



Nature-based Solutions for Flood Mitigation and Coastal Resilience

Analysis of EU-funded projects

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Research and
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Nature-Based Solutions for Flood Mitigation and Coastal Resilience Analysis of EU-funded Projects

European Commission
Directorate-General for Research and Innovation
Directorate C — Healthy Planet
Unit C3 — Climate and Planetary Boundaries

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Manuscript completed in April 2020

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PDF

ISBN 978-92-76-18197-2

doi:10.2777/374113

KI-01-20-259-EN-N

Luxembourg: Publications Office of the European Union, 2020

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Nature-Based Solutions for Flood Mitigation and Coastal Resilience

Analysis of EU-funded projects

Zoran Vojinovic

Valorisation of NBS projects

The initiative to analyse the impacts of EU-funded projects in the area of NBS and valorise their results in terms of EU added value and policy relevance was initiated in December 2019. Six policy reports and a final consolidated report were produced and can be found at: <https://ec.europa.eu/research/environment/index.cfm?pg=nbs>

The present report aims to provide an overview of results from EU-funded NBS projects and how they support policy implementation in relation to Flood Mitigation and Coastal Resilience.

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EXECUTIVE SUMMARY

It has become a well-accepted fact that traditional “grey” responses to floods and coastal resilience are no longer achieving desirable results. Nature-based Solutions (NBS) represent a relatively new response towards disaster risk reduction, water security, and resilience to climate change, which has a potential to be more efficient, cost-effective and sustainable than traditional measures.

This report aims to provide an overview of the results from EU-funded NBS projects in support of policy instruments and to identify the gaps for future R&I investments. The term ‘policy instruments’ refers here to documents such as directives, frameworks and strategies at EU or Member States levels. A number of projects from several EU research programmes such as FP7, HORIZON 2020, INTERREG, COST Actions and LIFE were reviewed in relation to the three related policy instruments, namely Floods Directive, EU Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 and EU Strategy on Adaptation to Climate Change.

The review confirms that a considerable knowledge and evidence base has been gained through various EU research programmes and actions and through the Commission’s own internal scientific services (Joint Research Centre). However, there is still a large gap between the research efforts concerning small- and large-scale NBS, as small-scale interventions have received greater attention. In view of the limitations of individual small-scale interventions, which is mainly related to their inability to cope with larger rainfall events, future research efforts should address “networks” (or “trains”) of interconnected small-scale NBS, as well as large-scale NBS and their hybrid combinations with grey infrastructure for a range of topics (e.g., performance characteristics, design standards and guidelines, coupling between modelling technologies and real-time monitoring and operation systems, cost-effectiveness, financing mechanisms, governance, social acceptance, etc). Understanding the performance of different types and scales of NBS, associated investment and operational costs, possibilities for achieving benefits and co-benefits as well as their unforeseen negative effects and how they change over time would prove valuable information for successful implementation of new and optimisation of existing interventions. For small-scale NBS, further research concerning their multi-functionality and co-benefits would be very beneficial.

The reviewed policy instruments do not sufficiently address contribution from NBS, and when included, they provide more general statements without specific reference to concrete set of actions and how or in what way they should (or can) be taken to support these interventions. Hence, future versions of these documents should provide more explicit reference to NBS interventions individually and in their hybrid combinations with grey infrastructure. Furthermore, the need for implementation of NBS provides an

opportunity to achieve better synergy and coordination of efforts at the EU and national Member States levels through integration of such measures into the national policy instruments of Member States.

Nature-based Solutions to societal challenges are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-based Solutions must benefit biodiversity and support the delivery of a range of ecosystem services.

For more information visit the European Commission webpages on Nature-based Solutions <https://ec.europa.eu/research/environment/index.cfm?pg=nbs>

1. INTRODUCTION

Out of all types of natural disasters those disasters that are related to hydro-meteorological phenomena (e.g. floods, storm surges, hurricanes/typhoons, among others) have shown the fastest rate of increase in their frequency and intensity (e.g., Guha-Sapir et. al., 2016). With growing trends of climate change and sea level rise, the challenges concerning flood management are likely to become even more demanding. Adaptation to climate change provides an opportunity to improve our current practices by introducing Nature-based Solutions (NBS) which, if implemented properly, can also provide multiple co-benefits¹ besides flood risk reduction.

The term NBS appeared in 2008 and it is considered to be an “umbrella concept” for a range of different terms. Ruangpan et. al., (2020) identified eight different terms that relate to NBS in the context of hydro-meteorological risk reduction. These are: low-impact developments (LIDs) which appeared in 1977, best management practices (BMPs) appeared in 1980, water-sensitive urban design (WSUD) appeared in 1994, green infrastructure (GI) appeared in 1995, sustainable urban drainage systems (SuDs) appeared in 2001, ecosystem-based adaptation (EbA) appeared in 2009, ecosystem-based disaster risk reduction (Eco-DRR) appeared in 2010 and blue-green infrastructure (BGI) appeared in 2013.

These terms are mainly related to small-scale NBS which represent solutions applied at the urban or local scale, for instance at the level of individual buildings, streets or roofs (e.g., filter drains, porous pavements, green roofs, rain gardens, vegetated swales, retention/detention ponds and basins, rainwater harvesting, bioretention, infiltration trenches, Figure 1a and Figure 2). Large-scale NBS are solutions which are applied in rural and coastal areas, river basins and/or at the regional scale (e.g., large retention basins, lakes, flood plains, wetlands, forests, beach nourishment, mangroves, coral reefs, etc., Figure 1b).

The review of literature to date confirms a large gap between the research efforts concerning small- and large-scale NBS with small-scale NBS receiving far greater attention. This could be due to several reasons. One reason is that small-scale NBS are very attractive for storm water management and regeneration of urban areas. They are also less complex and their benefits and co-benefits can be observed relatively soon after their implementation. Also, research experiments concerning small-scale technologies are more conveniently installed in labs. Furthermore, the costs concerning their pilot implementations, operation and maintenance, at both individual and public levels, are also more affordable.

Further to the above, there is growing evidence that small-scale NBS can provide multiple benefits to urban areas and ecosystems (e.g., flood mitigation, enhancement of biodiversity, creation of new jobs and promotion of human well-being). For example, Eckart et. al., (2017) reviewed the performance and implementation of LIDs (which can be regarded as small-scale NBS) and provided a summary of the knowledge of LID

¹ In the context of NBS, terms benefits and co-benefits refer to their primary and secondary functions. For example, in case of hydro-meteorological risk reduction, benefits would typically refer to the reduction of floodwater depth, flood extent and flood duration, while the co-benefits would refer to aspects such as energy saving, amenity, aesthetics and human well-being.

as a promising stormwater management technique and climate change mitigation measure. Compared with traditional urban stormwater management practices, LID alternatives have the function of returning the runoff using natural processes (Stovin et. al., 2010; 2015; 2017). Qin et. al., (2013) analysed the performance of an urban drainage system in an urbanizing area of Shenzhen, China, where some LID practices (e.g., swales, permeable pavements and green roofs) are designed to reduce urban flooding. It was reported that such measures are more effective in flood reduction for shorter storm events. In addition, Dietz (2007), reported that a green roof can reduce 60–70% of stormwater volume when compared to a conventional roof. Alfredo et al. (2010) found that green roofs can delay and prolong the roof discharge and reduce its peak rate by 30–78% compared to a standard roof surface. Keesstra et. al. (2018) and Bengtsson et. al. (2005) also provided evidence of green roof water quantity performance benefits.

Figure 1. Examples of small (a) and large-scale NBS (b)



(a) Green roof in Malmo, Sweden. The main purpose is to reduce the stormwater runoff and mitigate flood risk. A green roof can also provide other economical, ecological and social benefits, i.e., co-benefits (e.g., purify the air, reduce the ambient and indoor temperature, save energy and enhance biodiversity in the city).

(Photo: Alison Duffy)



b) The lake Egå Engsø in the bay of Aarhus, Denmark - one of the H2020 RECONNECT demonstration sites. The purpose of establishing the wetland “Egå Engsø” is to reduce the nitrogen supply to Aarhus Bay, to improve the natural conditions in Egådalen (the valley of Egå) and to reduce the flood risk from the river Egå. The wetland also enhances the area’s recreational value. (Photo: Casper Tybjerg, TTF)

Other NBS have also been shown to attenuate runoff volumes. Abbott and Comino-Mateos (2003) measured the outflow from a car park with a permeable pavement system and found that on average, only 22.5% of runoff leaves the system during a storm, and that a 2-hr storm event takes two days to drain out of the system. Fassman & Blackburn (2010), in turn, found that the peak flow from a permeable pavement underdrain is less flashy and tends to show less variation overall than that from asphalt surface during storms. Chapman & Horner (2010) reported that a street-side bioretention facility in Washington can achieve 26–52% of runoff retention for certain rainfall events.

Figure 2. Examples of small-scale interventions



a) Filter drain, Dunfermline, Scotland.
(Photo: Alison Duffy)



(b) Filter strip and swale, Dundee, Scotland.
(Photo: Alison Duffy)



c) Permeable pavement, Dundee, Scotland.
(Photo: Alison Duffy)



d) Infiltration Basin, Angmering, England.
(Photo: Alison Duffy)



e) Pond, Bicester, England.
(Photo: Alison Duffy)



f) Streetside rain garden, Eindhoven, Netherlands.
(UNaLab project. Photo: L. Postmes)

A good example of an initiative that combines several GI flood protection measures at the urban scale (i.e., small-scale NBS) is the Sponge City Programme (SCP) in China (Chan et al., 2018). The measures implemented within this initiative aim to provide multiple opportunities for integration between stormwater management and flood control, landscape architecture and building design, eco-hydrology and land-use planning as well as social and environmental well-being.

In the UK, flood risk mitigating remains a key priority for the Government and in the draft London Environment Strategy, the Mayor encouraged the use of SUDS as a way to manage stormwater in view of their co-benefits that they can also deliver (e.g., improved air and water quality, greater biodiversity and reduced noise). The UK Construction Industry Research and Information Association (CIRIA) developed the SUDS construction manual as a guidance document for the construction of SUDS to support those designing, specifying and constructing such measures and helping them to understand and avoid common pitfalls (CIRIA, 2015).

With regards to large-scale NBS, the Dutch 'Room for the River' Programme represents a paradigm case for implementation of such measures. It consisted of 39 local projects which combine different types of measures such as floodplain lowering, dike relocation, groyne lowering, summer bed deepening, water storage, bypasses and floodways, high-water channels, removal of hydraulic obstacles, and dike strengthening (Klijn et al., 2013). The benefits of that programme were not observed only with respect to flood risk reduction but also in relation to enhanced opportunities for recreation, habitat and biodiversity enhancement (Klijn et al., 2013).

The [European Environment Agency](#) reports that 70 to 90% of Europe's floodplain areas are degraded due to the human intervention into the river bodies. Restoration of floodplains through implementation of NBS would not only ensure protection from flood damages further downstream but it would also prevent erosion, replenish groundwater aquifers, improve soil health and restore biodiversity, which are all necessary for healthy and resilient ecosystems.

Another example of large-scale NBS implementation is the Laojie River restoration project in Taoyuan in Taiwan. The focus of this work was on changing the channelised, culverted watercourses into an accessible GI corridor for the public (Chou, 2016). This work was inspired by the Cheonggyecheon Stream restoration project in South Korea which represents yet another example of a successful large-scale NBS project, which provides effective flood prevention, ecological, recreational and aesthetic improvements. The Cheonggyecheon Stream restoration project also brought numerous economic benefits where development capital has been invested and property prices have doubled (CABE, 2011).

In terms of the other types of large-scale NBS, Acreman & Holden (2013) show how wetlands play an important role in the hydrological cycle, influencing groundwater recharge, low flows, evaporation and floods. Prior to that, a major review of scientific literature reporting hydrological functions of wetlands was undertaken by Bullock & Acreman (2003). They reviewed the evidence for whether wetlands reduced flooding. They found that around 80 % of relevant studies suggested that floodplain wetlands reduced flooding while 41 % of studies indicated that some of the wetlands enhanced flooding. Field observations have shown that vegetation cover can affect the velocity of water flowing across wetlands and hence flood generation (Holden et al., 2007). Using plot-scale measurements, Holden et al. (2008) showed that *Sphagnum* spp. have ability to slow the flow of water across peat surfaces when compared to sedge-covered surfaces and bare peat surfaces (for an order of magnitude slower). Keeler et al., (2019) reports that vegetation with high roughness is the most effective at slowing overland flow of stormwater runoff. Species root depth and structure influence infiltration and retention of nutrients, and leaf nutrient content and phenology affect the amount and timing of nutrient export to stormwater systems.

Typical examples of coastal NBS are mangrove, mudflats, dunes, beach nourishment and coral reefs and they all require certain conditions to be effective. Balke et al., (2011) reported that mangrove restoration is not very effective in environments that do not have the right range of tidal exposure, salinity, and nutrients required for mangrove establishment. Similarly mudflats are also reported to be more effective in low wave energy environments, whilst dunes and beaches and coral reefs are typically more effective in higher energy environments (Pontee et al., 2016). Other typical examples of coastal NBS are beach nourishment interventions which often rely on coastal processes to redistribute the sediment. The Netherlands has adopted a relatively new approach known as 'building with nature' which makes the use of the dynamics of the natural environment and provides opportunities for natural processes. It represents a collection of coastal NBS interventions including sand engines, oyster reefs and wave-attenuating forests (De Vriend et al., 2015).

In view of the numerous benefits and co-benefits of NBS, it can be concluded that such measures have strong potential to contribute towards meeting objectives of policy documents addressed in this document, namely Floods Directive, Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 and EU Strategy on Adaptation to Climate Change. This document aims to provide an overview of the results from EU-funded NBS projects in support of these policy instruments and to identify the gaps for future R&I investments. Examples of such support used in the review process include provision of theoretical knowledge and practical evidence, development of knowledge base platforms and portals, provision of materials for capacity development, and development of standards and guidelines for implementation, monitoring and evaluation of NBS interventions.

The following section provides an overview of the three EU policy instruments.

2. OVERVIEW OF MAIN FLOOD-RELATED POLICIES AND THEIR CONNECTION WITH NBS

This section addresses the three EU policy instruments and their connection with NBS. Regarding the use of terminology, it can be noted that NBS and its related terms are not equally used in all three documents. Terms such as ‘green (and blue) infrastructure’, ‘ecosystem-based management/approach’ and NBS are explicitly mentioned in two documents (i.e., EU Action Plan on the Sendai Framework for Disaster Risk Reduction 2015–2030 and EU Strategy on Adaptation to Climate Change). The Floods Directive does not provide explicit reference to any of these concepts, since it was published prior to the date of appearance of these terms.

2.1 FLOODS DIRECTIVE (FD)

The Floods Directive (FD), originally proposed in 2006 and formally published in the Official Journal of the EU in November 2007 (ES, 2007; Directive 2007/60/EC), envisions the following:

- Preliminary flood risk assessment: first step of the implementation cycle, identification of areas where significant flood risks exist or are reasonably foreseeable in the future.
- Flood risk maps: the second step is to make flood hazard maps and flood risk maps available to the public; support the process to prioritise, justify and target investments and develop sustainable policies and strategies; support flood risk management plans, spatial planning and emergency plans.
- Flood risk management plans (FRMPs): third step, these need to be developed and implemented at river basin/sub-basin level to reduce and manage the flood risk. The plans need to include the analysis and assessment of flood risk, definition of the level of protection, and identification and implementation of sustainable measures by applying the principle of solidarity in relation to transboundary flood risk governance. In this case, large-scale NBS can play an important role in promoting the *solidarity principle*² as they require strategies that address land management across transboundary landscapes or jurisdictions, involving a great variety of actors and stakeholders.

The FD was as an important step towards harmonising and establishing a common flood management framework for EU member states. As such, it established a set of formal rules with regards to flood risk management at both EU and at the national level. Taking the present day’s view, despite some shortcomings, this Directive still

² ‘Solidarity’ is defined as one’s act to support members of a particular community to which one believes to belong (Bayertz 1999). The Floods Directive requires from Member States to pursue an integrated and co-ordinated approach for selection of flood protection measures based on the principle of solidarity and shared responsibility. Although the principle is in itself straightforward, the precise meaning of solidarity is unclear in the context of upstream–downstream practices of transboundary flood risk management. It is necessary to more specifically define the meaning of solidarity for future cross-border adaptation governance (Van Eerd et al., 2015a).

provides a good foundation for those countries that may be less advanced in their flood risk mitigation practices.

However, for those countries that are more advanced in flood risk management, their existing practices have gone beyond objectives to harmonize flood risk management across EU. For example, in the Netherlands, the effect of the FD on the national policy has been minimal (see for example, van Eerd et al. 2015b). Priest et al., (2016) suggest that the Directive could be strengthened by requiring more intensive cooperation and providing the competent authorities in international river basin districts with more power. A number of shortcomings associated with this document are discussed in Tsakiris et al., (2009) and Eleftheriadou et. al., (2015).

The **FP7 RISC-KIT** project final report states that coastal authorities need to assess levels of impact and risk for their coastal zones, implementing Disaster Risk Reduction (DRR) measures to prevent or mitigate coastal disasters. To facilitate risk reduction, the UNISDR (2015) formulated the Sendai Framework and the EU has issued the FD. The project findings suggest that both frameworks do not provide sufficient details to address coastal hazards and impact issues adequately and they also do not provide appropriate tools. The RISC-KIT project has developed a set of [tools](#) to support these demands.

There are several aspects where the future versions of the FD can address NBS and/or their related concepts and foster their implementation across the European Union. As a starting point, there should be a clear reference to the available evidence of NBS in relation to different types of floods. The range of flood reduction measures, even though the present version of the FD document makes the reference to 'multi-purpose measure that can be used for different forms of sustainable human activities (e.g. flood risk management, ecology, inland navigation or hydropower)', should be broadened to more explicitly and specifically discuss applicability and effectiveness of small- and large-scale NBS for different types of floods, contexts and situations.

Updates to the FD should also acknowledge the need to integrate these solutions into the national policy instruments of Member States. Implementation of small-scale interventions has several advantages when compared to traditional grey infrastructure. However, their effectiveness in mitigating effects from large and extreme events is rather limited which in turn may necessitate combinations with large-scale interventions. Also, large-scale NBS could play important role in flood risk mitigation for transboundary river basins (e.g., [INTERREG DANUBE FLOODPLAIN](#) Project [Report on Possible Restoration Approaches](#)).

Taking the above into account, it can be concluded that while the current FD provides a good foundation for those Member States that are not so advanced in flood risk reduction practices, there is significant potential for the future implementation cycles of this document to explicitly address NBS and support creation of new and optimise

performance of existing interventions individually and in their hybrid combinations with grey infrastructure. Most of the flood risk management plans (FRMPs) within the EU for the first implementation cycle are either complete or in their final stages of completion and the second cycle flood risk management plans are due in 2021. The information compiled in the recent fitness check of the WFD and the FD (EC, 2019), which represents a comprehensive policy evaluation, indicates that all 26 Member States included NBS (i.e. natural water retention measures), in some or all of their FRMPs.

2.2 EU ACTION PLAN ON THE SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION (APSFDRR)

The Third UN World Conference on Disaster Risk Reduction was held in Sendai (Japan) in 2015. At that event, the United Nations Member States agreed and adopted the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030, UNISDR (2015). That framework represents the main guiding instrument for Disaster Risk Management (DRM) and it highlights the sense of urgency for “substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries”.

The implementation of the Sendai Framework represents an opportunity for EU to take forward its DRM agenda which is reflected in the EU Action Plan on the SFDRR (EC, 2016). This document is planned to be updated in 2020 and the new version will guide EU implementation of the SFDRR for the next 10 years. It identifies four priority areas: understanding risk, strengthening disaster risk governance to manage disaster risks, investing in disaster risk reduction and resilience, and enhancing disaster preparedness for effective response and to ‘Build Back Better’.

NBS have the potential to improve the condition and resilience of ecosystems in urban, rural and wilderness areas and as such, they can contribute to implementing the Sendai Framework for Disaster Risk Reduction 2015–2030, while also contributing to achieving other policy objectives - from biodiversity conservation to climate change adaptation and mitigation (Faivre et al., 2018). The EC has been active in engaging the research community to better address the related knowledge and technology gaps through its Research and Innovation strategy and Framework Programmes. Fostering green growth and promoting implementation of such approaches is a priority of the EU Action Plan on the Sendai Framework for Disaster Risk Reduction 2015–2030, which sets the basis for a disaster-risk-informed policy making at EU level. The Union Civil Protection Mechanism which includes requirements to carry out risk assessments, is an important instrument in this respect, covering also other forms of natural and manmade risks than floods.

The SFDRR represents an essential step towards global political awareness for climate change adaptation and the use of NBS for disaster risk reduction and resilience. It has been indicated that for some of the EU countries the local practices still remain oriented towards the emergency response phase of the disaster cycle (prevention, preparedness, response, recovery, restoration), without particular reference to the goals of the framework (see for example, Goniewicz & Burkle, 2019).

H2020 NAIAD investigates how the (re)insurance industry could support the risk reduction measures including NBS, in line with the Sendai Framework. The project results illustrate how the (re)insurance industry is gaining a better understanding of hazards and mitigation, in turn opening the possibility of new arrangements like natural insurance schemes and evidence-based assessment of avoided damage costs from green protective measures, in Europe and beyond (see also Marchal et al., 2019). The results provide valuable references for the APSFDRR and the EU Climate Change Adaptation Strategy to emphasise the importance of insurance as a non-structural flood protection measure.

The **CASCADE** project funded by DG ECHO (Directorate General for Civil Protection and Humanitarian Aid) addresses climate change risk management at the local authority level in the Baltic Sea Region (BSR). It supports the implementation of the UN's SFDRR in the BSR. The project points to the lack of political support for DRR at the international level. This is important to highlight since some of the countries in the region are very active in providing various forms of support for DRR to the countries that are the most vulnerable and exposed to severe natural threats. The project's findings to date suggest the lack of political support to the Sendai implementation, which makes coordination and organisation of the work more challenging. This project has particular relevance for the APSFDRR as it aims to increase the knowledge and capacity of civil protection experts and city planners by developing training courses in DRR.

The APSFDRR document makes explicit reference to NBS and other related terms such as GI and ecosystem-based approaches. The relevant sections acknowledge the benefits from such interventions in a more general context of disaster resilience. However, what is not sufficiently addressed are the concrete actions and how or in what way they should (or can) be taken to support these interventions.

When mentioned, the reference to these interventions is primarily given in the context of Key Area 3 - Promoting EU risk informed investments (Sendai Priority 3 "Investing in disaster risk reduction for resilience") with some reference made to the NBS-evidence brought by the current H2020 Framework Programme for Research and Innovation as well as the previous Framework Programmes and actions. Also, the numerous benefits and co-benefits of NBS for DRR are not explicitly mentioned.

Furthermore, there is no explicit mentioning of the financing mechanisms and business models that can be used to support NBS implementation. Overall, although the APSFDRR document encourages NBS interventions (either implicitly or explicitly) there should be more explicit and stronger support for NBS in all four key areas of Sendai priorities. For example, in relation to (i) understanding risk - NBS has a role towards risk mitigation opportunities; (ii) DRR governance - NBS provide opportunities in bringing multiple stakeholders together - thereby strengthening governance and management of disaster risk; (iii) investing in DRR - NBS provide an opportunity in cost-effective investments; and (iv) building back better - NBS offer multiple benefits that provide greater societal benefits.

2.3 EU STRATEGY ON ADAPTATION TO CLIMATE CHANGE (SACC)

The EU Strategy on Adaptation to Climate Change (SACC) was adopted in April 2013 (EC, 2013) and aims to increase the resilience across the EU's territory by enhancing the preparedness and capacity of all government levels to respond to the impacts of climate change. As part of the EU Green Deal, this strategy is currently under review and will be updated in 2021. The Strategy should be fulfilled through the implementation of eight Actions in three thematic areas:

1. Promoting action by Member States

- Action 1. Encourage all Member States to adopt comprehensive adaptation strategies (Member State strategies);
- Action 2. Provide LIFE funding to support capacity building and step up adaptation action in Europe (LIFE);
- Action 3. Introduce adaptation in the Covenant of Mayors framework (Covenant of Mayors);

2. Better informed decision making

- Action 4. Bridge the knowledge gap (Knowledge gap);
- Action 5. Further develop Climate-ADAPT as the 'one-stop shop' for adaptation information in Europe (Climate-ADAPT);

3. Climate-proofing EU action by promoting adaptation in key vulnerable sectors

- Action 6. Facilitate the climate-proofing of the Common Agricultural Policy, the Cohesion Policy¹⁶, and the Common Fisheries Policy (ESIF/CAP/CFP)

- Action 7. Ensure more resilient infrastructure (Infrastructure)
- Action 8. Promote insurance and other financial products for resilient investment and business decisions¹⁷ (Insurance and finance)

The EU is integrating adaptation into several of its own policies and financial programmes. Currently, most EU Member States have adopted the EU Adaptation Strategy. A considerable amount of knowledge and information concerning climate adaptation measures, monitoring and modelling practices as well as region-specific issues and challenges has been generated through various EU research programmes (e.g., H2020, FP7, INTERREG, COST Actions, LIFE) and can be accessed through the European Climate-ADAPT platform.

Many projects financed by the EU have addressed topics such as floods, sea level rise, droughts or intense heat. Future work should give more attention to specific vulnerabilities of certain communities and multiple risks that are posing threats to different regions around Europe. The new EU Adaptation Strategy should scale-up NBS implementation and stimulate related business opportunities, based on reliable and standardised data and evidence. Additional research and innovation actions at EU level that promote systemic NBS and their benefits in cities and territories are planned with the aim to improve the implementation capacity and evidence base for NBS and developing corresponding future markets (Faivre et. al., 2017).

OPPLA – the repository of NBS reports that the water retention reservoir in Podutik in Ljubljana (Slovenia) has two main objectives: 1) to improve and maintain a good ecological status of the nearby watercourses and, 2) to mitigate floods in the nearby settlements of the city of Ljubljana, to help deliver FD and Water Framework Directive (WFD) objectives. The existing reservoir was redesigned into a multifunctional flood reservoir that provides a broad range of ecosystem services through the integration of NBS. The city of Ljubljana and the FP7 project TURAS co-funded the project.

Out of the three policy instruments reviewed, the SACC document provides more prominent support to NBS and other related terms and concepts, making explicit reference to some of their benefits and co-benefits and pointing to the knowledge base platforms and evidence obtained from the current and previous programmes and actions. Therefore, when comparing the level of support in all three documents, the support for NBS in the SACC document can be characterised as ‘strong explicit support’; for the APSFDRR it can be characterised as ‘medium explicit support’; and for the FD that support is rather ‘low’ and/or implicit.

2.4 KEY RECOMMENDATIONS

In short, NBS offer invaluable strategic and practical options towards meeting objectives of the three EU policy instruments and the level of support to their implementation should be more explicitly stated in future versions of these documents. They can benefit from direct incorporation of NBS in the following ways:

- Contributing towards the global climate change agenda - NBS are increasingly recognised as an essential aspect in the development of climate change mitigation and adaptation strategies. Since the three policy instruments addressed in this document aim at reducing disaster risk and increasing resilience to climate change, by setting up a more quantifiable and measurable targets in relation to NBS will ensure that the collective measures have the capacity to strengthen the global response.
- The need for holistic planning - All three policy documents advocate the need for holistic planning and development of measures with multiple benefits. By its nature, the process of implementing NBS necessitates holistic thinking and working that pulls together a range of sectors and disciplines. Combined with traditional grey infrastructure these measures offer city managers, planners, water and environmental authorities with a variety of hybrid solutions that can be selected in relation to desired benefits and trade-offs.
- Sustainability and multi-functionality - One of the key characteristics of NBS is their capacity to provide multiple functions which go beyond mere stormwater runoff control or flood risk reduction for which they may have been originally designed. They can also offer a number of benefits to multiple sectors. Hence, by incorporating NBS into the existing policy documents the goal of achieving sustainable and multifunctional solutions, which is clearly advocated in all three documents, can be realised.
- Active stakeholder participation and collaborative governance - Successful implementation of NBS projects requires active stakeholder participation and collaborative governance at different levels. In case of large-scale interventions their implementation will also require trust in the local and regional governments. As such, they also provide an opportunity to strengthen inter-governmental as well as transboundary relationships and promote the solidarity principle. This can in turn foster the possibilities for their implementation and operationalisation at the EU and National levels. Schleyer et al., (2015) argue that factors such as the degree of bindingness, policy obligations and impacts on multi-level governance as well as the types of interventions targeted, type of support, etc. are diverse and of crucial importance in this context.

3. CONTRIBUTION FROM EU-FUNDED PROJECTS TO FLOOD-RELATED POLICIES

The findings from several EU projects on NBS (H2020, FP7, INTERREG, COST Actions and LIFE) were reviewed in relation to their potential to contribute towards the EU policy instruments mentioned in the previous section and to identify the gaps for future R&I investments (for the list of reviewed projects see Annex 1). Three key large-scale NBS demonstration projects concerning hydro-meteorological risk reduction are currently under implementation within the H2020 programme. These are RECONNECT, OPERANDUM and PHUSICOS. In all three projects, the ongoing work relating to real-time monitoring and control, business models, standardisation, NBS performance indicators, evaluation frameworks and upscaling will contribute to the policies described above.

In its demonstration and upscaling activities, RECONNECT draws on a network of Demonstrator and Collaborator schemes covering diverse local conditions, geographic characteristics, institutional/governance structures and social/cultural settings, to successfully upscale NBS throughout Europe and internationally, Figure 3.



Figure 3. Creation of an additional space controlled by portable flood gates that sit under the road and within the flood plain in the IJssel region in the Netherlands (H2020 RECONNECT project demonstration site). This site is part of the “Room for the River” programme. It aims to provide flood protection, enhance the landscape and improve environmental conditions in the areas surrounding the Netherlands’ rivers. (Photo: Zoran Vojinovic)

RECONNECT has the potential to contribute to FD, APSFDRR and SACC with respect to novel risk assessment approaches and methodologies for selection and evaluation of NBS. For example, Alves et. al., (2019) proposed a method that can be used to analyse the trade-offs between different benefits and co-benefits of NBS. The same work also provides evidence that evaluation of flood reduction measures can be significantly different when the co-benefits are not included in the analysis. The RECONNECT case area in Thailand applies an evaluation framework proposed by Watkin et. al., (2019) to quantify the benefits and co-benefits of implemented NBS.

OPERANDUM combines ten NBS sites, or Open-Air Laboratories (OALs) covering a wide range of hazards, with different levels of climate projections, land use, socio-economic characterization, existing monitoring activities and NBS acceptance (see Figures 4 & 5). Renaud et al., (2019) provide a systematic literature review on vulnerability and risk assessment frameworks addressing natural hazards, focusing on NBS. Their contribution to EU policy implementation, and particularly FD, relate to the selection and use of indicators for measuring social and ecological vulnerability to natural hazards, and how these indicators can be used to assess the success of NBS in reducing vulnerability and risk.



Figure 4. Po Valley (Panaro river, Comacchio valleys, Reno, Emilia Romagna coastal area), Italy, is part of the OALs within the H2020 OPERANDUM Project. The delta of Po river represents the transition between the river and the sea with differing hydraulic, morphological and biological characteristics. The NBS addresses multiple hazards such as floods, droughts, coastal erosion and storm surges and it also presents economic and biodiversity values. (Photo: Michael Loupis)



Figure 5. Sterea Ellada region is a location for OPERANDUM's Greek OAL NBS situated in the basin of the Spercheios river. It springs from the mountainous parts of the catchment, mainly from Tymfristos mountain in the West, as well as Vardousia and Oiti mountain ranges in the Southwest and South respectively and it deals with floods and droughts. This NBS also has considerable economic and biodiversity values. (Photo: Michael Loupis)

PHUSICOS focuses on demonstrating the effectiveness of NBS and their ability to reduce the impacts from small, frequent events (extensive risks) in rural mountain landscapes (see Figure 6). Autuori et al., (2019) describe a comprehensive framework to verify the performances of NBS from technical and socioeconomic points of view which plays an important role in the overall evaluation of measures. Further results concerning application and verification of this framework will prove its usefulness and contribution towards the three policy documents with particular reference to hazards and risks in mountainous settings.



Figure 6. The Isar river (Germany) during (left) and after (right) the hydro-morphological restoration. It is one of the main tributaries of the Danube, sources in the Alps, and crosses the Bavarian capital Munich. Heavy rain events in the Alps in the years of 1999, 2005 and 2013 led to major floods. Today's near-natural landscape raises awareness on the usefulness of NBS both for DRR and recreational purposes. (Photo: Zingraff-Hamed)

The **NAIAD** project combines eight demonstration sites to address questions of insurance value of ecosystems to reduce the human and economic cost of risks associated with water (floods and drought) by developing and testing - with key insurers and municipalities - the concepts, tools, applications and instruments (business models) necessary for its mainstreaming. This work has particular relevance for APSFDRR and SACC to better link insurance and financial services with Cost-Benefit Analysis (CBA) of flood protection measures. Altamirano & de Rijke (2017) assess the life cycle costs of NBS by providing an overview of the temporal and spatial distribution of costs related to NBS.

H2020 BRIGAD project deals with the development of innovations for climate adaptation and risk reduction from climate-related disaster impacts in Europe and beyond. It also demonstrates innovative NBS for different situations and contexts. One of them is the use of [planting techniques](#) in support of flood risk mitigation and as such it provides value for the FD document. It focuses on two alternative solutions: 1) The installation of Coir Logs at the bottom of the river and 2) planting three levels of vegetation (willow, reed and poplar) at different depths along the river banks to prevent erosion and flooding with natural materials. This

NBS also creates a green corridor, enhancing flora and fauna habitats in the area. This measure is demonstrated along the Erzeni River in Albania. The results from this project provide relevant reference for riverine flood risk assessment and management methods and approaches. Other guidelines and tools that are being developed under this project may also contribute to the development (or fine tuning) of national policy documents for the focus countries.

H2020 RESIN is developing practical and applicable tools to support cities in designing and implementing climate adaptation strategies for their local contexts. The project aims to compare and evaluate the methods that can be used to plan for climate adaptation in order to move towards formal standardisation of adaptation strategies. RESIN public deliverables can be found [here](#). The project provides material to support the implementation of all three policies, all three policies, particularly in future cyclic updates of the FD, with respect to vulnerability assessment, standardisation for urban climate adaptation, hazards and risk analysis, and the methods for prioritising adaptation options (e.g. de Jong et. al., 2018; Mendizabal & Zorita, 2018).

The main outcome from the **PLACARD** project is the platform (PLATform for Climate Adaptation and Risk reDuction) that supports dialogue, knowledge exchange and collaboration between the Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) communities. PLACARD produced several policy briefs, visuals and webinars which can be found [here](#) and used as a reference for all three policy documents. More specifically, the project's [policy brief on NBS](#) recommends that Ecosystem-based approaches must be community-based and consider large spatial scale to minimise trade-offs between communities.

The **Smart Mature Resilience** project aims to deliver resilience management guidelines to support city decision-makers in developing and implementing resilience measures. The project hosted several events, some focusing on sharing experiences and knowledge on how to best co-create NBS. The tools and lessons learnt can contribute to the policies in relation to resilience management guidelines.

H2020 RESCCUE aims to contribute towards improvement in urban resilience through the capability of cities to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage. Although the project does not specifically focus on NBS, its methodologies and tools for assessment of hazards and risk (and particularly risk cascading) can be useful for the FD.

The **FP7 RESCUE** project addressed impacts of climate-induced floods on stability of existing river flood embankments and looked into the natural reinforcement which can be successfully exploited to strengthen the embankments. In this respect,

vegetation is considered as a remedial measure in the sense that it promotes the generation of suction via evapotranspiration (i.e., it is a form of NBS). The work was validated in the case study of the Adige River (Italy) and the results obtained provide a good reference for the FD document.

FP7 BASE project dealt with sustainable climate change adaptation in Europe. Some of the case study work addressed pluvial, fluvial and coastal types of floods and application of different types of measures including NBS (which are in the project documents referred to as “ecosystem-based” or “green measures”). The results provide a valuable reference for the FD document in relation to uncertainty analysis and efficacy of different measures for different types of floods.

FP7 OPERAs project was a five year EU research project dealing with practical aspects of ecosystem science. It addressed the construction and maintenance of semi-fixed dunes across 15 km of Barcelona's (Spain) urban coastline, effectively representing coastal NBS, with the potential to provide protection from coastal floods and sea-level rise as well as to bring numerous co-benefits to coastal ecosystems. The results provide valuable reference material on coastal management for future development of the FD.

LAND4FLOOD COST Action aims to address different aspects in relation to Natural Flood Retention on Private Land and to establish a common knowledge base and channels of communication among scientists, regulators, land owners and other stakeholders in the field. Its potential contribution to FD, APSFDRR and SACC is their approach to nature-based flood risk management on private land. The book produced by Hartmann et. al., (2019) addresses potentials and experiences of NBS with respect to private and partly public land, and as such, it provides a valuable reference for design and evaluation of NBS of particular value for the new FD.

H2020 UNaLab aims to develop a ‘living lab’ of NBS sites and provide a robust evidence base to enhance the climate and water resilience of cities. The project also underlines a variety of barriers that prevent wider replication and uptake of these measures. Information that the project aims to produce will be particularly relevant for the SACC's thematic area 2 (Better informed decision making).

PEARL addressed several aspects of flood risk reduction ranging from the early warning systems technologies to ecosystem-based (NBS) approaches that can be used for multiple-hazards and vulnerability assessment. The work was carried for a number of European and International case studies (see Figure 7). The project brings tools and experiences which are directly relevant for all three policy documents. The project also proposes improved Quantitative Microbial Risk Assessment methods to address public health issues associated with flood waters

in urban areas. The work has also addressed application of NBS measures in areas with cultural heritage (e.g., Vojinovic et. al., 2016a; Vojinovic et. al., 2016b). This could be particularly relevant for FD (e.g. Chapter II, Article 4), APSFDRR (e.g. Key Area 4 - Supporting the development of a holistic disaster risk management approach in relation to cultural heritage), and SACC as well as for other directives for Member States that aim to address cultural heritage requirements.



Figure 7. Coastal flood risk reduction with hybrid measures (i.e., combination of hard engineering and Ecosystem-based approaches) in Taiwan, FP7 PEARL project. (Photo: Zoran Vojinovic)

FAST (Foreshore Assessment using Space Technology) was an EU FP7 Collaborative project which developed down-stream services for the European Earth Observation Programme Copernicus to support cost-effective, nature-based shoreline protection against floods and erosion (see for example, Morris et. al., 2015). Wave reduction properties of nature-based shoreline protection against floods were assessed using satellite data and incorporated in a wave and flood model which showed dramatic reduction in extent and depth of flooded area, i.e., the inundated surface without vegetation approximates 340 ha, and only 193 ha with vegetation. The results obtained can serve as a reference to improve FD implementation.

The objective of LIFE **SimetoRES** project is to address climate change adaptation of urban areas in the Simeto Valley (Italy). The work concerns the inclusion of Blue Green Infrastructure (BGI) into municipal regulations and the construction of six BGIs within the urban territory of the municipalities of Paternò and Ragalna. It can support FD, APSFDRR and SACC through the implementation of BGI measures, being of particular relevance for national policy instruments in Italy and beyond.

LIFE GRIN project (Promoting urban integration of Green INfrastructure to improve climate governance in cities) focuses on urban integration of GI for climate governance in cities. It establishes an integrated policy framework to manage, monitor and evaluate Urban Green Areas as a form of BGI, specifically addressing urban climate impacts such as heat waves and heat island effects, stormwater runoff and energy consumption. It provides a useful reference for FD, APSFDRR and SACC in relation to climate change adaptation and mitigation and gives explicit support for the development of national policy instruments in Greece. Their key deliverables provide analyses of the current situation regarding climate change mitigation and adaptation needs (SWOT analysis) in two cities: Amaruson and Heraklion. GRIN's public deliverables can be found [here](#).

FP7 ECONADAPT built the knowledge base on the economics of adaptation to climate change and converted it into practical information for decision makers for more effective adaptation planning. The project developed a policy-led approach to frame the research and policy analysis focusing on the practical application of adaptation economics, serving as a reference for the SACC (e.g., ECONADAPT 2015).

RISES-AM was an EU FP7 project which addressed the economy-wide impacts of coastal systems to various types of climatic scenarios (including storm surges and sea level rise). The project developed a set of adaptation pathways for vulnerable coastal systems at regional and global scales, introducing adaptation strategies and innovative solutions to help implement the FD and SACC (see the final report [here](#)).

FP7 SECOaquaA studied 17 coastal metropolitan/urban areas of international, national and regional importance, and 26 environmental contrasts/conflicts in 8 countries in Europe and Asia. The outcomes confirmed that climate change is one of the most important challenges for all the coastal areas that have been studied.

In summary, the potential for contribution from R&I projects towards the three policy documents is given in Table 1.

TABLE 1. Potential contribution of EU-funded R&I projects for flood adaptation policies

PROJECT NAME	FLOODS DIRECTIVE	EU ACTION PLAN ON THE SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION	EU STRATEGY ON ADAPTATION TO CLIMATE CHANGE
AQUAVAL	Low	Low	Low
BASE	Medium	Low	Medium
BRIGAD	Medium	Medium	High
CASCADE	Medium	High	Medium
ECONADAPT	Low	Low	Medium
FAST	Medium	Low	Low
GRIn	Low	Low	High
LAND4FLOOD	High	Low	Medium
NAIAD	High	Low	Medium
OPERAs	Medium	Low	Medium
OPERANDUM	High	Medium	High
PEARL	High	Medium	Medium
PHUSICOS	High	Medium	High
PLACARD	Low	Medium	Medium
RECONNECT	High	Medium	High
RESIN	Medium	Low	High
RESCUE	Medium	Low	Medium
RESCCUE	Medium	Low	Low
RISC-KIT	High	Medium	Medium
RISES-AM	Medium	Low	High
SECOaquaA	Low	Low	Low
SimetoRES	Medium	Low	Low
SMR	Low	Low	Low
UNALAB	Low	Low	High

4. THE EVIDENCE BASE

The review of NBS-related literature to date shows more reports of evidence for small-scale NBS (see Ruangpan et al., 2020). Also, within a range of small-scale NBS, certain measures have received greater attention compared to other measures, see for example Nagase and Koyama (2020). In terms of the risk-based economic assessment, which is a fundamental method for climate adaptation assessment, the majority of such economic analyses remain in the form of traditional CBA, see for example Gafni (2006).

The LIFE project **AQUAVAL** researched SUDS measures (infiltration basin, green roof, swales, etc.) in six sites across the Valencian region in Spain. The measures were implemented and analysed in relation to pluvial flood mitigation and the discharge of combined sewage into receiving watercourses. Monitoring results showed that the measures were effective in both flood mitigation and improvement of the water quality (Perales-Momparler et al., (2016).

There are numerous studies that address effectiveness of green roofs for rainfall-runoff reduction (see Table 2). For example, Burszta-Adamiak and Mrowiec (2013) performed experimental work at four roof platforms with different sizes and slopes in an urban area in Poland. The estimated effectiveness of green roofs for peak flood reduction ranged from 23% to 99% depending on the intensity and magnitude of rainfall events. However, they further conclude that more research is needed to determine the role of the green roof slope, vegetation cover and drying process for runoff delay and peak reduction.

TABLE 2. Examples of effectiveness of small-scale NBS (see also Ruangpan et. al., 2020)

NBS	SOURCE	EFFECTIVENESS	
		Runoff volume reduction	Peak flow reduction
Porous Pavements	Shafique et al., (2018), Damodaram et al., 2010	~30–65%	~10% - 30%
Green Roofs	Burszta-Adamiak and Mrowiec (2013), Ercolani et al. (2018), Carpenter and Kaluvakolanu, (2011), Stovin et al. (2012)	up to 70%	up to 96%
Rain Gardens	Ishimatsu et al. (2017), Goncalves et al. (2018)	up to 100%	~48.5%

TABLE 2. *cont.*

NBS	SOURCE	EFFECTIVENESS	
		Runoff volume reduction	Peak flow reduction
Vegetated Swales	Luan et al. (2017), Huang et al. (2014)	up to 9.60%	~23.56%
Rainwater Harvesting	Khastagir and Jayasuriya (2010), Damodaram et al. (2010)	~57.8-78.7%	~8%-10%
Detention Ponds	Liew et al. (2012), Damodaram et al. (2010), Goncalves et al. (2018)	up to 55.7%	up to 46%
Bioretention	Luan et al. (2017), Huang et al. (2014), Khan et al., (2013)	up to 90%	up to 41.65%
Infiltration Trenches	Huang et al. (2014), Goncalves et al. (2018)	up to 55.9%	up to 53.5%

Ercolani et al. (2018) also addressed the effectiveness of green roofs and performed a study in the Metropolitan city of Milan. They showed that such measures can be considered a valuable strategy to deal with frequent storms of smaller magnitude at urban watersheds. They further conclude that the planning of such measures should be done considering the local limitations of the drainage network conveyance capacity which can influence the effectiveness of green roofs. Li and Babcock (2014) reviewed the technical literature on green roof hydrology. They found that green roofs can reduce stormwater runoff volume by 30-86%, peak flow rate by 22% to 93%, and delay peak flows by 0-30 minutes, thereby decreasing pollution, flooding and erosion during precipitation events. They conclude that their efficiency can vary substantially due to design characteristics making performance predictions difficult.

Regarding coastal resilience, coastal habitats can reduce wave heights between 35% and 71% (Narayan et al., 2016). Restoration projects in mangroves and salt marshes for wave reduction can be several times cheaper than alternative such as breakwaters, for the same level of protection. They are also able to self-repair after strong storms and have much lower maintenance costs than artificial infrastructures (Narayan et al., 2016; see also Table 3).

TABLE 3. Examples of effectiveness of NBS interventions for coastal applications

NBS	SOURCE	EFFECTIVENESS	
		Runoff volume reduction	Peak flow reduction
Coral Reefs	Ferrario et al. (2014); Narayan et al. (2016); Debele et al. (2019)	~70-91%	~34 – 3200%
Salt Marshes	Ferrario et al. (2014); Narayan et al. (2016); Debele et al. (2019)	~72-92%	~5 – 425%
Mangroves	Ferrario et al. (2014); Narayan et al. (2016); Debele et al. (2019)	~31-53%	~32 – 260%
Seagrass	Ferrario et al. (2014); Narayan et al. (2016); Debele et al. (2019)	~36-58%	~258-949%

The EU continues to help build the evidence-base of NBS through various platforms and initiatives (Faivre et al., 2017). There are several NBS-related platforms, portals, databases, networks and initiatives at global, European, national and sub-national levels (Annex 2). Figure 8 illustrates the geographical spread of NBS-related projects, case studies and initiatives on climate adaptation and DRR taken from four EU platforms OPPLA, NWRM, Climate-ADAPT and Urban Nature Atlas.

[OPPLA](#) is an open platform on NBS, consisting of a knowledge market place, and it currently provides the most in-depth information out of all platforms given in Annex 2. It contains 282 case studies with NBS that deal with DRR, climate change adaptation, biodiversity, food, sustainable cities, health and ecosystem services.

[NWRM](#) is a website that gathers information of European GI measures applied in the water sector. So far, there are 139 case studies in the database which spread across four sectors (urban, forestry, agriculture and hydro-morphology) with numerous cases that deal with DRR and climate adaptation (see also Table 4).

[Climate-ADAPT](#) is a platform supported by the EC and the EEA to help users to access and share data and information about NBS-related case studies and initiatives. The database includes adaptation options, case studies, guidance, indicators, information portals, organisations, publications and reports, research and knowledge projects, tools and videos. It supports a range of sectors such as agriculture, biodiversity,

buildings, coastal, DRR, EbA, energy, finance, forestry, health, marine and fisheries, transport, urban and water management. Currently, there are about 100 case studies in the database.

The [Urban Nature Atlas](#) has been developed as part of the H2020 NATURVATION project and it contains 1000 examples of NBS from across 100 European cities. Projects included address various urban societal challenges and use nature as an inspiration to address these challenges.

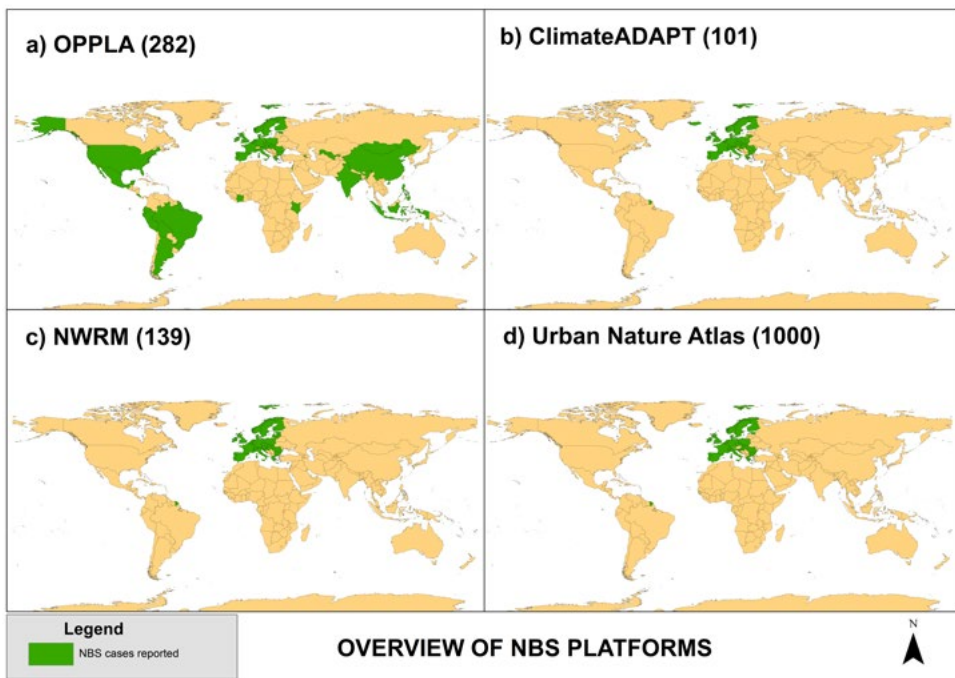


Figure 8. Illustration of the number of projects, case studies or initiatives and their geographical spread reported at different platforms (Accessed in May 2020).

TABLE 4. Examples of cases reported at the NWRM platform.

NBS	PLATFORM, CASE LOCATION	FEATURES REPORTED
<p>Green roofs, Permeable surfaces, Swales, Rain gardens, and Infiltration basins</p>	<p>http://nwrn.eu/case-study/climate-proofing-social-housing-landscapes</p> <p>London, UK</p>	<ul style="list-style-type: none"> • 472 residents engaged • 90% of residents reported an increased understanding of climate change • 81% of residents said they agree or strongly agree that the quality of the green spaces has improved significantly • 58% of residents reported their use of the green spaces had increased • 48% of residents reported an increased sense of belonging • 67% of residents reported increased pride in the area they live in • 22 Green Team trainees involved (a training and employment programme for those who are young, unemployed and lacking experience and qualifications) • 11 job outcomes for Green Team trainees
<p>Permeable surfaces, Swales, Filter Strips, Detention Basins and Retention Ponds</p>	<p>http://nwrn.eu/case-study/sustainable-stormwater-management-and-green-infrastructure-fornebu-norway</p> <p>Oslo, Norway</p>	<ul style="list-style-type: none"> • Increase in water storage 230 m³/ha • 60 % reduction pollution Phosphorus (P) • 40 % reduction pollution Nitrogen (N) • 80% reduction Total Suspended Solid (TSS) • 65 % reduction pollution Copper (Cu) • 45 % reduction pollution Zinc (Zn)
<p>Permeable surfaces, Swales, Filter Strips, Soakaways Detention Basins, Retention Ponds, and Infiltration basins</p>	<p>http://nwrn.eu/case-study/leidsche-rijn-sustainable-urban-development-netherlands</p> <p>Utrecht, Netherlands</p>	<ul style="list-style-type: none"> • Retained water 2,200,000 m³/year • Increase water storage 1,000 m³/ha • 80 % reduction pollution Phosphorus (P) • 50% reduction Total Suspended Solid (TSS) • Potential for recreational activities in the water courses that will be created

5. INNOVATIVE GOVERNANCE MODELS

Governance plays an important aspect for achieving desired results from NBS interventions and some of the H2020 NBS projects are specifically dealing with innovative ways to promote sustainable governance of small- and large-scale NBS.

The **Nature4Cities** H2020 project defines governance in the context of NBS as “collective action arrangements designed to achieve the implementation of NBS”. It identifies five main clusters of governance models which can be sourced from their study of 56 NBS cases across Europe. These five clusters are:

1. Traditional Public Administration: hierarchical governance structures and centralised government control of NBS.
2. New Public Management: ‘public-private partnerships’ and the corresponding ‘hollowing-out’ of government services.
3. Private-private partnerships: this would include sole governance of the NBS by private sector or community organisations, joint community-private sector co-governance, Sustainable Local Enterprise Networks (SLEN), etc.
4. Societal resilience: this is characterised by a high level of community leadership and low-level role played by governments.
5. Network Governance: recognises the necessity to engage many different actors in service delivery and the complexity involved in managing such networks effectively.

Clusters 3, 4 and 5 represent examples of new types of governance models. Cluster 5 has a similar concept to Polycentric governance proposed by the **PHUSICOS** project, which identifies three areas for governance innovation:

1. Polycentric governance which aims to involve multiple institutions and/or sectors (i.e., not only flood and coastal resilience but also natural conservation, planning, water quality, socio-economic organisations and others). This also could refer to engaging different stakeholders in open innovation processes that could identify problems or deliver solutions (e.g., citizens, academia, public authorities, businesses including SMEs, creative sectors and social entrepreneurs) (Martin et. al., 2019).
2. Participation in the design, production and delivery phases by involving stakeholder participatory processes that co-determined the eventual shape of the NBS implemented. This helps to integrate user knowledge and provides insights into the tools they intend to use, to re-define operational processes and to create new

working relationships beyond established departments and silos.

3. Financial incentives: local authorities designed and implemented novel incentives for households in consultation with villagers to monitor illegal logging in a nature reserve.

The work to date highlights the importance of analysing existing governance systems and actors prior to implementation of NBS projects. This is particularly important for large-scale interventions which may require careful consideration of legal frameworks of international cooperation on transboundary water governance.

6. MARKET UPTAKE, FINANCING APPROACHES AND BUSINESS MODELS

Collecting evidence about cost-effectiveness of NBS interventions has been the focus of many researchers and practitioners. However, systematic presentation of their construction, deployment, and operation and maintenance costs is still needed. In many cases, only aggregated costs of construction works can be found (e.g. information concerning their operation, maintenance and deployment costs is almost non-existent). This is partly due to the fact that NBS interventions differ in terms of hazard scales and types (e.g. pluvial, fluvial or coastal floods), climatic conditions and local contexts. Thus, their implementation costs will also vary, as will the nature of the borrower, business models and financing mechanisms. Also, there is a vast range of possible design and construction alternatives which adds further to the uncertainty (e.g., Keating et al., 2015). NBS schemes may also require the purchase of land and/or relocation of existing properties for which costs are not always reported

In terms of the costs associated with implementation of green roofs, there is a significant price variation depending on their type, size, local conditions and country. Although they are known to provide good value for money when compared with other infrastructures, in some cases their high initial investment costs appear to be a barrier to implementation. Some examples of costs concerning implementation of small-scale NBS are given in Table 5.

TABLE 5. Examples of costs of small-scale NBS interventions (see also Ruangpan et. al., 2020)

NBS	COST	SOURCE
Porous Pavement	~\$252/m ²	Shafique et al., (2018), Damodaram et al., 2010
Green Roofs	~\$564/m ²	Carpenter and Kaluvakolanu, (2011)
Rain Gardens	~\$501/m ²	Ishimatsu et al. (2017), Goncalves et al. (2018)
Vegetated Swales	~\$371/m ²	Luan et al. (2017), Huang et al. (2014)
Rainwater Harvesting	~\$865/m ³	Khastagir and Jayasuriya (2010), Damodaram et al. (2010)
Detention Ponds	~\$60/m ²	Liew et al. (2012), Damodaram et al. (2010), Goncalves et al. (2018)
Bioretention	~\$534/m ²	Luan et al. (2017), Huang et al. (2014), Khan et al., (2013)
Infiltration Trench	~\$74/m ²	Huang et al. (2014), Goncalves et al. (2018)

As part of the FP7 PEARL and H2020 RECONNECT projects, Alves et. al. (2019) address economic comparison of green-blue, grey and hybrid strategies for flood mitigation, and examine how this changes in view of the co-benefits. The NBS considered are small-scale NBS such as permeable paving, detention basins and rainwater harvesting. The authors also acknowledge difficulties in monetising the value of co-benefits (e.g., aesthetic value and biodiversity enhancement) and advocate for further advances in this direction. Some other studies provide quantitative data enabling to calculate annual values of those co-benefits which can be directly monetised (e.g. Woods-Ballard et. al., 2007, Center for Neighbourhood Technology, 2010, Horton et al., 2016, Alves et al., 2019). Present value of co-benefits is often calculated for lifetime with discount rate, given per unit of measure.

Information on the costs concerning implementation of large-scale NBS is very scarce, and when it is reported, it also shows significant price variation. Nisbet et al (2012) quote Saraev (2012) as follows: "While the potential of greenspace and woodland in particular to reduce stormwater run-off and reduce flood risk by slowing water flows is often acknowledged, economic estimates are scarce and tentative. The study, at Pickering, that provides economic estimates of the benefits of woodlands for flood management and erosion reduction reports a present value for these over 100 years of about £180 000 for 85 ha of woodland created". Table 6 gives examples of aggregated costs concerning implementation of large-scale NBS.

TABLE 6. Examples of aggregated costs of large-scale NBS interventions (see also Ruangpan et. al., 2020)

NBS	COST	SOURCE
De-culverting (river restoration)	~€16.92 million	Chou (2016)
Floodplain lowering	~€136.7 million	Klijn et al. (2013)
Dike relocation/floodplain lowering	~€342.60 million	Klijn et al. (2013)
Floodwater storage	~€386.20 million	Klijn et al. (2013)

The H2020 **Connecting Nature** project argues that business models and return-on-investments for NBS interventions are limiting interest from traditional financial institutions. The H2020 **NATURVATION** Urban Nature Atlas shows that almost 75% of NBS are funded from public sources (public budget / direct funding or subsidies). The same project, although not specifically focused on floods and coastal resilience, produced a Business Model Catalogue for Urban NBS with eight different business models (Sekulova and Anguelovski, 2017). These were identified based on a number of

case studies of urban NBS, both in- and outside of Europe. This is also a dialogue tool for understanding what values can drive the realization of an urban NBS, and which stakeholders may be willing to pay for those values.

The H2020 **RECONNECT** project, dealing with floods, is taking into consideration a variety of investment funds to support promotion and uptake of innovative investment strategies and business models for large-scale NBS, with similar cases covered by the H2020 **OPERANDUM**, **PHUSICOS** and **NAIAD** projects.

The results from H2020 **NAIAD** project, which focus on floods, demonstrate that viable business models (e.g., the natural insurance scheme developed under the **NAIAD** project) could play a significant role to increase the financing for the development of NBS. It has also been argued that NBS projects at different scales could support a diversification of risks and help the development of a larger portfolio of return on investments (e.g., Marchal et. al., 2019).

7. POLICY RECOMMENDATIONS AND R&I GAPS

7.1 POLICY RECOMMENDATIONS

As a more general comment, it is necessary to better connect the three policy instruments in relation to how they foresee NBS interventions and also, where appropriate, connect with the Water Framework Directive (WFD). The policy documents must be carefully coordinated in this respect or otherwise there is a chance that the process of implementing NBS may become less effective or even hampered. More specifically, the process of implementing NBS provides an opportunity to maximise synergies between the FD and the WFD by identifying multifunctional cost-effective measures which can result in win-win measures being implemented. This will enhance further coordination during the development of flood risk management plans as well as river basin management plans (FRMPs and RBMPs) at national levels.

Furthermore, the need for implementation of NBS provides an opportunity to achieve better synergy and coordination of efforts at the EU and national Member States levels through integration of such measures into the national and local policy instruments of Member States. In some cases, such local policies already exist and the appropriate actions are being implemented. For example, after some research efforts, the City of Hamburg began to implement its [policy on green roofs](#) already in 2015 where no less than 70% of all suitable rooftops are to be topped with vegetation. In Belgium, for the Brussels Region, the [Regional Planning Regulations](#) (RRU: Title I, Chapter 4, page 19, Article 13) require the transformation of inaccessible flat roofs with an area of more than 100 m² into green roofs. This is applicable for any totally or partially inaccessible roof, for main buildings and annexes. To this end, identifying areas of synergy between policies at different levels, where common goals can be met at the same time, can strengthen the capacity to achieve the EU-wide response. This would ensure that the uptake of NBS is carried out in a systematic and coordinated manner.

The EU's Green Deal sets an agenda for transforming EU's economy and society into a more sustainable path. In doing so, the Green Deal has a strong focus in protecting the health and well-being of citizens from natural or man-made disasters including floods. Furthermore, in view of the current pandemic situation and discussions at the EU level to ensure post COVID-19 economic recovery, the related funds need to be consistent with the EU's Green Deal which in turn provides an opportunity to integrate NBS in these discussions. Given that one of the cornerstones of the EU's Green Deal is to enhance the EU's natural capital and that natural capital can significantly contribute to reducing the impact of floods, NBS can play a significant role in stimulating economic growth that will put EU in the path of "building back better".

Some of the key recommendations concerning the Floods Directive are summarised below:

- There is a need to better address data and model uncertainties which in turn can have significant impacts on estimation of peak discharges and corresponding flooded areas (see for example Eleftheriadou et. al., 2015). This is particularly important when NBS interventions are considered.
- The work concerning analysis and planning of NBS should be done for a range of scenarios combining different land use characteristics, urbanisation, climate trends and other future projections. Furthermore, vulnerability and risk analysis should be considered as dynamic processes which continuously evolve through time (see also Tsakiris et al., 2009).
- All possible types of floods should be equally addressed. The analysis of hazards should also combine multiple sources and events as well as their cascading effects. Delineation of flood hazard maps should combine different variables (e.g., flood depths, velocities, durations and concentrations of pollutants) depending on the processes that dominate different flood types.
- The search for measures should encourage consideration of different kinds of measures (grey, small- and large-scale NBS) and their hybrid combinations.

Key recommendations on the EU Climate Change Adaptation Strategy are that:

- Inclusion of co-benefits from different measures (which is particularly relevant for NBS) will ensure that climate adaptation is undertaken in a timely, cost-effective and sustainable manner. This also refers to indirect effects of floods (i.e., human well-being, culture value, etc.) and these should be taken into account in assessing costs and benefits of adaptation and risk management;
- Stakeholder and citizen participation in adaptation decision making should be promoted at all levels of governance;
- Economy-wide assessments should be used to analyse the efficiency of adaptation decisions at a national and wider European level;
- Agriculture sector authorities at the EU level and Member States are one of the key stakeholders for the planning of large-scale multipurpose NBS interventions. The policy should also include the agriculture sector and promote NBS as cost-effective multipurpose adaptation options.

Key recommendations concerning the EU action plan for the SENDAI Framework for DRR are summarised below:

- Key Area 2 ('An all-of-society approach in disaster risk management') would benefit from some concrete examples of how to strengthen the links between disaster risk management, climate change adaptation, forestry and biodiversity strategies. This could be given through numerous examples of NBS for different scales of intervention. For example, there is growing awareness that NBS can provide simultaneous benefits such as protection from floods, mitigation of climate change, biodiversity enhancement and other ecosystem services. The three H2020 large-scale NBS hydro-meteorological projects (OPERANDUM, PHUSICOS and RECONNECT) will soon have evidence available to support this.
- Regarding Key Area 3 ('Promoting EU risk informed investments'), this area could be strengthened by providing some concrete examples of mechanisms for flood-related disaster risk financing, risk transfer and insurance, which have been realised in the H2020 NAIAD project.
- Discussion concerning Key Area 4 ('Supporting the development of a holistic disaster risk management approach') should make a more explicit reference to the benefits of NBS for DRR. Large-scale NBS are particularly relevant for flood-related disasters in view of their capacity to deal with extreme events. Also, a 'building back better' approach, which is defined within the same priority area, refers not only to rebuilding of disaster-resilient infrastructure, but also to building of disaster-resilient ecosystems and societies. Hence, the existing document should make a more direct connection between the benefits/co-benefits of NBS interventions and pre- and post-DRR responses.

7.2 RESEARCH AND INNOVATION GAPS

There is a large body of knowledge and evidence produced through various EU research programmes and actions and through the Commission's own internal scientific services (Joint Research Centre). A joint publication between the three EU-funded large-scale NBS projects RECONNECT, OPERANDUM and PHUSICOS identified a number of remaining research and innovation gaps which could provide a good basis for future research programmes (e.g., Horizon Europe) to address NBS interventions for hydro-meteorological risk reduction (Ruangpan et al. 2020).

Some of the key research and innovation gaps are summarised below:

- **Barriers** - Despite the numerous reports on the effectiveness of NBS (e.g., Kong et al., 2017; Zölch et al., 2017; Versini et al., 2018), in practice, these measures are still being applied at a slow rate while grey infrastructure remains as a preferred choice (e.g., Dhakal and Chevalier, 2017; Qiao et al., 2018). This situation can be attributed to several barriers which range from political (e.g.

NBS require longer periods of time to generate benefits while politicians tend to prioritise investments to those interventions that generate outcomes in shorter or immediate future); governance (e.g. many water and environmental management authorities operate in silos and often follow different visions, goals and regulatory frameworks while successful implementation of NBS requires full cross-sectoral cooperation); social (e.g. NBS represent a relatively new approach and there can be a negative perception due to uncertain outcomes and preference towards traditional hard engineering “grey infrastructure” and technological. From the technological point of view, limited implementation of NBS for flood risk reduction is mainly due to the lack of sufficient technical references, design standards and guidelines (Qiao et al., 2018). Furthermore, there is still a general perception that the construction and especially maintenance of NBS are more costly than traditional grey infrastructure measures (see for example, Dhakal and Chevalier, 2017). Therefore, a more substantial knowledge and evidence base is needed in order to promote their wider acceptance and upscaling/uptake (see also Kabisch et al., 2017).

- **General knowledge and evidence base of small-scale NBS** – With respect to small-scale NBS, apart from the need to continuously gain further evidence on their individual performance characteristics in different settings (i.e., different climate conditions, quantity and quality, cultural and governance contexts, single and multiple hazards, etc.) and associated costs, more efforts are needed to address the full potential of their co-benefits and how these can be quantified and/or monetised. Furthermore, the question concerning performance of “networks” (or “trains”) of interconnected small-scale NBS, as well as their hybrid combinations with large-scale NBS and grey infrastructure still remains unclear and should be addressed in the future work (see for example the work of Damodaram et al., 2010; Dong et al., 2017; Huang et al., 2014; Luan et al., 2017).
- **General knowledge and evidence base of large-scale NBS** – There is a large gap between the amount of research concerning small scale NBS in urban areas and large scale NBS at the catchment (or river basin), rural, coastal and regional level. Hence, further research concerning their performance individually and in hybrid combinations with small-scale NBS and grey infrastructure would be very beneficial. This is also a focus research component of the RECONNECT project, which in turn may provide some new knowledge and directions for further work. Understanding of the associated natural processes and how they change over time would also prove invaluable information. Also, a platform (or a database) with lessons learnt and their implementation costs (e.g., construction, monitoring, operation and maintenance and decommissioning costs) should be developed and kept up to date. There is an opportunity to expand OPPLA (and other NBS-related platforms) to incorporate the evidence base for large-scale NBS.

- **Planning tools** – Currently, the tools, such as real-time data acquisition and modelling, optimisation algorithms and decision-support systems, which are necessary for planning and implementation of NBS, are rather scattered and incomplete. Also, to support efforts for wider uptake of NBS it is necessary to advance the methodologies and tools for systematic evaluation of benefits and co-benefits (especially those related to social and ecological system, e.g. aesthetics values, community liveability, and human health), frameworks and methods for optimal selection of “hybrid measures” (i.e. combinations of grey infrastructure and small- and large-scale NBS). This aspect is being addressed in the three large-scale NBS projects (i.e. RECONNECT, OPERANDUM and PHUSICOS) and the results that will be obtained could provide a basis for future research activities.
- **Operational tools** – Further efforts should also be placed on the developments of tools that combine real-time monitoring and control systems, advanced flood risk assessment methodologies and models, smart early warning systems, numerical weather prediction models and flood risk models to advance real-time operational potential of NBS (i.e., development of SMART NBS).
- **Standards, guidance and design tools** – Development of practical design standards, guidance documents and supporting tools would also be very beneficial. This would maximise the chances for their multi-functionality and minimise the chances for their undesirable performance effects.
- **Stakeholder participation** - There are also several challenges associated with stakeholder participation. The future work should maximise the use of decision-support platforms and online tools to enable more effective co-creation processes.

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9. ANNEX 1. LIST OF REVIEWED PROJECTS

AQUAVAL (Sustainable Urban Water Management Plans, promoting SUDS and considering Climate Change, in the Province of Valencia), LIFE, January 2010 – September 2013, EU contribution: € 499 458, [project link](#).

BASE (Bottom-up Climate Adaptation Strategies Towards a Sustainable Europe), FP7, October 2012 – September 2016, EU contribution: € 7 555 674,25, [project link](#).

BRIGAD (BRIdges the GAP for Innovations in Disaster resilience), H2020, May 2016 – April 2020, EU contribution: € 7 739 805,79, [project link](#).

CASCADE (Community Safety Action for Supporting Climate Adaptation and Development), DG ECHO (European Union Civil Protection and Humanitarian Aid), January 2019 – December 2020, Budget: € 850 871, [project link](#).

ECONADAPT (Economics of climate change adaptation in Europe), FP7, October 2013 – September 2016, EU contribution: € 2 928 617,50, [project link](#).

FAST (Foreshore Assessment using Space Technology), FP7, January 2014 – December 2017, EU contribution: € 2 224 160, [project link](#).

GRIn (Promoting urban integration of GReen INfrastructure to improve climate governance in cities), LIFE, June 2018 – December 2021, EU contribution: € 1 015 505, [project link](#).

LAND4FLOOD (Natural Flood Retention on Private Land), COST Action, September 2017 – September 2021, [project link](#).

NAIAD (NAture Insurance value: Assessment and Demonstration), H2020, December 2016 – August 2020, EU contribution: € 4 994 370, [project link](#).

OPERAs (Operational Potential of Ecosystem Research Applications), FP7, December 2012 – November 2017, EU contribution: € 8 997 909,50, [project link](#).

OPERANDUM (OPEn-air laborATORies for Nature based solUTions to Manage environmental risks), H2020, July 2018 – June 2022, EU contribution: € 12 257 343,25, [project link](#).

PEARL (Preparing for Extreme And Rare events in coastaL regions), FP7, January 2014 – April 2018, EU contribution: € 4 998 851,04, [project link](#).

PHUSICOS ('According to nature' - solutions to reduce risk in mountain landscapes), H2020, May 2018 – April 2022, EU contribution: € 9 472 200, [project link](#).

PLACARD (PLAtform for Climate Adaptation and Risk reduction), H2020, June 2015 – May 2020, EU contribution: € 2 852 760, [project link](#).

RECONNECT (Regenerating ECOSystems with Nature-based solutions for hydro-meteorological risk rEduCTion), H2020, September 2018 – September 2023, EU contribution: € 13 520 689,64, [project link](#).

RESCUE (River flood Embankments Subject to Climate change: Understanding Effects of future floods and novel 'low-carbon' adaptation measures), FP7, May 2014 – September 2016, EU contribution: € 231 283,20, [project link](#).

RESCCUE (Resilience to Cope with Climate Change in Urban Areas), H2020, May 2016 – April 2020, EU contribution: € 6.896.991,76, [project link](#).

RESIN (Climate Resilient Cities and Infrastructures), H2020, May 2015 – October 2018, EU contribution: € 7 466 004,50, [project link](#).

RISC-KIT (Resilience-Increasing Strategies for Coasts – toolkit), FP7, November 2013 – April 2017, EU contribution: € 5 999 692, [project link](#).

RISES-AM (Responses to coastal climate change: Innovative Strategies for high End Scenarios -Adaptation and Mitigation), FP7, November 2013 – October 2016, EU contribution: € 4 407 648, [project link](#).

SECOaquaA (Solutions for Environmental Contrasts in Coastal Areas), FP7, December 2009 – November 2013, EU contribution: € 6 159 118,44, [project link](#)

SimetoRES (Urban Adaptation And Community Learning For A Resilient Simeto Valley), LIFE, June 2018 – December 2021, EU contribution: € 568 037, [project link](#).

SMR (Smart Mature Resilience), H2020, June 2015 – June 2018, EU contribution: € 4 641 233,25, [project link](#).

UNALAB, H2020, June 2017 – May 2022, EU contribution € 12 768 931,75, [project link](#).

10. ANNEX 2: NBS PLATFORMS, PORTALS, DATABASES, NETWORKS AND INITIATIVES

NAME	WEB-LINKS	TERMINOLOGY USED
OPPLA	https://oppla.eu/casestudy/17577	Nature-Based Solution, Natural capital, Ecosystem services
Natural Water Retention Measures	http://nwrn.eu/	Natural water retention measures
Urban Nature Atlas	https://naturvation.eu/atlas	Nature-Based Solution
ClimateADAPT	https://www.eea.europa.eu/themes/climate/european-climate-adaptation-platform-climate-adapt	EbA, Nature-Based Solution, GI
Natural Hazards – Nature Based Solutions	https://naturebasedsolutions.org/	Nature-Based Solution
BiodivERsA	https://www.biodiversa.org/8	Ecosystem services
BISE	https://biodiversity.europa.eu/	Ecosystem services, Green infrastructures
ThinkNature	https://www.think-nature.eu/	Nature-Based Solution
Disaster Risk Management Knowledge Centre	https://drmkc.jrc.ec.europa.eu/	Eco-DRR
Nature-based Solutions Initiative (Nature Based Solutions Evidence Platform)	https://www.naturebasedsolutionsevidence.info/	Nature-Based Solution
weADAPT	https://www.weadapt.org/	Ecosystem-based Adaptation
Nature of Cities	https://www.thenatureofcities.com/	Green Infrastructures
ClimateScan	https://www.climatescan.nl/projects/2262/detail	Blue-Green Infrastructures
Partnership for Environment and Disaster Risk Reduction (PEDRR)	https://pedrr.org/	Ecosystem-based Adaptation
PANORAMA	https://panorama.solutions/en	Ecosystem-based Adaptation

11. ANNEX 3: ABBREVIATIONS AND ACRONYMS

APSFDRR	EU Action Plan on the Sendai Framework for Disaster Risk Reduction
BGI	Blue-Green Infrastructure
BMPs	Best Management Practices
BSR	Baltic Sea Region
CAP	Common Agricultural Policy
CBA	Cost-Benefit Analysis
CCA	Climate Change Adaptation
CIRIA	Construction Industry Research and Information Association
COST	Cooperation in Science and Technology Programme
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DG ECHO	Directorate General for Civil Protection and Humanitarian Aid
EBA	Ecosystem-based Adaptation
EC	European Commission
Eco-DRR	Ecosystem-based Disaster Risk Reduction
EEA	European Environment Agency
EU	European Union
FD	Floods Directive
FP6	6th Framework Programme
FP7	7th Framework Programme
FRMP	Flood Risk Management Plans
GI	Green Infrastructure
H2020	Horizon 2020 EU Framework Programme for Research & Innovation
INTERREG	EU Regional Development Fund
LID	Low Impact Development
MS	Member States of the EU
NBS	Nature-Based Solutions
OAL	Open-Air Laboratory
R&I	Research and Innovation
SACC	EU Strategy on Adaptation to Climate Change
SCP	Sponge City Programme
SFDRR	Sendai Framework for Disaster Risk Reduction
SUDS	Sustainable Urban Drainage Systems
UNISDR	United Nations International Strategy for Disaster Reduction
WFD	Water Framework Directive
WSUD	Water Sensitive Urban Design

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This document summarises outcomes relating to flood mitigation and coastal resilience from the report 'Nature-based Solutions: State of the Art in EU-funded Projects' (Wild et al. (Eds.) 2020) prepared through the EC's Valorisation of NBS Projects Initiative. EU research and innovation projects were scanned for results pertaining to key areas such as Floods Directive, EU Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 and EU Strategy on Adaptation to Climate Change. Evidence from the reviewed projects (and the EC's NBS policy topic area) is framed within knowledge from the literature within the realm of flood-related policy, to give as full a picture as possible about the state-of-the-art with relevant NBS. Contextualised information is provided on policy developments, research results and key lessons. The resulting evidence base includes figures and monetary values showing the relative cost-effectiveness of NBS, and exploring how they support flood-related policy implementation. Policy recommendations and knowledge gaps are also highlighted to support the strengthening of strategies and practical action for the uptake of NBS, to deliver targeted and efficient interventions to help solve societal challenges in Europe and beyond.

Studies and reports

