and knowledge among the different institutional and non-institutional actors. Lack of trust or limited understanding of the role played by the others, could hamper the cooperative implementation of important tasks required for the NBS implementation. It is worth noting that the improvement of institutional cooperation has been defined as one of the most important steps for the institutional readiness by several stakeholders during NBS implementation. Specifically, we learned that, in order to be effective in reducing water-related risks and in producing the expected co-benefits, NBS implementation needs to be supported by several socio-institutional measures, claiming the involvement and cooperation of other institutional actors. Finally, the experiences carried out in the Copenhagen demo demonstrated that, in urban areas, NBS need be thought as a part of an urban systemic interventions' strategy, whose implementation requires the cooperative intervention of different decision-actors.

19.5.3 Lessons Learned for NAS Building in Europe and Other Contexts

Our results also point to some important implications for NBS uptake. For one, our detailed case study analysis showed that decision support models and tools were only marginally used during the planning and implementation process.

Government actors did not rely on the extensive cost-benefit and multi-criteria assessments that were available, focusing on political and institutional issues instead. This is somehow contradicting (Droste et al., 2017), who emphasizes the importance of a comprehensive assessment of the multi-functionality of NBS through elaborated cost-benefit or multi-criteria assessment methods. Findings suggest that for NBS uptake it is far more important to have willingness and commitment from the key stakeholders. Nevertheless the need for evidence on cost-benefit ratios of the NBS in the case studies was highlighted during a mock funding pitch at a January 2020 stakeholder meeting in Copenhagen. The repetitive feedback of experts from the private and public funding and financing community (such as TNC, EIB, and private investors) here was that costs and benefits of the proposed projects should be better evidenced before investors. This indicates that importance of evidence might arise at later stages of the NBS planning process and also toward upscaling, calling for support by above mentioned methods and tools.

Secondly, we found that co-benefits can be a driver for success when the funding is available, a clear owner of the NBS project exists and there is a concretized level of service. In the case of Rotterdam, the NBS' ability to generate cheaper water supply for the sport arena nearby, leveraged the needed support for TKI funding and ownership, with flood reduction and recreational value as co-benefits functioning as leverage for the willingness and acceptability of the project by other stakeholders. In cases where the added value of the NBS is not clearly linked to an existing operator, co-benefits have to play a stronger role. This was for example the case of the Lez and Braque demo, where public-good co-benefits (air quality improvement, biodiversity, climate regulation) represent the largest value given by residents to NBS scenarios but may be more challenging to turn into revenue streams for project funding as potential mobilizer of institutional support. However more in-depth analysis is needed in all demos to see whether co-benefits can play this role in general.

Thirdly, we made a number of observations on the aspect of integration that underlies successful planning and implementation of NBS. Case study analysis shows a reality where objectives and related indicators are driven by sectoral interests. This makes that what is defined as a benefit or co-benefit depends on the viewpoint of the stakeholders involved. In the Rotterdam case, the decision making on the NBS was defined by the leading organization (related to mandate and funding) and the clear risk/benefit cycle (involving Evides and Stadium) proved crucial to facilitate that decision making (see point above). The case shows that institutional coordination is a key barrier to implementation (and that this is happening even within the municipality). Finally we observed that in order to mainstream the NBS, evidence of performance across (co-) benefits is needed. However, little to no monitoring incentives or interest exists.

Our findings show that the investment and institutional readiness are an important factor to consider in the mainstreaming of NBS and NAS. While TRL are generally higher at the start of the projects, large differences existed in the IRL and IvRL and tools and methods need to be adapted to address this appropriately.

This has implications for the implementation of NBS in non-EU contexts. A study of the relation between NBS and policy support by Van Cauwenbergh et al. (2021) highlight that while international policies such as Sendai, the Paris agreement and SDGs are generally favorable for the integration of NBS into NAS, policy support at national and regional level are equally important. Indeed, for NBS to be integrated into operational management plans at different scales, they need to be linked to the practices and policy frameworks at lower institutional levels. Likewise, the presence of funding and financing opportunities is a fundamental condition for the implementation of NBS and NAS. While nature restoration and ecosystem-based investment is starting to become accepted in more developed nations, earmarking funds in less developed nations is challenging. It remains to be seen to what extent global and international finance players and investment funds such as the Green Climate Fund and the Natural Capital Financing Facility are able to promote mainstreaming of NBS in context with low national and regional investment capacity.

19.6 Conclusion and Recommendations

This chapter set out to discuss the methodological approach for natural assurance schemes (NAS) in a broad range of case studies. Incorporating inter- and transdisciplinary approaches in a structured participatory adaptive planning process, we discuss and assess how the step-wise use of multiple methods and tools in combination with stakeholder engagement and capacity building, is able to increase readiness for NBS and NAS. To structure and support this process, (i) technological, (ii) investment and (iii) institutional readiness levels are considered to assess the potential of NBS operationalization in different physical, socio-economic and institutional settings. This is demonstrated for contrasting cases to facilitate upscaling and replication.

Results of selected case studies show the assessment of investment, institutional and technology readiness before and after the participatory adaptive planning (PAP) approach. The PAP approach is endorsed to address the inherent uncertainty in the NBS implementation process and in turn, increase readiness. It has been demonstrated that most case studies have achieved substantial technology readiness, given the large amount of data-driven and physical modelling driven approaches combining engineering and natural sciences expertise. Hydrogeological and hydraulic modelling techniques were applied from urban scale to large floodplain scale and physically based assessments obtained of NBS effects to mitigate water related hazards. In addition, system dynamic modelling mapped stakeholder risk perception and the interaction among stakeholders and decision maker in the planning process, to support the assessment of institutional readiness.

Obtained knowledge and experience from the included case studies showed that most multifaceted tailoring was needed to assess and generate institutional readiness and investment readiness. Institutional readiness is generated throughout the

entire planning and design process, through a combination of joint assessment of risk perceptions, crafting of institutional set-up and facilitation of awareness and agreement on responsibilities in the NBS planning process. Investment readiness is supported through the generation of the NAS business canvas to highlight the value proposition and opportunities for risk-benefit transfers in a regulated environment. The NAS canvas can be translated in investment plans built around the 5 business cases for water security proposed in the Financing Framework for water security.

Recommendations from the work presented in this book take point of departure in the developed stepwise approach to assist in generating the natural assurance schemes, demonstrated in case studies at contrasting scales as a guideline for NBS planning and using the concept of technological, investment and institutional readiness in the participatory and adaptive planning process. Considering the inherent uncertainty of NBS and their implementation in the future (related to the multitude of actors involved and the dynamic nature of NBS performance), the proposed adaptive planning and management approach aims to provide sufficient flexibility on the risk-benefit transfers while providing needed investment security. These findings provide operational guidelines for practitioners and researchers to facilitate the creation of NAS.

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