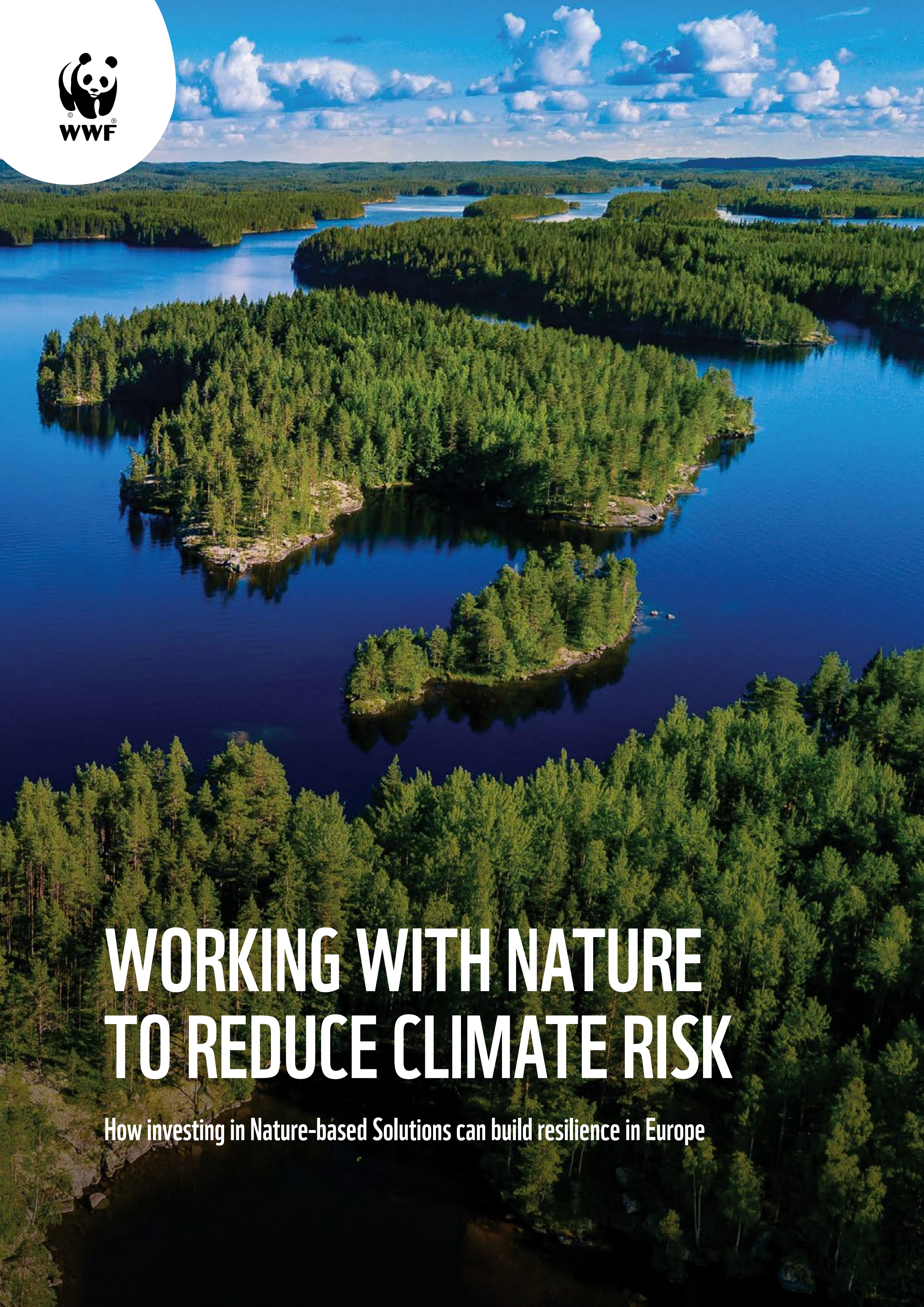

WWF

WORKING WITH NATURE TO REDUCE CLIMATE RISK

How investing in Nature-based Solutions can build resilience in Europe

CONTENTS

Lead author: Jeff Opperman

Thanks to the following WWF experts who contributed reviews or data: Eva Hernandez, Laurice Ereifej, Ariane Laporte-Bisquit, Georg Rast, Michael Allen, Alexis Morgan, Christopher Weber, and Bas Roel.

Design: Alexandra Kiss

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WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

EXECUTIVE SUMMARY

Climate change is the greatest threat to the future of our societies and economies. All the science points to worsening risks from extreme floods, droughts, melting glaciers and rising sea levels. But the climate crisis is not just a future threat. Climate change is already affecting water resources and exacerbating water-related risks across the globe, with impacts being felt by communities, corporations and countries.

In Europe, these rising risks are occurring on a landscape that has already been dramatically altered by people – including in ways that exacerbate these challenges, such as the loss of floodplains, channeling of rivers, construction of dams and rampant coastal development. All of these changes are part of a widespread loss of ecosystems and biodiversity on the continent, including the destruction of 56 per cent of its natural wetlands.

Increasingly, it seems as if the forces of nature are arrayed against our homes, businesses and economies – and that traditional responses can no longer hold back the tide or the floods or the droughts. The answer involves a greater focus on harnessing the power of nature to help increase our resilience and reduce these risks – by investing in Nature-based Solutions (NbS).

While we can only tackle Europe's worsening water-related challenges by employing a diverse range of solutions with a basin perspective and in an integrated way, it is essential to prioritise NbS – solutions that use natural systems or processes to help achieve a societal goal, such as managing water supplies or reducing disaster risk for people. A hallmark of NbS is that they can provide a range of other benefits to people and nature and thus can help tackle today's other great global crisis – the loss of the biodiversity, including an 83 per cent collapse in freshwater species populations on average since 1970. NbS can also contribute to the achievement of other international objectives, such as the Sustainable Development Goals and Paris Climate Agreement.

Although most of Europe features extensive infrastructure and water-management systems, the continent still confronts a number of water-related challenges that are projected to intensify with climate change. Using NbS to address these challenges can also help restore nature across Europe – boosting efforts to achieve other critical policy objectives, including the attainment of good ecological status for all rivers and other waters under the Water Framework Directive (currently 60 per cent are in bad health) and helping Europe lead the transition to a healthy planet, as outlined in the European Commission's new Green Deal.

Nature-based Solutions are key to planning for the following five objectives across Europe:

• ***Reducing risk from extreme river flooding***

Due to a combination of climate change and development in floodplains, the number of people affected by floods in Europe has been rising and flood damages are predicted to increase considerably in the future. A consensus is emerging that a much broader approach – a 'diversified portfolio' – is needed to manage current and future flood risks.

Along with non-structural measures, such as improved zoning and building codes, there needs to be much greater investment in NbS, which can reduce the impact of extreme floods by slowing runoff (i.e. by protecting natural forests and adopting best agricultural practice) and lowering flood levels (i.e. by preserving and restoring floodplains), while also helping to restore floodplain ecosystems, which are among the most diverse habitats on the planet.

• ***Reducing risk from coastal flooding or erosion***

Sea level has been rising and will continue to rise this century. While hard engineering solutions will still be needed in some situations to reduce coastal flood risk, the best option will include a mix of approaches that draw on NbS as much as possible, such as the protection or restoration of salt marshes and oyster reefs. These will help to reduce wave energy, minimize the impact of storm surges, and stabilize shorelines, while also providing other diverse benefits, such as carbon sequestration and habitats for wildlife.

• ***Reducing the risk of flooding in cities***

Coupled with all their impervious surfaces, many cities have paved over their wetlands and channelized their rivers, so that heavy rainfall can rapidly overwhelm storm drainage systems and cause severe flooding. Investing in a range of NbS, such as porous pavements and the restoration of wetlands, can slow down and store runoff, and reduce flood peaks. Fortuitously, most of these NbS contribute to greener and more vibrant urban environments.

• ***Managing water scarcity and reducing risk from droughts***

The droughts of 2003 and 2015 were among Europe's most severe in the past 250 years. Managing for water scarcity and drought risk should strive for a diverse, integrated and comprehensive approach – with an emphasis on NbS, including using natural features to increase water availability, such as recharging groundwater and retaining water in soils. This can help countries move from simply reacting to droughts to building a 'drought resilient society'.

• ***Improving water quality***

Around 60 per cent of European water bodies are still polluted with chemicals, primarily from agriculture. A number of NbS can help improve water quality, ranging from biodiversity-based approaches to restoring wetlands that filter sediment and pollution from runoff.

CALL TO ACTION

As these examples show, Nature-based Solutions have considerable potential to improve land and water management and to reduce water-related risks. But despite the multiple benefits that NbS can provide, currently less than 1 per cent of total investments in water-management infrastructure is allocated toward NbS. European countries and companies must urgently increase investment in NbS to build more resilient societies, economies and ecosystems.

- **The European Commission** must ensure that the EU Biodiversity Strategy for 2030 includes legally binding targets for restoring wetlands, peatlands and floodplains, strengthen the implementation of the Water Framework Directive so that all surface and ground waters will be in good status by 2027, and launch a large-scale deployment of Nature-based Solutions for water management in order to enhance the natural treatment of pollution, sustain biodiversity, and increase resilience to climate change.

- **European countries** must integrate NbS into river basin management plans and protect remaining free-flowing stretches of rivers for their biodiversity, ecological and societal values. In addition, EU Member States must integrate NbS into Flood Risk Management Plans and as part of the full implementation of the WFD.

- **Private sector companies** must adopt water stewardship, beginning by assessing their water risks and then developing a strategy that mitigates them, including promoting the individual and collective application of NbS where possible.

- **The financial sector** must better understand water risk and how to account for it when valuing investments, engage with existing efforts and start to create offerings that finance NbS, and support policy that lays the foundation for credible green investments.

Europe's past features a dramatic loss of nature. Along with diminishing the continent's wildlife, the loss of forests, wetlands and floodplains has increased the risks from flooding, drought, and poor water quality. Climate change will exacerbate these risks – even if we succeed in holding the rise in global temperature to under 1.5 degrees.

We do not suggest that NbS are the sole solution to water-related challenges, but they should be prioritized because they have the potential to restore some of the losses of the past, while reducing the risks of the future. NbS provide diverse benefits that will help communities, corporations and countries to increase resilience and adapt to climate change, especially when NbS are planned and implemented at a river basin scale and in an integrated way across sectors.

Similar to advice on how to be a savvy investor, those managing rising climate risks should strive for a "diversified portfolio approach" that integrates NbS with more conventional solutions. In a warming world, we risk seeing nature's power as only a threat. By investing in Nature-based Solutions, we also get nature's power on our side.

INTRODUCTION

The news is filled with stories of extreme floods and droughts and scientists are increasingly able to link the changing climate to the worsening impacts of these events. Communities suffer losses, companies see their supply chains and production interrupted, insurance rates rise. Meanwhile, a steady stream of scientific papers and international reports makes a strong case that, without rapid action on reducing emissions, these challenges will only get worse.

Collectively, these stories and reports make it seem as if the forces of nature are increasingly arrayed against our homes, our businesses and our economies. But we can also harness the power of nature to help build resilience and defend us against these risks by investing in Nature-based Solutions (NbS), which will also contribute to tackling the other great global crisis: biodiversity loss.

As the landmark Global Commission on Adaptation report *'Adapt Now'* made clear, the impacts of "climate change will most immediately and most acutely be felt through water." Warmer air can hold more moisture, resulting in larger and more frequent floods. Rising seas will raise flood risks along the coasts. Meanwhile, some regions of the world, including parts of Europe, are projected to become drier and to experience longer and more frequent droughts. The melting of glaciers and reduction in snow cover in high mountain areas will drastically alter run off and river flows. Furthermore, warmer temperatures not only increase evaporation from soils and water demand from irrigation, they can also exacerbate challenges that arise from poor water quality. More intense rainfall is predicted to increase the amount of hazardous substances that are flushed into river systems from urban and agricultural land.[1]

These risks will be felt by communities, companies and countries. Communities will face increasing risks from extreme floods, including loss of life and property, and disruptions to water supplies. Companies will confront these same local risks, along with disruptions to their supply chains, as well as reputational and regulatory risks as communities and countries respond to changing conditions. All of these translate into risks for financial institutions and insurance companies (Box 1). Finally, national governments will need to address these diverse risks to their people, infrastructure, and economic systems to ensure that their countries remain strong and resilient in the face of climate change.

¹ EEA. (2012). European Waters – assessment of status and pressures. Copenhagen: European Environment Agency

Box 1. Climate change will increase stress on disaster-risk finance

A recent study led by Dutch scientists (Jongman et al. 2014) found that large flood events in Europe tend to occur in several rivers at the same time. Thus, events with high financial losses will tend to affect multiple countries at once. This puts high stress on insurance companies and other mechanisms for transferring risk. Furthermore, the authors project that "extreme flood losses could more than double in frequency by 2050 under future climate change and socio-economic development." They posit that managing growing risk is feasible but will require collaboration from communities, corporations and countries, including a commitment to investing in measures to reduce flood losses.

In Europe, these rising risks and challenges from climate change are occurring on a landscape that has already been dramatically altered by people – including in ways that exacerbate these challenges, such as the loss of floodplains, channeling of rivers, construction of dams and rampant coastal development. For example, the widespread loss of wetlands and floodplains, and expansion of hard surfaces have contributed to higher flood levels. By constricting channels and concentrating floodwaters, dikes intended to prevent flooding can actually increase flood risk up and downstream. Floodplains and coastlines have been extensively developed, dramatically increasing the number of people and the property value at risk from floods and storms.

All of these changes are part of a widespread loss of natural ecosystems and biodiversity on the continent, and thus a loss of functionality of our rivers. Europe has lost more than 56 per cent of its natural wetlands, most of them in the last century.[2] Due to the high number of dams, along with dikes and other infrastructure, none of Europe's long rivers can be classified as free-flowing,[3] which not only has an impact on the rivers themselves, but also on the coasts. Barely 40 per cent of water bodies (Figure 1) and less than 15 per cent of floodplains can be considered to be in good ecological status.[4] As a result of these widespread habitat changes, along with pollution and other threats, Europe's freshwater species are in crisis with 59 per cent of molluscs, 40 per cent of fish and 23 per cent of amphibians threatened with extinction.[5]

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[2] Davidson, Nick. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research. 65. 936-941. 10.1071/MF14173. https://www.researchgate.net/publication/266388496_How_much_wetland_has_the_world_lost_Long-term_and_recent_trends_in_global_wetland_area
[3] Sensu Grill et al. 2019 Mapping the world's free-flowing rivers. Nature, 569(7755), p.215.
[4] European Environment Agency. 2018. Why should we care about floodplains; https://www.eea.europa.eu/themes/water/european-waters/why-should-we-care-about-floodplains
[5] PBES (2019): Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany.(2.2.7.14)

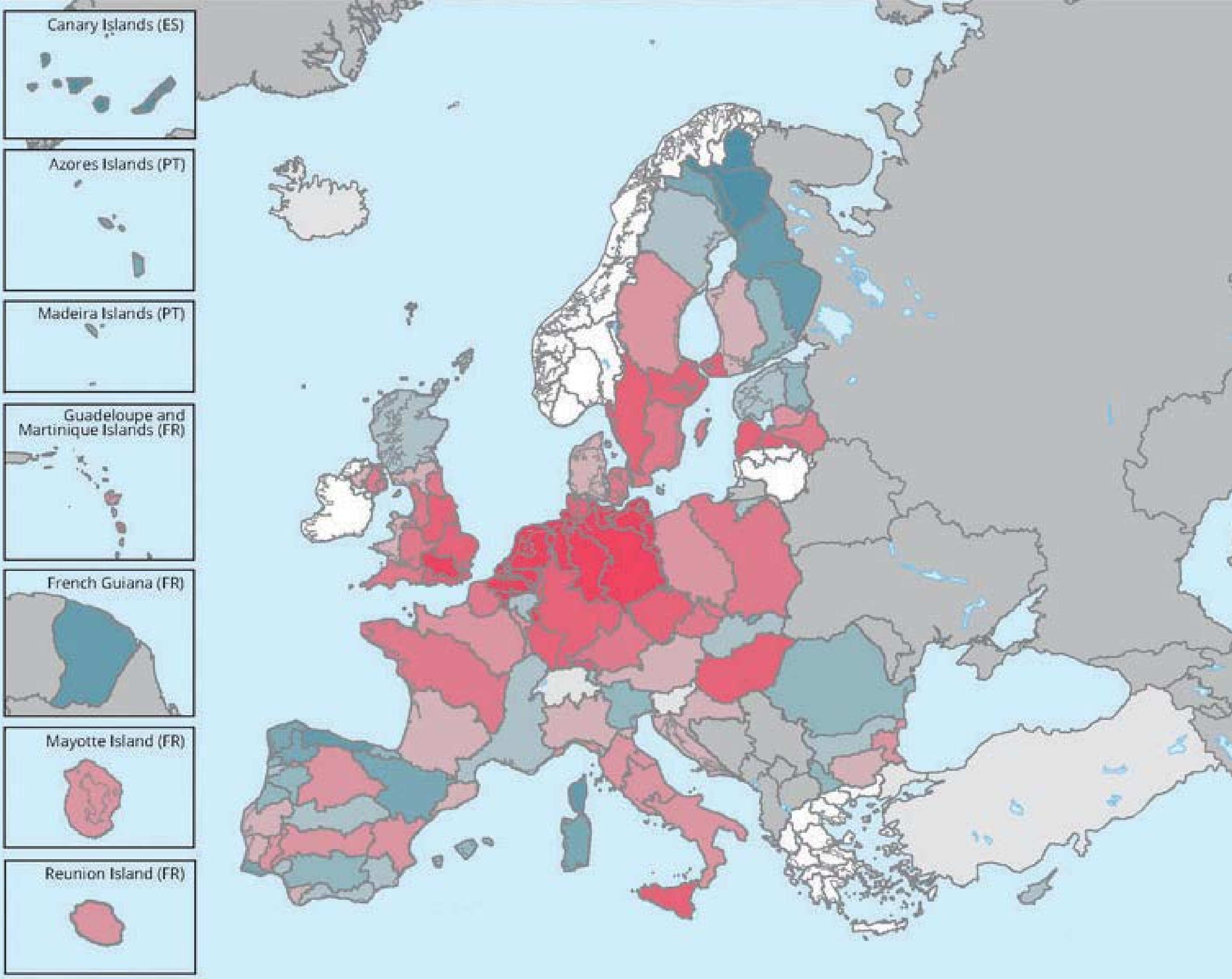
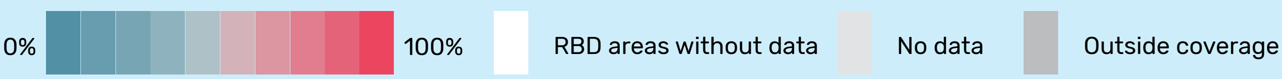


FIGURE 1

PERCENTAGE OF WATER BODIES NOT IN GOOD ECOLOGICAL CONDITION

Percentage of number of water bodies not in good ecological status or potential per river basin district (RBD) in second River Basin Management Plans.

European waters - Assessment of status and pressures 2018. EEA




KD Köln-Düsseldorfer

While we can only tackle Europe's worsening water-related challenges by employing a diverse range of solutions, it is essential that we prioritise Nature-based Solutions – defined in the World Water Development Report as those that use natural systems or processes to help achieve a societal goal, such as managing water supplies or reducing disaster risk for people.[6] NbS can substitute for, or complement, the services provided by conventional engineering approaches and at the same time provide a range of other benefits to people and nature – such as natural treatment of water pollution, habitat for wildlife and climate mitigation – and can thus boost progress towards the Sustainable Development Goals and contribute to countries' commitments under the Paris Climate Agreement. With the European Commission pursuing a new Green Deal to lead the transition to a healthy planet, there is a unique opportunity to mobilize and prioritize investments in Nature-based Solutions to accelerate climate action.

Similar to advice on how to be a savvy investor, those managing rising climate risks should strive for a "diversified portfolio approach" that integrates NbS with more conventional solutions. NbS have the potential to not only reduce risks from future climate change, but to begin reversing the losses of the past, especially by helping to restore healthy rivers and freshwater habitats, which are central to efforts to adapt to climate change and strengthen mitigation.

In this report, we explore the potential for NbS to help Europe manage freshwater resources and reduce water-related risks, especially those affected by climate change. We start by analyzing risks for communities, companies and governments and how they are shifting with climate change. We then explore a set of NbS that can contribute to reducing these risks and illustrate some of them with case studies drawn primarily from Europe. Finally, we conclude with a set of recommendations for policies, funding mechanisms, and corporate practices that can accelerate adoption of NbS as countries strive to improve their management of water resources and achieve a range of other societal objectives.

[6] UN-Water. 2018. The United Nations World Water Development Report 2018: Nature-based Solutions for Water. Paris, UNESCO.

THE NEED AND OPPORTUNITY FOR NBS IN EUROPE

Climate change is already affecting water resources and water-related risks in Europe. Due to shifting precipitation patterns, parts of Europe have already seen extreme floods become more frequent. Meanwhile, some parts of the continent are projected to become drier and to experience longer and more frequent droughts. Overall, patterns of rainfall are projected to become more 'flashy' so that some places will experience increased risk of *both* floods and droughts. Furthermore, warmer temperatures can exacerbate challenges that arise from poor water quality; excess nutrients in runoff can trigger harmful algal blooms in lakes and coastal waters, and warmer temperatures can increase the scale and frequency of these blooms. Economic losses caused by climate and weather-related extreme events in Europe have soared since the 1980s, from €7.5 billion per year to over €13 billion per year between 2010 and 2017 (all figures in 2017 values).[7]

For many of these challenges, NbS – defined as solutions "inspired and supported by nature [that] use, or mimic, natural processes to contribute to" achieving societal goals[8] – can help countries expand beyond traditional water-management responses and potentially produce more durable and sustainable outcomes (Table 1).

[7] European Environment Agency https://www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-3/assessment-2

[8] UN-Water. 2018; see note 6.

Table 1. Examples of Green Infrastructure solutions - a key component of Nature-based Solutions - organized by the water-management objective they are intended to achieve.[9]

Water management issue (Primary service to be provided)		Green Infrastructure solution	Location: Watershed	Location: Floodplain	Location: Urban	Location: Coastal	Corresponding Grey Infrastructure solution (at the primary service level)
Water supply regulation (incl. drought mitigation)		Re/afforestation and forest conservation	■				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Water harvesting*	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
Water quality regulation	Water purification	Re/afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
	Erosion control	Re/afforestation and forest conservation	■				Reinforcement of slopes
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
	Biological control	Re/afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
	Water temperature control	Re/afforestation and forest conservation	■				Dams
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (shading of water ways)			■		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	■				Dams and levees
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Establishing flood bypasses		■			
	Urban stormwater runoff	Green roofs			■		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			■		
		Water harvesting*	■	■	■		
		Permeable pavements*			■		
	Coastal flood (storm) control	Protecting/restoring mangroves, coastal marshes and dunes				■	Sea walls
		Protecting/restoring reefs (coral/oyster)				■	

[9] United Nations Environment Programme. 2014. Green Infrastructure Guide for Water Management: Ecosystem-based management approaches for water-related infrastructure projects ISBN: 978-92-807-3404-1

Furthermore, since co-benefits of NbS include enhancing ecosystem health and biodiversity, using NbS to address water-management challenges can support efforts to achieve European environmental policy objectives that have not yet been met, such as the widespread attainment of good ecological status for rivers. In addition, they will have a key role to play in the European Green Deal, which aims to lead the transition to a healthy planet, make Europe the first climate-neutral continent by 2050 and preserve Europe's natural environment.

NbS can help Europe address these key water-management challenges:

- ***Extreme flooding from rivers.*** Although flooding is a natural phenomenon that contributed to the fertilization of agricultural land in the past, the increase in settlements and the intensification of land uses, and, in many cases, inadequate water management have led to the disasters we see in the news. Floods have caused more damage than any other natural extreme event in Europe this century[10] and economic losses from floods are predicted to increase considerably in the future (Figure 2), rising to €23.5 billion by 2050 – nearly five times greater than the annual losses between 2000 and 2012 (€4.2 billion). Two-thirds of this increase are attributed to continued development in floodplains while one-third is due to climate change.[11]

  Reviewing various pathways for Europe to respond to rising flood risk, a team of scientists note that relying strictly on traditional measures (e.g., increasing dike heights) is "not sustainable in the long term". Instead, Lorenzo Alfieri and his colleagues recommend a diversified approach that combines a range of measures "working in synergy and optimized at the level of river basins."[12] Along with non-structural measures, such as improved zoning and building codes, a diversified approach should prioritize much greater investment in NbS, which can reduce the impact of extreme floods by slowing runoff (i.e. by protecting natural forests, restoring wetlands and adopting best agricultural practice) and lowering flood levels (i.e. by preserving and restoring floodplains, dike setbacks and floodways). As a co-benefit, NbS approaches in floodplains could help restore these important and fertile ecosystems, which play a key role as natural water retention areas and hotspots for biodiversity.

  A range of economic activities – from agriculture to urban expansion – have contributed to the conversion or degradation of Europe's floodplains, so that less than 15% can be classified as having good ecological status. Diverse EU policies now promote the protection and restoration of floodplains, including the Water Framework Directive, the Floods Directive, the EU 2020 Biodiversity Strategy, and the Habitats and Birds Directive.[13]

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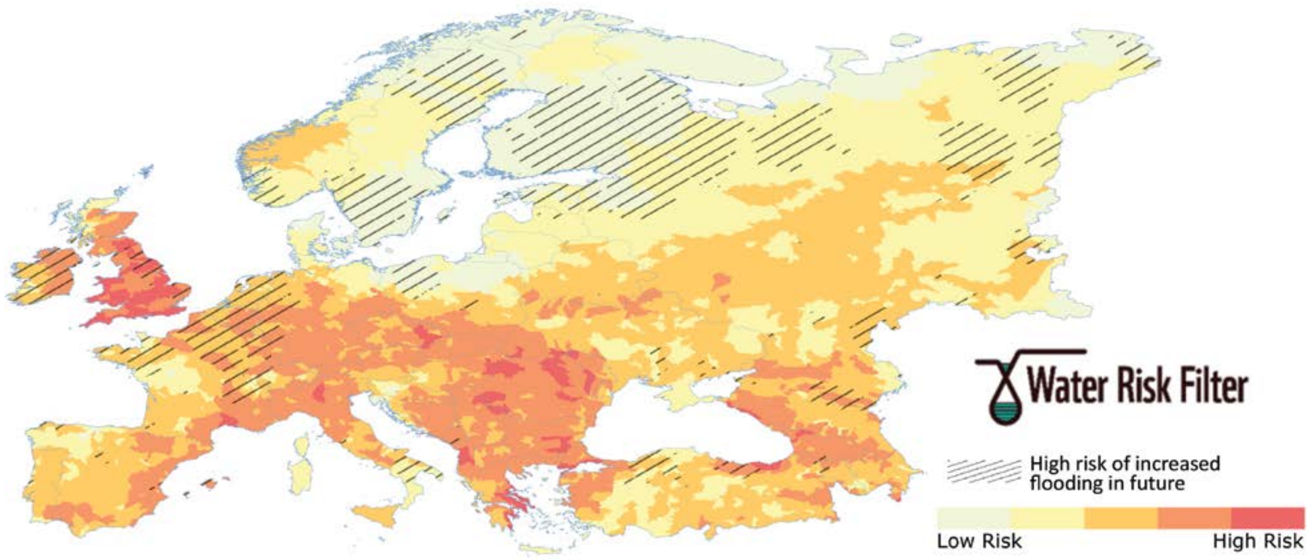
[10] European Environment Agency. 2011. Disasters in Europe: more frequent and causing more damage. EEA. Denmark

[11] Jongman, B., Hochrainer-Stigler, S., Feyen, L., Aerts, J.C., Mechler, R., Botzen, W.W., Bouwer, L.M., Pflug, G., Rojas, R. and Ward, P.J., 2014. Increasing stress on disaster-risk finance due to large floods. Nature Climate Change, 4(4), p.264.

[12] Alfieri, L., Feyen, L. and Di Baldassarre, G., 2016. Increasing flood risk under climate change: a pan-European assessment of the benefits of four adaptation strategies. Climatic Change, 136(3-4), pp.507-521.

[13] European Environment Agency. 2018; see note 4.

Figure 2. Current and future flood risk, highlighting areas projected to experience the greatest increase in flooding (WWF Water Risk Filter)



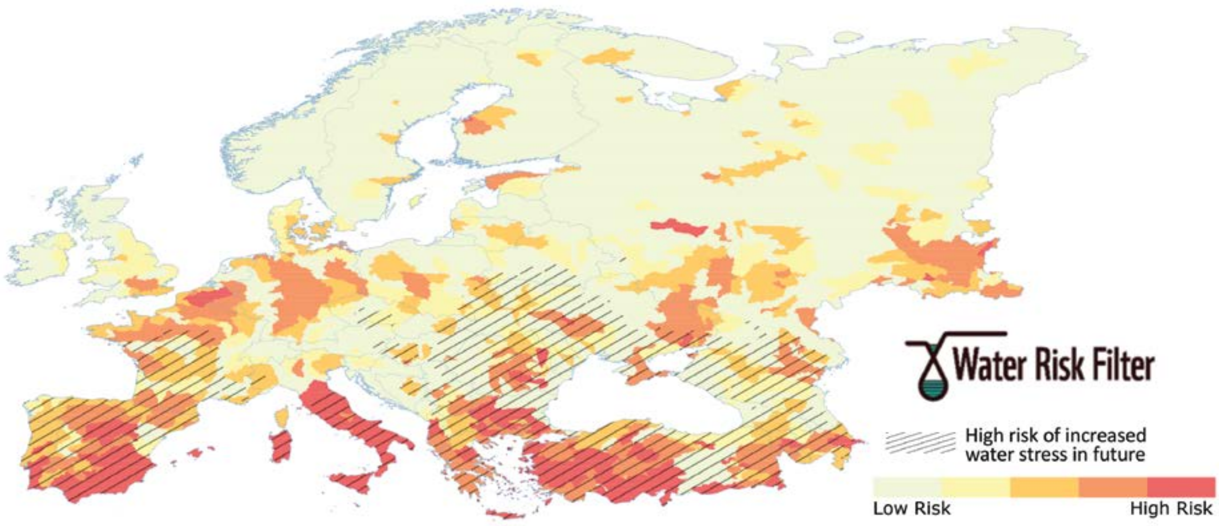
- ***Drought.*** The droughts that Europe experienced in 2003 and 2015 were among the most severe in the past 250 years.[14] The 2003 drought resulted in approximately €10 billion in economic losses, primarily to agriculture,[15] and widespread declines in river levels reduced hydropower generation, negatively affected power plants that use rivers for cooling water, and interrupted navigation on the Danube, Elbe and Rhine Rivers.[16]

  Although droughts have generally been associated with southern Europe, countries in norther Europe are also now experiencing drought. In 2018, Germany suffered its fourth driest year since 1881 and €2.5 billion in crop losses.[17] In 2019, the French power company, EDF, was forced to temporarily halt operations at some of its nuclear power plants because the water in the Rhone river was too low and too warm.

  Due to rising temperatures – which increase evapotranspiration and reduce soil moisture – and shifting precipitation, much of Europe is projected to face increased drought risk and water scarcity in the coming decades. Southern Europe is particularly vulnerable (see Figure 3), especially since excessive water consumption, mainly for agriculture, results in these countries experiencing continuous water stress, undermining their capacity to withstand extreme drought events.

[14] Hanel, M., Rakovec, O., Markonis, Y., Máca, P., Samaniego, L., Kyselý, J. and Kumar, R., 2018. Revisiting the recent European droughts from a long-term perspective. Scientific reports, 8(1), p.9499.
[15] European Commission. 2007. Drought Management Plan Report, including Agricultural, Drought Indicators and Climate Change Aspects. Water Scarcity and Droughts Expert Network. November 2007.
[16] Sayers, P.B., Li Yuanyuan, Moncrieff, C, Li Jianqiang, Tickner, D., Xu Xiangyu, Speed, R., Li Aihua, Lei Gang, Qiu Bing, Wei Yu and Pegram G. 2016. Drought risk management: A strategic approach. Published by UNESCO, Paris on behalf of WWF.
[17] WWF Germany. Drought Risk: The Global Thirst for Water in the Era of Climate Crisis. 2019 https://mobil.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_DroughtRisk_EN_WEB.pdf

Figure 3. Current and future water stress, highlighting areas projected to experience the greatest increase in water stress (WWF Water Risk Filter)



Water scarcity issues have usually been tackled by increasing the number of dams to store water and through water transfers, but paradoxically we see that despite the intense level of regulation of our rivers, water risk remains high in the Mediterranean region, and will increase further. Managing for water scarcity and drought risk should strive for a diverse, integrated and comprehensive approach – with an emphasis on demand management as well as on NbS, including using natural features to increase water availability, such as recharging groundwater and retaining water in soils. This can help countries move from simply reacting to droughts to building a 'drought resilient society'.

• ***Coastal flooding and erosion.*** Sea levels have been rising and will continue to rise this century. The risks of coastal flooding and erosion are predicted to increase due to a combination of climate change, development in coastal zones, sinking of coastal areas – as sediments that naturally reached the coast are now trapped by dams upstream – and habitat destruction. A recent study projected that – without increased investment in coastal defenses – annual losses in Europe would increase by orders of magnitude by the end of the century, from just over €1 billion per year to between €90 and €900 billion per year. The number of people affected would similarly soar, from approximately 100,000 per year to 1.5 to 3.6 million per year.[18]

While hard engineering solutions will still be needed in some situations to reduce coastal flood risk, the best option will include a mix of approaches that draw on NbS as much as possible, such as the protection or restoration of salt marshes, coastal lagoons, coastal peatlands, sand dunes and oyster reefs. These will help to reduce wave energy, minimize the impact of storm surges, and stabilize shorelines, while also providing other diverse benefits, such as carbon sequestration to boost climate mitigation, and habitats for wildlife.

[18] Vousdoukas, M.I., Mentaschi, L., Voukouvalas, E., Verlaan, M., Jevrejeva, S., Jackson, L.P. and Feyen, L., 2018. Global probabilistic projections of extreme sea levels show intensification of coastal flood hazard. Nature communications, 9(1), p.2360.

• ***Water quality.*** While some aspects of water quality in European water bodies have improved over the past few decades, excess nutrients remain a problem, with the majority of nutrient pollution coming from agricultural runoff. Excess nutrients, such as nitrogen and phosphorous, washed into lakes and coastal areas can lead to eutrophication and harmful algal blooms and dead zones, which in turn will increase greenhouse gas emissions.[19] Warmer water can increase the duration and severity of these blooms – and intense rainfall events can wash more fertilizer runoff into rivers – so climate change could exacerbate this challenge. Indeed, parts of Europe, including the Baltic Sea are projected to see an increase in harmful algal blooms as the world warms.[20]

Agricultural practices can increase soil erosion and sedimentation in rivers, which can negatively affect aquatic species and require greater treatment costs in water supply systems and greater maintenance and replacement costs. Runoff from conventional farms can also carry herbicides and pesticides into streams and rivers, affecting aquatic species and drinking water. By 2015, 41% of waterbodies in Europe had achieved "good chemical status" under the Water Framework Directive, but 50% still remained polluted to varying degrees. In 10% of cases the pollution levels had not even been analyzed.

A number of NbS can help improve water quality, ranging from biodiversity-based approaches for managing agricultural pests that require less use of pesticides to better soil management, to building or restoring wetlands and riverine vegetation that filter sediment, nutrients and other pollution from runoff.

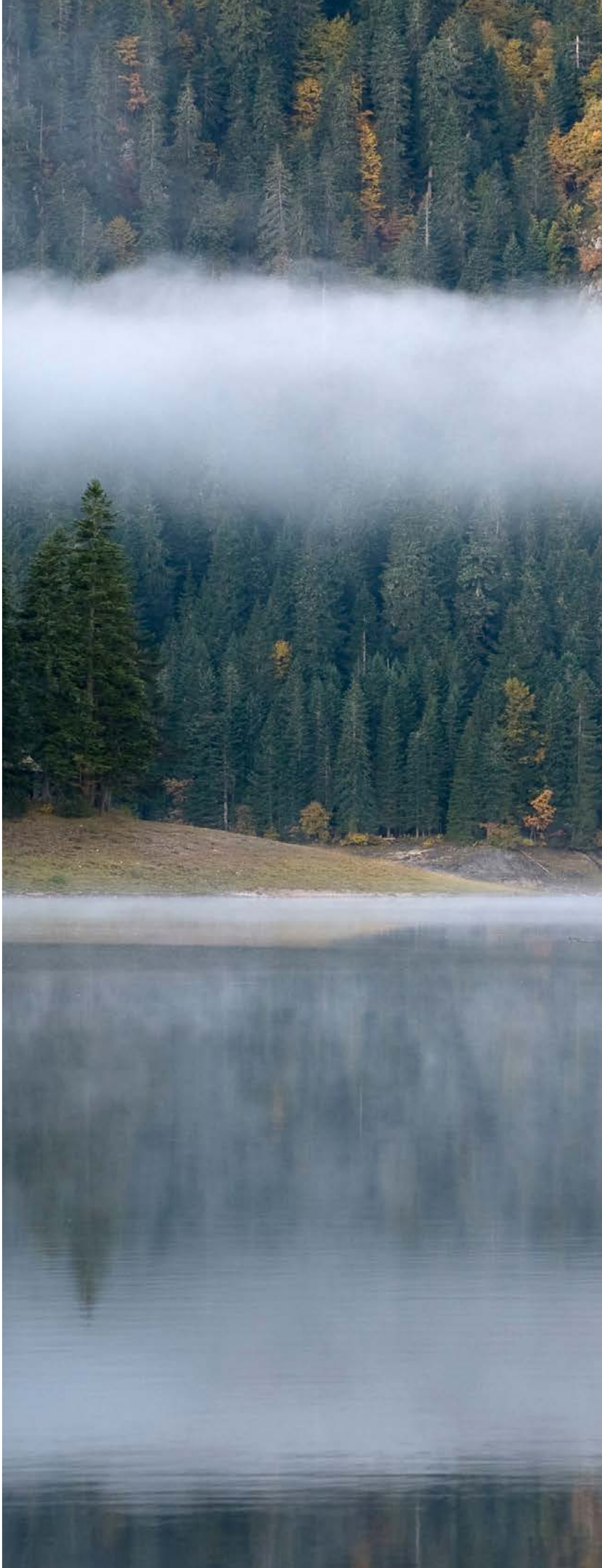
[19] Beaulieu, J.J., DelSontro, T. and Downing, J.A., 2019. Eutrophication will increase methane emissions from lakes and impoundments during the 21st century. Nature Communications, 10(1), p.1375.
[20] Glibert, P.M., Icarus Allen, J., Artioli, Y., Beusen, A., Bouwman, L., Harle, J., Holmes, R. and Holt, J., 2014. Vulnerability of coastal ecosystems to changes in harmful algal bloom distribution in response to climate change: projections based on model analysis. Global change biology, 20(12), pp.3845-3858.

Box 2. Water Framework Directive: a key tool to handle climate change

The Water Framework Directive (WFD) is a key tool for water management in the countries of the European Union, as well as some others outside. Approved in 2000, it includes among its purposes *"to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which […] prevents further deterioration and protects and enhances the status of aquatic ecosystems […] aims at enhanced protection and improvement of the aquatic environment […] and contributes to mitigating the effects of floods and droughts and thereby contributes to the provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use".*

To achieve those goals the WFD demands a basin perspective, incorporates deep analysis of the current status of waters, including their hydromorphology, and requests the establishment of a Programme of Measures to recover the good status of all waters by 2027 at the latest.

One of the so-called *daughter directives* of the WFD is the Floods Directive, which establishes the need for flood risk management plans focused on prevention, protection and preparedness, both for river and coastal floods. The European Commission has already stressed the need to prioritise Nature-based Solutions in dealing with floods.[21]



[21] DG Environment. EU Commission. "Towards Better Environmental Options in Flood Risk Management". March 2011

TYPES OF NBS INTERVENTIONS AND CASE STUDIES

In this section we review NbS interventions intended to address five specific objectives and provide one or more short case studies of each (Figure 4), drawing primarily on examples from Europe. Although we feature individual sections on each of these objectives, we want to emphasize that a hallmark of NbS projects is that they provide multiple benefits. For example, using floodplains to reduce flood risk can also often contribute to groundwater recharge (reducing drought risk) and, by promoting deposition of sediment and nutrients, improve water quality. Thus, implementation of one type of NbS can often contribute to improvements in several water-management challenges. Beyond diverse water-management benefits, floodplain reconnection also supports carbon sequestration, biodiversity, wildlife and recreation.

The potential to achieve these diverse benefits will be maximized when NbS — and how they integrate with other infrastructure and management activities — are planned and implemented at a system-scale, such as that of a river basin.

This report looks at the following five objectives that can be achieved with NbS interventions:

- Reducing risk from river flooding
- Reducing risk from coastal flooding or erosion
- Reducing the risk of flooding in cities
- Reducing risk from droughts
- Improving water quality

Figure 4. Conceptual figure of different types of NbS interventions in a river basin and the benefits they provide. (River basin background image used with permission from the Natural Heritage Institute)

- Reduction of river flood risk
- Water quality improvements
- Drought risk management
- Reduction of coastal flooding and erosion
- Urban NbS

A. Levee setback/floodplain reconnection
- reduction of river flood risk
- water quality improvements
- drought risk management (groundwater recharge)

B. Flood bypass (same benefits as A)

C. Managing catchment soils and vegetation
- drought risk management
- water quality improvements

D. Wetlands integrated into agricultural landscape
- water quality improvements
- drought risk management

E. Riparian buffers/filter strips
- water quality improvements

F. Coastal wetland restoration
- reduced coastal flooding and erosion

G. Various urban green infrastructure interventions

NATURE-BASED SOLUTIONS TO REDUCE RISK FROM RIVER FLOODING

Flooding already causes average annual losses of nearly €40 billion around the world.[22] Forecasts suggest that even relatively small increases in the global average temperature will result in an increase in the frequency of intense and damaging storms and floods, and the modeled predictions are already being confirmed with extreme flood events across the world.[23] Beyond climate change, flood risk is rising for other reasons. In regions with mature flood defense systems, the engineered structures, such as dams and dikes, are often deteriorating with insufficient budgets for repairs and maintenance. Furthermore, ongoing changes in river basins – including conversion of forests and wetlands into agriculture land and the expansion of urban areas dominated by impervious surfaces – are increasing the size and frequency of floods.

Too often, debates about investing in flood-risk management focus strictly on engineered structures, such as dams, dikes and floodwalls. However, a consensus is emerging that a much broader approach – a 'diversified portfolio' – is needed to manage current and future flood risks.[24] This portfolio should emphasize non-structural measures such as improved zoning, building codes and insurance, as well as include investment in an under-appreciated line of defense: Nature-based Solutions, such as wetlands and floodplains managed to reduce flood risk.[25]

In addition to providing the benefit of flood-risk reduction, NbS projects can also help restore floodplain ecosystems, which are among the most productive and diverse habitats on the planet.

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[22] Cooley, H., 2006. Floods and droughts. In The World's Water 2006–2007: The Biennial Report on Freshwater Resources (p. 392). Island Press.
[23] Mallakpour, I. and Villarini, G., (2015). The changing nature of flooding across the central United States. Nature Climate Change, 5(3), p.250.
[24] Sayers, P.B. et al; see note 16.
[25] World Wildlife Fund. 2016. Natural and nature-based flood management: A Green Guide. Washington, DC.

There are three main categories of NbS for reducing risk from river flooding:

- ***Managing land to retain and slow runoff.*** Precipitation across a watershed or river basin leads to runoff into streams and rivers; above a given rate this runoff can lead to flooding. Land — including soils, vegetation and wetlands - can be managed to slow down and retain runoff as much as possible, potentially reducing flooding downstream (with impact varying by size of runoff event and area of watershed). Specific interventions can include protection of natural forests, reforestation, restoring healthy wetlands, and best practices in agriculture and grazing that encourage infiltration into soils or the addition of features — such as small wetlands, including those created by dams built by reintroduced beavers — that can retain runoff. Note that these interventions also reduce erosion and risk of landslides. They generally also overlap with those intended to improve water quality or increase resilience to drought.

- ***Large-scale preservation of floodplains along rivers*** can reduce flood levels and risk in some situations, both through storage of floodwaters that reduces flood levels downstream and –because land that remains in forest, wetland, or other flood-tolerant land uses is generally not vulnerable to damage during floods – by minimizing economic damage from floods.

- ***Hybrid gray-green approaches including dike setbacks and floodways.*** Dikes can be repositioned further from the river to increase the area of floodplain available to convey floodwaters, potentially reducing flood levels elsewhere in the system (see Figure 5). Floodways are large areas that are designated to be inundated during floods, greatly expanding the area available to store and convey floodwaters (see Box 3). Depending on the frequency with which a floodway is inundated, the land within it can be used for low intensity activities, such as certain types of agriculture or forestry and/or recreation, including ecotourism. Both floodways and the additional floodplain area connected to the river after a dike setback can provide important habitat for fish, birds and other wildlife. From a flood-management perspective, these interventions are often focused on large, potentially damaging floods. However, small and frequent floods can have great value to ecosystems. To promote these ecological benefits, NbS interventions can be planned to incorporate features that maximize the benefits of these small floods.[26]

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[26] Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L. and Manfree, A.D., 2017. Floodplains: Processes and management for ecosystem services. Univ of California Press.

Box 3. A gray-green hybrid approach reduces flood risk in California's Sacramento Valley and demonstrates the multiple benefits of NbS.

The 60,000 acre Yolo Bypass in California's Sacramento Valley – a vast area of floodplain that was reconnected to the Sacramento River nearly a century ago – provides an effective demonstration of the potential for large-scale reconnection of floodplains to help manage flood risk for cities and farms. The Bypass conveys nearly 80 percent of the Sacramento River's flood volume during major storms, reducing flood risk as it flows past its namesake city, which it has a long history of flooding. Although engineers designed it strictly for flood management, the Bypass provides the best remaining lowland floodplain habitat in the Central Valley, supporting vast flocks of native birds and providing rearing habitat for endangered fish species, such as salmon. Because it is inundated frequently and for long periods, floodwaters can recharge the groundwater and the Bypass served as an important contributor to a groundwater bank during a drought.

A major highway crosses the Yolo Bypass while it conveys a large volume of floodwaters to protect the city of Sacramento.

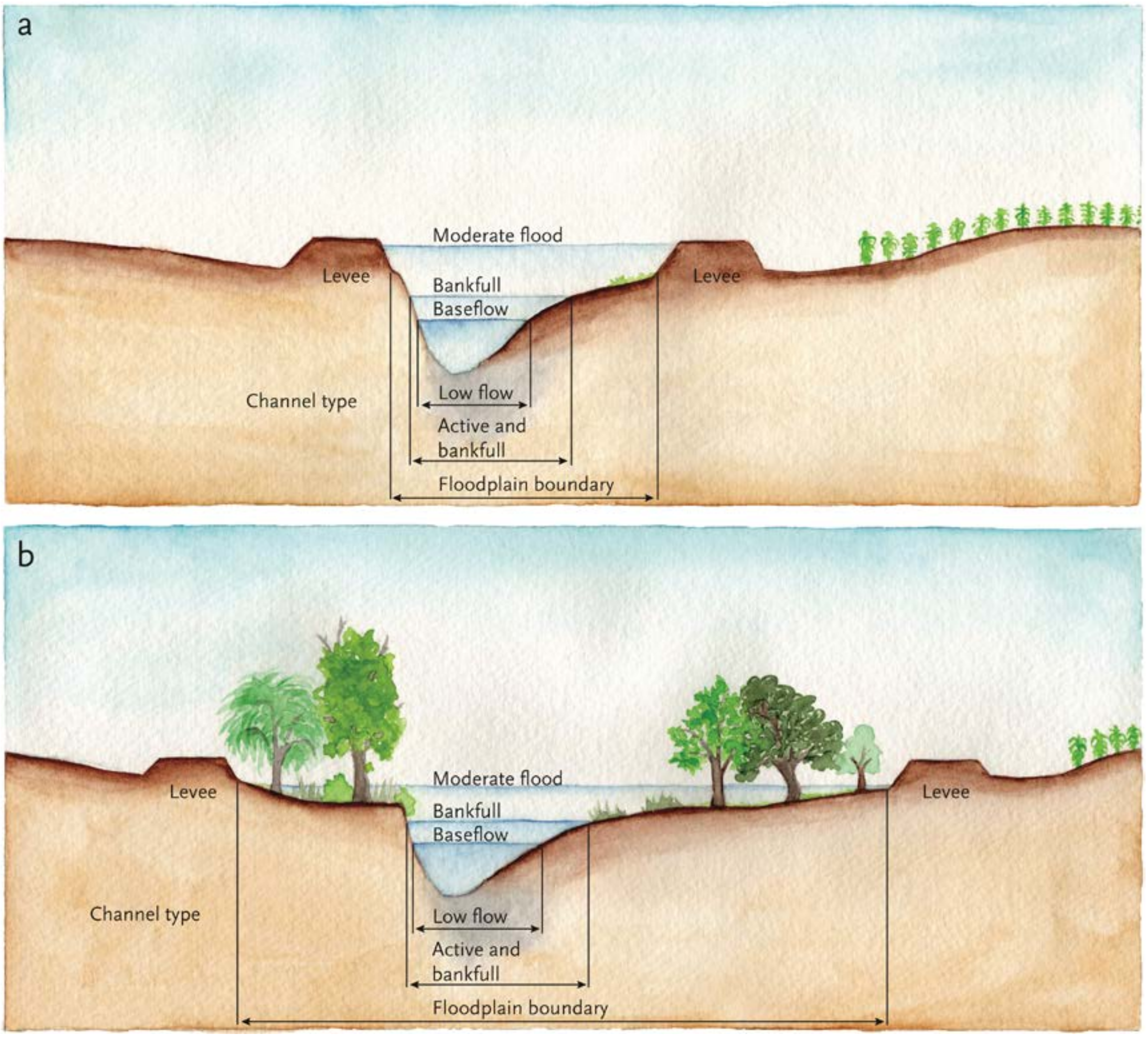


Figure 5. Conceptual diagram of a dike setback project. (A) The dikes are located close to the channel and, during floods, are exposed to high velocity flows, increasing the risk of erosion and need for maintenance. There is limited room for river-floodplain connectivity and ecosystem processes between the dikes. (B) Dikes that are set back from the river; for the same flood as in A, the setback dikes are exposed to lower water stages and flow velocities, reducing erosion and maintenance costs. The area available to support floodplain ecosystems is greatly expanded. From Opperman et al. (2017) and used with permission from the University of California Press.

CASE STUDIES: Lödderitzer Forest

The Elbe River begins in the Krkonoše Mountains of the Czech Republic before flowing into Germany and ultimately reaching the North Sea just downstream of Hamburg. Flowing for 1,329 km, it is slightly longer than the Rhine and its basin, at nearly 150,000 square kilometers, is one of the largest in Europe. The rich floodplains along the Elbe have been farmed for centuries, with an estimated 80 per cent of its floodplain area disconnected from the river by dikes.

Mosaic of floodplain habitat in the reconnected floodplain along the Elbe River at Lentzen

Although dikes and floodwalls have been built to hold back the Elbe's floodwaters, the river and its basin have experienced major floods several times this century. During the record European flooding of 2002 – which caused more than 100 deaths across the central part of Europe – the Elbe reached all-time high flood stages and the city of Dresden suffered significant damage. Just four years later, portions of the lower Elbe saw flood stages even higher than those of 2002, and yet another record flood occurred in the Elbe basin again in 2013.

WWF-Germany has focused on restoring the biodiversity-rich floodplain forests and meadows along the Elbe since the 1990s.[27] The Lödderitzer Forest, with its centuries-old stands of oaks, has been a priority and WWF and partners began a project to remove an existing dike, located close to the channel, along seven kilometers of river bank and construct a new dike further from the river. Completed in 2018, the project reconnected 600 hectares of floodplain forest to the river.

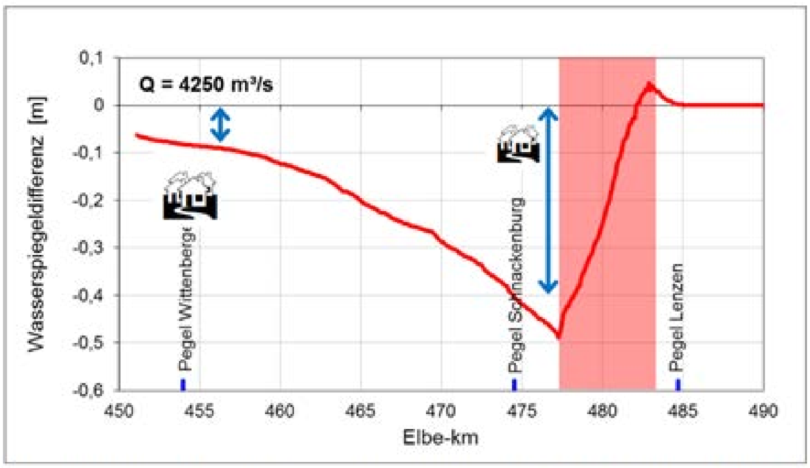
The Lödderitzer Forest supports the last native population of the Elbe beaver *(Castor fiber albicus)*

[27] WWF-Germany https://www.wwf.de/themen-projekte/projektregionen/elbe/projekt-mittlere-elbe/

In addition to restoring some of the most important floodplain habitat in Central Europe, the project is a model of "ecological flood protection" in Germany. Because floodwaters can now spread across the reconnected floodplain, modeling results indicate that there will be significant reduction of flood stages – up to nearly 30 centimeters for a flood with a 100-year recurrence interval – for 8 km upstream of the project site, providing a considerable reduction in flood risk for the city of Aken.

These two main project benefits – flood-risk reduction and biodiversity conservation — are reflected in WWF's two partners on the project: the State Agency for Flood Protection and Water Management of Saxony-Anhalt and Biosphere Reserve of the Middle Elbe. The €35 million project was funded largely the Federal Ministry of the Environment (75%) along with the state of Saxony Anhalt (15%) and WWF-Germany (10%).

The Lödderitzer Forest is one of several recent projects that have relocated dikes and reconnected floodplains to the Elbe River. One of those projects, at Lenzen, was completed in 2009 and so was tested by the 2013 flood. During that event, the expanded area for floodwaters reduced the flood stage upstream by nearly 0.5m, providing significant flood-risk reduction for the town of Schnackenburg; even 20 km upstream at the city of Wittenberge, the flood stage was lowered by approximately 10cm (Figure 6). These dike relocation projects on the Elbe demonstrate the flood-risk reduction benefits of creating more "room for the river" (Box 4) and the potential for floodplain reconnection to improve habitat for wildlife.



Decrease in water level between Wittenberge and Lenzen at maximum discharge during extreme flood in 2013 (Source: Promny et al. 2014)

Figure 6. Decrease in flood stage upstream of the Lentzen Project during the flood of 2013.

Box 4. Room for the River in the Netherlands

The Netherlands' "Room for the River" programme is an influential and often-cited effort to diversify the tools used for flood management. I n fact, the phrase "room for the river" is now often used to denote flood management that more fully incorporates floodplain features into flood management. People in the Netherlands began building dikes approximately 1000 years ago along the Rhine, Meuse and other rivers. This constriction of channels between dikes, combined with sediment deposition between the dikes, resulted in flood stages that rose higher over time, requiring multiple increases in dike height to keep up. Significant floods in the 1990s – which required the evacuation of hundreds of thousands of people – highlighted the potential dangers of continually raising dikes. Those concerns – along with the realization that, due to climate change, flood levels and sea level would continue to rise, and further increase flood risks – prompted the Netherlands to explore new approaches.

Engineers and planners decided to emphasize measures that would be more resilient to a future of higher flood stages. The plans that emerged focused on increasing the cross-sectional area available to convey floodwaters, including allowing the river to spread into former floodplains in some places. Collectively, these measures were intended to lower the height of the flood stages rather than raising the height of dikes. In 2007, construction began on 34 of the projects intended to increase the area available for floodwaters. Specific actions include: relocating dikes further away from the river; constructing side channels to carry high flows; removing or raising obstacles (e.g., bridges); increasing the capacity of channels and/or floodplains through excavation; and (5) "de-poldering" which will allow floodwaters to access areas formerly protected from flooding. While these interventions were driven primarily for purposes of reducing flood risk, the programme included a legal mandate to maximize values for nature and people in the design of projects. Thus, many projects included reconnecting rivers and floodplains, or creating new side channels, and will have benefits for fish and wildlife, along with recreation and aesthetics (see Haringvliet case study in coastal flooding section below).

NATURE-BASED SOLUTIONS TO REDUCE RISK FROM COASTAL EROSION AND FLOODING

Coastal storms, floods and erosion are already a major cause of damage to countries, with US$300 billion in insured losses globally in the past decade and potentially three times more in uninsured losses.[28] Rising sea levels will increase these losses. Without significant investments to reduce risk, global flood damage to coastal cities will increase by an order of magnitude or more by 2050, according to a 2013 study led by a World Bank economist.[29]

Similar to management of river flooding, investments to reduce coastal flood risk have traditionally focused on hard engineering solutions such as flood walls and dikes. These will continue to be needed in some situations, but they require continued maintenance and rehabilitation and contribute to the loss of coastal wetlands and other ecosystems. Europe has witnessed considerable declines in the extent of coastal wetlands: approximately two thirds of the coastal wetlands existing a century ago have been lost.[30]

A range of NbS interventions can reduce risks of coastal erosion and flooding, while also helping to reduce the loss of coastal habitat and providing other diverse benefits, including habitat for fish, birds and wildlife and carbon sequestration. Coastal NbS interventions relevant to Europe include protection or restoration of salt marshes, coastal peatlands and lagoons, seagrass meadows[31], sand dunes and oyster reefs.

These natural features provide protection in three ways:[32]

- *Reducing wave energy.* Plants and other natural features dissipate the energy of waves breaking on the shore, while roots help bind soil to reduce erosion from waves (Figure 7);

- *Attenuate storm surges.* Major storms send a large volume of water inland, raising water levels. Natural features break up the energy of the surge and, if the features are sufficiently broad, they can reduce the height of the surge experienced further inland; and

- *Maintain shoreline elevation.* Vegetation and other complex physical structures found within natural ecosystems trap sediment, which helps to build new land and stabilize shorelines – a benefit that is particularly important to counteract sea level rise.

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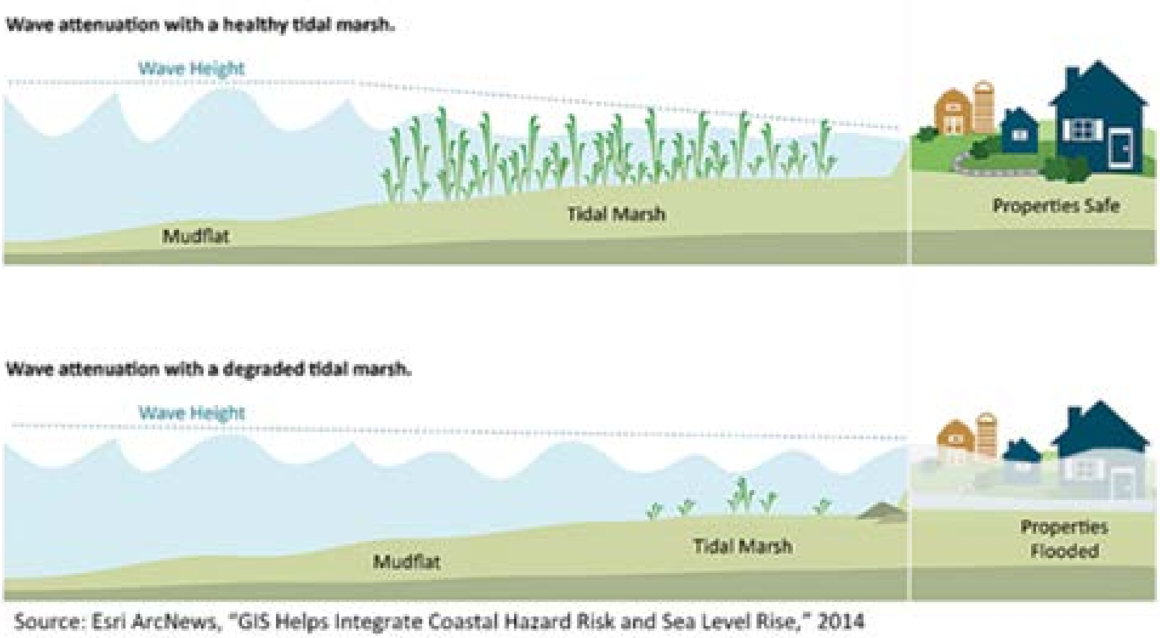
[28] Spalding et al. 2016. Atlas of Ocean Wealth. TNC
[29] Hallegatte, S., Green, C., Nicholls, R.J. and Corfee-Morlot, J., 2013. Future flood losses in major coastal cities. Nature climate change, 3(9), p.802.
[30] Airoldi, L. and Beck, M.W., 2007. Loss, status and trends for coastal marine habitats of Europe. In Oceanography and marine biology (pp. 357-417). CRC Press.
[31] Infantes et al (2012). Effect of a seagrass (Posidonia oceanica) meadow on wave propagation. Marine Ecology Progress Series, Vol. 456: 63–72, 2012
[32] Spalding et al. 2016; see note 28.

Restored wetlands and sand dunes in the Cape May region of New Jersey, USA, provide habitat for migratory birds, fish and other wildlife. When Superstorm Sandy struck the region in 2012, those same ecosystem features helped reduce damages.[33] A study of the overall region found that coastal wetlands reduced damages by a total of over US$600 million during that storm.[34]

Because coastal ecosystems are among the most important for sequestering carbon,[35] protection or restoration of coastal wetlands could serve as NbS for both climate change mitigation (sequestering carbon) and adaptation (reducing losses from rising risk).[36] For example, a study by the UK's Royal Society for the Protection of Birds examined the spatial overlap of areas that support high habitat values and also have high potential for carbon sequestration in Great Britain.[37] They found that, among these habitats with multiple values, coastal habitats provided among the highest carbon sequestration potential – and also could help protect coastal property from erosion and storm surges.

Figure 7[38] Conceptual diagram of a tidal marsh attenuating waves and reducing risk of coastal flooding.



[33] https://blog.nature.org/science/2017/10/29/sandy-resilience-nature-cape-may/
[34] Narayan, S., Beck, M.W., Wilson, P., Thomas, C.J., Guerrero, A., Shepard, C.C., Reguero, B.G., Franco, G., Ingram, J.C. and Trespalacios, D., 2017. The value of coastal wetlands for flood damage reduction in the northeastern USA. Scientific reports, 7(1), p.9463.
[35] Mcleod, E. , Chmura, G. L., Bouillon, S. , Salm, R. , Björk, M. , Duarte, C. M., Lovelock, C. E., Schlesinger, W. H. and Silliman, B. R. (2011), A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment, 9: 552-560. doi:10.1890/110004
[36] https://www.klimaatbuffers.nl/uploads/news/08112018-blue-carbon-in-nederland-9968b7.1a1d71.pdf
[37] https://rspb.maps.arcgis.com/apps/Cascade/index.html?appid=2b383eee459f4de18026002ae648f7b7
[38] https://stormrecovery.ny.gov/focus-area-coastal-marshland-restoration

CASE STUDIES: Coastal NbS in the Netherlands

Much of the Netherlands is at risk of flooding from the ocean, rivers or both; in fact, approximately 70 per cent of the Gross Domestic Product of the Netherlands is derived from land that is below sea level. Nine million people – approximately half the country's population – are protected by dikes or other engineered structures.[39] Thus, managing coastal flood risk and erosion is a major priority for the country.

As described in Box 4, to deal with rising flood risk, the Dutch have recently sought to diversify their methods beyond strict reliance on engineered infrastructure. For example, in addition to sea level rise, the Dutch must contend with subsidence – a lowering of the land surface due to compaction – that can reach nearly 1 cm/year in parts of the Netherlands.[40] Thus, the Dutch are exploring ways to use natural processes to reduce erosion or to trap or distribute sediment to counteract sea level rise and subsidence. Furthermore, following centuries of loss and degradation, there is increasing interest in projects that can help restore coastal ecosystems and biodiversity.

WWF is contributing to these efforts by promoting research and pilot projects on how NbS can contribute to both coastal protection and nature restoration.

Below we summarize three NbS projects in the Netherlands intended to reduce coastal flood risk and/or erosion and that are also intended to restore coastal ecosystems.

- Oysters can be considered "ecosystem engineers" in that populations of oysters can build structures, create habitats and affect physical processes. Oysters form reefs that act like breakwaters that dissipate wave energy.[41] In Europe, native oyster reefs were largely eliminated before the 1950s, primarily due to overexploitation.[42] A pilot project in the Oosterschelde Bay of the Netherlands explored the potential for constructed oyster reef structures to promote natural recruitment of oysters – and reef expansion – and the efficacy of restored oyster reefs to protect tidal flats and a dike from wave erosion. Results showed that constructed foundations could attract recruitment of oysters and lead to vertical growth of the reef and provided insights into the designs associated with greater recruitment and persistence. Critically, the oyster reefs reduced erosion rates behind them.[43] Since 2015, WWF has been investigating the site conditions and project designs that have the greatest chance for success.[44]

[39] https://www.climatechangepost.com/netherlands/coastal-floods/
[40] https://www.climatechangepost.com/netherlands/coastal-floods/
[41] Ysebaert, T., Walles, B., Haner, J. and Hancock, B., 2019. Habitat modification and coastal protection by ecosystem-engineering reef-building bivalves. In Goods and Services of Marine Bivalves (pp. 253-273). Springer, Cham.
[42] Airoldi, L. and Beck, M.W., 2007; see note 30.
[43] Ysebaert, T., et al.2019; see note 41.
[44] https://www.wwf.nl/wat-we-doen/resultaten/projecten/noordzee-herstellen/schelpdierbanken

- In the Wadden Sea, a restoration project has employed a "mud motor" to rebuild salt marsh. The "mud motor" is a combination of natural ocean currents and flows and dredged sediment. Sediment is continuously dredged from the harbour of the Port of Harlingen and, previously, was disposed of in a designated area in the sea. However, a substantial portion of the disposed sediment was picked up by currents and washed back into the port. The new approach deposits the sediments in places where ambient currents are likely to carry them and deposit them into salt marshes, helping the marshes expand. Implementation began in 2016 and 2017 and initial results indicate that 80% of disposed sediments are reaching the marsh. This approach will likely contribute to the expansion of salt marsh habitats – productive for birds and fish – while reducing repetitive dredging of the harbour. The expanded marsh will also provide a NbS by naturally helping to protect dikes from wave erosion.

- The Rhine and Maas rivers flow into the North Sea near Rotterdam through the Haringvliet and Nieuwe Waterweg. While the Nieuwe Waterweg remains largely open to the sea, the Haringvliet was closed to the sea by a dam and floodgate complex. This changed the Haringvliet from a tidal and estuarine system to a largely freshwater system with limited tidal flux and a consequent steady decline in ecosystems such as sandflats and salt marshes. Beginning in 2015, WWF began working with a range of partners to open the Haringvliet floodgates and restore the estuarine ecosystems and allow migratory fish, such as salmon and eel, to once again enter the Maas and Rhine through the Haringvliet. The opening will also allow more natural sediment deposition, helping to rebuild elevations in the estuary, so counteracting subsidence and reducing risks of flooding and erosion. Preliminary opening of the floodgates began in 2018 and will continue over the next few years in a process of learning-by-doing.

As part of this larger project, WWF has restored habitats within the Haringvliet Estuary combined with interventions to enhance people's ability to experience these restored habitats, including the development of hiking trails and excursions, and the promotion and training of the local nature-based tourism sector. These investments are intended to stimulate public support for the restoration of Haringvliet, which can then bolster government backing of further restoration. These efforts have produced a measurable positive impact on the local economy, even before considering any benefits in terms of climate adaptation.[45]

A pilot project is also exploring how to make some NbS projects bankable, which is critical to leveraging private finance. A former agricultural polder in the Haringvliet will be allowed to revert to natural habitats, which will create valuable amenities in terms of recreation and aesthetics. In addition, a sustainable housing development will be built on a small elevated portion of the former polder. The value of the houses will rise due to the proximity to the restored wetland and the increased real estate value will help fund the restoration project. Similar projects could generate revenue for investors. Meanwhile, the restored areas will be allowed to flood during times of high river flows and sediment will be naturally deposited — contributing to the larger NbS benefits in the Haringvliet provided by the opening of the floodgates.

[45] van Beukering, P., Rienstra, G., Koetse M., van Teeffelen, A., de Groot, D., van Wieringen, D. & Schulp, N. (2019). De Dynamische Delta: Socio-economische effecten van toekomst alternatieven van een duurzame Haringvliet. IVM-rapport (R-19/02). Instituut voor Milieuvraagstukken, Vrije Universiteit Amsterdam.

NATURE-BASED SOLUTIONS TO MANAGE WATER SCARCITY AND REDUCE RISK OF DROUGHT

Globally, the demand for water has been increasing at approximately 1 percent per year and demand will continue to grow due to shifting patterns of consumption and population growth.[46] Studies consistently forecast a shortfall between supply and demand and, in much of the world, climate change will likely exacerbate these challenges. By 2050, over half the world's population could live in regions with water stress.[47] Meanwhile, many parts of the world — including much of southern Europe — are predicted to face more frequent and severe droughts.

There is growing evidence that healthy and well-managed freshwater ecosystems can reduce drought risk, from helping to maintain rainfall patterns by protecting forests to using wetlands to regulate flows and native plants to minimise impacts such as soil erosion and wildfires. Ensuring drought management planning processes are built into ecosystem management and ecological restoration is vital.[48]

Sustainable water allocation – adjusting water demand to the real availability of water, taking into account the increasing uncertainties derived from climate change – is essential to mitigate the impact of droughts. The good status of rivers, wetlands and aquifers, as recognized by the Water Framework Directive, is critical to ensuring the availability of clean water. Healthy floodplains can promote groundwater recharge and have the potential to be managed in conjunction with water supply reservoirs. In some cases, forested areas with deep soils can promote infiltration and, by reducing excess surface erosion, decrease the amount of sediment and associated nutrients that enter water supplies.

The 2018 World Water Development Report[49], from UN Water, emphasizes that NbS should play a central role in how the world manages water supplies in the context of growing demand and climate change, including increased risk of drought. The report recommends a range of NbS, including using natural features to increase water availability (e.g., recharging groundwater and retaining water in soils).

Specific agricultural practices can also increase water availability and resilience to drought, including maintaining wetlands within the agricultural landscape, recovering hedges and copses to act as windshields[50], improving soil quality to enhance water retention and other agroecology practices, which aim to increase the resilience of farming systems to climate change, including droughts.[51]

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[46] UN-Water. 2018; see note 6.
[47] Schlosser, C.A., Strzepek, K., Gao, X., Fant, C., Blanc, É., Paltsev, S., Jacoby, H., Reilly, J. and Gueneau, A. (2014). The future of global water stress: An integrated assessment. Earth's Future, 2(8), pp.341-36. DOI: 10.1002
[48] Sayers, P.B. et al; see note 16.
[49] UN-Water. 2018. The United Nations World Water Development Report 2018: Nature-based Solutions for Water. Paris, UNESCO.
[50] Global Nature, WWF. Informe técnico sobre medidas para la restauración de setos, lindes y sotos de ribera en explotaciones de regadío. Ministerio de Medio Ambiente y Medio Rural y Marino. Unpublished. 2008.
[51] http://www.fao.org/family-farming/themes/agroecology/en/

These NbS interventions that are aimed at improving the regulation of water quantity also generally improve water quality (see following section) along with providing other diverse benefits, including carbon sequestration in plants and soils, and habitat for fish and wildlife.[52]

Similar to managing flood risk, managing for water scarcity and drought risk should strive for a "diversified portfolio" approach that includes a comprehensive array of measures ranging from management practices, policies and incentives to strategic integration of engineered infrastructure and NbS. This diverse, integrated and comprehensive approach can help countries move from simply reacting to droughts to building a "drought resilient society." [53]

CASE STUDIES: Riviersonderend watershed

Cape Town provides a compelling example. The South African city suffered a historic drought, receiving global media coverage in 2018 for how close it came to running out of water.

While investing in some forms of engineered infrastructure – from additional reservoirs to groundwater pumping and desalination – are necessary, the region can also invest in NbS to improve its water supply. For example, in the watersheds that supply Cape Town's water, restoration of native vegetation can increase available water. Non-native species, such as eucalyptus, are 'thirstier' than the native plants they have replaced, sucking up through their roots and evaporating an additional 1.4 trillion litres of water across the country per year. This loss is equivalent to 4 percent of the nation's water supply (and because non-natives are spreading, the loss could quadruple to 16 percent).[54]

Removing non-native plants, and restoring native vegetation, as WWF-South Africa has been doing in the Riviersonderend watershed, is therefore part of the solution for ensuring adequate water supplies – at a cost comparable, or lower, than many other alternatives.[55] The broader effort of clearing non-native vegetation to boost waters supplies has also employed tens of thousands of people, an important co-benefit in a country with 26 percent unemployment.[56]

[52] The Nature Conservancy 2017. Beyond the Source. Arlington, VA.
[53] Sayers, P.B. et al; see note 16.
[54] WWF-SA. (2016). Water: Facts & Futures. Retrieved from http://awsassets.wwf.org.za/downloads/wwf009_waterfactsandfutures_report_web__lowres_.pdf
[55] WWF-SA. (2016); see note 54.
[56] Isa, M. (2016). The alien plants sucking South Africa dry – can companies help? The Guardian.

NATURE-BASED SOLUTIONS TO REDUCE URBAN FLOOD RISK

Cities are dominated by impervious surfaces – including rooftops, parking lots and roads – and thus only a small proportion of rainfall infiltrates into the soil. Compared to an undeveloped watershed, an urban area will produce five times as much surface runoff for the same rainfall event.[57] Additionally, many cities have paved over lakes and wetlands and channelized their streams and rivers so that heavy rainfall can rapidly overwhelm storm drainage systems and cause severe flooding. A range of NbS interventions can be used to increase infiltration, slow down and store runoff, and reduce flood peaks.

Some NbS for urban flood risk are methods integrated directly into buildings or infrastructure, such as porous pavements, "green" (vegetated) roofs, rain gardens and rain barrels – slowing and retaining runoff to replicate the hydrological functions of more natural systems. Other NbS features aim to attenuate runoff for larger areas, including grassy swales and detention basins.[58] These can even begin to overlap with the recovery of natural ecosystems and include the restoration - or construction - of lakes and wetlands.

Rapid urban runoff also contributes to water pollution. Runoff on roads and parking lots picks up trash and oil residues and other pollutants and carries them directly into storm drains that then flow into creeks and rivers. The rapid and high magnitude flows discharged from storm sewers into creeks also contribute to widespread erosion of channel bed and banks, contributing to excessive sedimentation downstream. By slowing down runoff, NbS can reduce this erosion, while other NbS features, such as wetlands and detention ponds, can serve to filter out trash and pollutants from runoff before they enter natural drainage systems.

Fortuitously, most NbS methods that slow runoff also make urban spaces healthier, greener and cooler in summer, improving recreational values and aesthetics for cities. Parks, urban gardens and wetlands all increase infiltration and slow stormwater but also contribute to more vibrant urban environments contributing to the physical and mental well-being of city dwellers (Box 5).[59]

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[57] Freitag, B., Bolton, S., Westerlund, F. and Clark, J., 2012. Floodplain management: a new approach for a new era. Island Press.

[58] Freitag, B. et al 2012; see note 57.

[59] MacKerron, G. and Mourato, S., 2013. Happiness is greater in natural environments. Global environmental change, 23(5), pp.992-1000.; UNEP-DHI 2014.

CASE STUDIES: Sponge Cities in China

Quzhou Luming Park by Turenscape, in Quzhou, Zhejiang, China

In China, a new initiative is supporting cities to integrate NbS into their programmes to reduce urban flood risk. The initiative's name, "sponge cities," evokes its goal for cities to build a range of features designed to soak up rainfall: the sponge parts get wet so the city part can stay dry. The sponge city initiative now encompasses thirty Chinese cities with an ultimate goal that, by 2030, 80 per cent of each city will feature sufficient wetlands and other sponge-y features to capture and absorb 70 per cent of storm water runoff.

Within sponge cities, interventions range from vegetated green roofs to restoration of natural aquatic ecosystems and addition of new, constructed wetlands[60] to replace some of the functions previously provided by natural wetlands lost during development.

For example, 120 lakes once dotted the city of Wuhan. Now with a population of 11 million, only 30 lakes remain. The city is vulnerable to localized flooding during heavy summer rainstorms. A 2016 flood led to 14 deaths and €300 million in damages. As one of the sponge cities, Wuhan now has nearly 230 projects under way in two districts that can serve as pilots for the rest of the city – and the other sponge cities. These pilot efforts have featured investments in flood-risk reduction that rely heavily on NbS, including rain gardens, grassy swales, and constructed ponds and wetlands — in areas that double as public parks, simultaneously reducing risk for residents while increasing their access to nature. Wuhan's commitment to working with wetlands for a more resilient future has led the city to apply for the prestigious Wetland City accreditation under the Ramsar Convention on Wetlands.

Wuhan city has applied to be a Wetland City under Ramsar Convention

60 https://www.theguardian.com/world/2017/dec/28/chinas-sponge-cities-are-turning-streets-green-to-combat-flooding

Box 5. NbS in cities in Italy

The city of Milan is a member of an EU Programme, Clever Cities, which promotes NbS and is supported by WWF-Italy and a range of partners. Through Clever Cities, Milan is designing wetlands and urban gardens to manage runoff and connect people to nature, and a "vertical forest" to showcase sustainable buildings. WWF-Italy is also promoting an urban NbS programme that includes constructing green roofs and ponds – projects focused primarily on supporting urban biodiversity and connecting city dwellers to nature but that also demonstrate methods for slowing and retaining urban runoff.

NATURE-BASED SOLUTIONS TO IMPROVE WATER QUALITY

A range of NbS can help improve water quality, particularly within agricultural landscapes or drinking water systems. NbS for improving water quality for drinking water systems largely overlap with those for managing for water security and decreasing drought risk. These largely entail improving the health of soils and vegetation within the watershed that generates water for a drinking water system.[61] Below we focus primarily on NbS for improving water quality in agricultural landscapes.

Agriculture is the largest contributor to diffuse water pollution for most of Europe[62] as runoff from farm fields carries sediment, fertilizer and pesticides into streams and ultimately into aquifers, rivers, lakes, estuaries and the ocean. Similar to other topics, a diverse approach is needed, including policies and best practices that increase the sustainability of how farmers use chemicals and how their practices affect runoff and erosion. NbS can make important contributions to these best practices, ranging from biodiversity-based approaches for managing pests that require less use of pesticides – resulting in cleaner water (Box 6) – to building or restoring natural habitats that filter sediment, nutrients and other pollution from runoff.

Increasing natural vegetation cover in permanent crops or between annual crops can reduce soil erosion. Filter strips or riparian buffers can be placed along streams to intercept runoff in the form of overland flow from farm fields. The roughness and complexity of the vegetation can filter out the sediment from the flow. Because nutrients such as phosphorous are largely absorbed into sediment particles, this filtering can reduce the amount of nutrients that enter streams as well as reducing sedimentation.

[61] TNC. 2017. Beyond the Source Arlington, VA.
[62] EEA. European waters: Assessment of status and pressures. 2018

However, much of the runoff from fields does not move as overland flow that can be intercepted by a filter strip but instead flows off fields in ditches or drains. Strategically placed wetlands or small ponds can help manage this more concentrated flow to reduce the volume and rate of runoff that flows into streams and to filter nutrients and other pollution. By creating areas of water with low or no velocity, ponds and wetlands allow sediment to drop out from the waters flowing off of fields – along with the phosphorous bound to the sediment[63]. Nitrogen can be removed through biological processing within wetlands as plants and bacteria convert nitrates to less harmful forms. Working in Illinois (USA), researchers found that converting 6 per cent of a farm's area into wetlands that intercepted the farm's drainage system could reduce runoff of nitrates by 36 to 44 per cent.[64]

Reconnecting rivers to their floodplains can also reduce nutrient pollution through deposition of sediment and phosphorous and biological processing of nitrates.[65] Thus floodplain restoration and reconnection have been recommended, or implemented, as strategies to reduce nutrient pollution to downstream water bodies such as the Great Lakes of North America[66], Chesapeake Bay[67] and the Gulf of Mexico.[68]

[63] Mitsch, W.J., Day, J.W., Gilliam, J.W., Groffman, P.M., Hey, D.L., Randall, G.W. and Wang, N., 2001. Reducing Nitrogen Loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to Counter a Persistent Ecological Problem BioScience, 51(5), pp.373-388.
[64] https://blog.nature.org/science/magazine/can-a-wetland-help-a-farm/
[65] Opperman, J.J., et al 2017; see note 26.
[66] https://www.epa.gov/sites/production/files/2018-03/documents/us_dap_final_march_1.pdf
[67] Noe, G.B. and Hupp, C.R., 2005. Carbon, nitrogen, and phosphorus accumulation in floodplains of Atlantic Coastal Plain rivers, USA. Ecological Applications, 15(4), pp.1178-1190.
[68] Mitsch et al. 2001; see note 63

CASE STUDIES: Finland

WWF-Finland, with funding from the EU, constructed 30 wetlands between 2008 and 2012 in southern Finland. The wetlands were built within heavily agricultural river basins that are responsible for the majority of Finland's contribution of agricultural nutrients that are washed into the Gulf of Finland and the Baltic Sea. Beginning in 2018, WWF-Finland sought to build on that foundation through the Water Protection 4K programme by constructing wetlands that will improve water quality in the Inkoo ($46km^2$), Ingarskila ($161km^2$) and Siuntio ($481km^2$) rivers (see Figure 8) – and also improve water quality in the Baltic Sea.[69] The programme relies strongly on collaboration between private landowners and farmers, who provide the land, and WWF, which covers the cost of wetland construction. The constructed wetlands are designed to increase water retention on the land, reducing the runoff from fields and erosion of streambanks. These improvements will reduce the amount of sediment and nutrients delivered to streams, rivers and the Baltic Sea.

Wetland constructed in Vassböle under the Water Protection 4K programme

Two wetlands have been constructed so far; a third site features a combination of stream and wetland restoration. More than 10 additional sites are planned for the next few years with current funding. The existing programme has a budget of €400,000 split between Finland's Ministry of the Environment (63%) and WWF-Finland (37%), with plans to secure a similar level of funding to extend the programme. WWF is also developing a guidance document on using wetlands to improve water quality to extend the reach of this programme and to inform projects funded through the €45 million that Finland has allocated to improve the ecological status of water bodies to achieve the targets of the WFD.

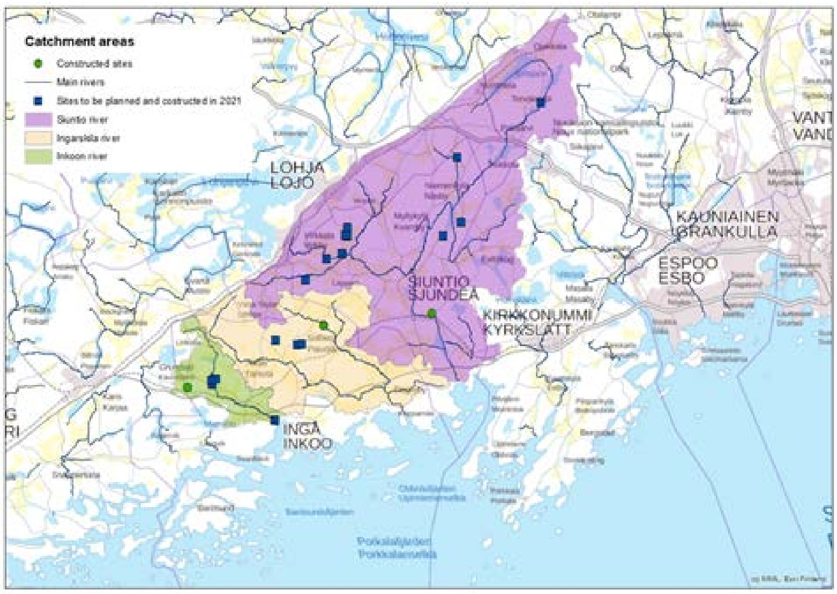

Figure 8. Map of focus area for the Water Protection 4k programme

[69] https://wwf.fi/alueet/itameri/kuormitus-kuriin/

Box 5: Ladybirds for clean water: promoting biodiversity in citrus farms to reduce use of pesticides

In the Seville province of Spain, along the Guadalquivir River, WWF has partnered with the supermarket company Edeka to pursue "farming with nature." The partners worked with 12 citrus farms in the region to improve their water management, following the guidelines of the Alliance for Water Stewardship (AWS), resulting in a reduction of water withdrawal of more than 15% – important in area prone to drought. Efforts also focused on promoting healthy soil and vegetation, particularly by promoting native vegetation in the rows between the trees. The native plants provided habitat for a number of species, such as various birds, lizards and ladybirds, which eat insect pests, allowing a 2/3 reduction in the amount of pesticides used in the citrus fields, improving water quality. Furthermore, the improved health of the vegetation and soils promotes greater infiltration during rainstorms, reducing runoff and erosion and also improving water quality.

OVERCOMING THE OBSTACLES TO SCALING UP NATURE-BASED SOLUTIONS

Despite the multiple benefits that we have seen NbS can provide, currently less than 1 per cent of total investments in water-management infrastructure is allocated toward NbS.[70] This is due to a number of constraints:

- *Inertia and lack of familiarity and capacity.* NbS approaches are much less known among engineers, planners and decision makers, making it less likely that they will be selected or even considered.

- *NbS may require more cooperation from more entities.* A major advantage of NbS is that they can provide multiple benefits – but fully planning for these multiple benefits may require involving a greater number of entities (e.g., various ministries) relative to standard approaches, which can complicate selection and design processes.

- *Calculations of costs and benefits of various options may be incomplete.* Many of the diverse benefits of NbS can be hard to quantify, particularly environmental and social benefits, and so these may not be adequately incorporated into decision processes. Furthermore, even if these other benefits could be quantified, mechanisms, such as markets, may not exist to link the beneficiaries of the service with those that provide the service. Additionally, some NbS approaches, such as dike setbacks and wetland restoration, require more land than do traditional approaches, which can increase up-front costs. While these additional costs of NbS are likely to be fully accounted for, the potential advantage that NbS may have in terms of lower long-term costs for maintenance, rehabilitation and replacement, may not be well represented in benefit-costs analyses.

- *Technical performance not documented or established among professionals.* While engineering methods have generally been tested, documented and provide the basis for regulatory standards, NbS approaches may lack the same quantitative rigour in terms of performance.

- *Regulatory frameworks may not be suitable* because they were established to oversee traditional approaches.

- *Weak evidence base for NbS* contributing to solving problems at a large scale, including evidence relating to costs and trade-offs of NBS as well as to benefits.

- *Absence of policy direction and political leadership* driving widespread implementation.

[70] UN-Water. 2018; see note 6.

Below we offer some recommendations of technical approaches that could help overcome these constraints:

- *Improve quantification of performance of NbS interventions.* Efforts are now underway to more rigorously quantify the performance of NbS projects under various conditions, which will provide engineers and decision makers with a stronger basis for comparing options.[71]

- *Involve stakeholders, especially local communities.* Experience shows that the involvement of local stakeholders and the consideration of the multiple benefits of NbS increases the success and sustainability of the interventions.

- *Ensure rigorous evaluation of NbS efficacy for a given context.* The likely performance and cost effectiveness of NbS options need to be rigorously evaluated for a given context.

- *Fully evaluate projects' costs and benefits.* Decision processes often focus on a narrow set of benefits, omitting many of the diverse benefits provided by NbS, while also not fully capturing the impacts on social and environmental values from more traditional approaches. Furthermore, traditional engineered projects' long-term costs for maintenance, rehabilitation and replacement are often underestimated; more realistic accounting for these long-term costs will help level the playing field for NbS, which may have lower long-term costs.

- *Combine multiple sources of funding and "stack" multiple ecosystem services.* Because NbS can provide multiple benefits, they can also potentially draw on multiple sources of funding. For example, a NbS for flood management that is somewhat less cost-effective than a traditional approach may be able to draw on funding for river restoration (if it can legitimately provide those benefits) and thus help the NbS option to be more competitive.

- *Ensure coherence between management and conservation* of water ecosystems and relevant sectoral policies – most notably energy, agriculture, transport, flood management and biodiversity – to avoid approaches that compete with each other.

- *Plan NbS at the system scale and plan for change.* Volumes of water at any given time — and thus the risk of floods or droughts — are a function of processes operating across the overall river basin. Understanding how these processes operate — and how they may be affected by climate change — is essential for designing sustainable water-management systems, including how to integrate NbS within them. A system-scale ensures that the opportunities for multiple benefits from NbS can be maximized and incorporated into the review of options, and allows for better integration of management between sectors and policies.

[71] See the Engineering with Nature program; https://ewn.el.erdc.dren.mil/; and https://www.naturebasedsolutionsevidence.info/

CONCLUSIONS

Nature-based Solutions have considerable potential to improve land and water management and to reduce water-related risks, particularly as these challenges and risks intensify with climate change. As emphasized and illustrated throughout this report, NbS can not only can provide benefits for water management or risk reduction, but they also generally support a diverse range of other social, economic and environmental benefits, including carbon storage, and can therefore become a strategic way to contribute to achieving the Sustainable Development Goals and the aims of the Paris Climate agreement, as well as enhancing the health of Europe's landscapes, people and nature, as the European Green Deal seeks.

The attempt to control – and even fight – natural processes, such as floods, contributes to the need for continued maintenance and replacement of engineered infrastructure and a range of negative impacts on ecosystems. Working with natural processes, such as through NbS, allows nature's regenerative processes to help deliver multiple benefits.

NbS are not the only solutions for water security or flood-risk management, but they can be a key part of an overall solution that draws upon diverse approaches. Independent of the combination of approaches, one critical thing to keep in mind is scale: both spatial and temporal. It is necessary to plan and implement water management at a system scale – and plan for change.

Climate change implies continuous changes, and so investment decisions, including NbS, should be planned with foreseeable variations and uncertainties already in mind. Solutions based in natural processes have the advantage of being generally more flexible and able to adapt to changing conditions.

In order to take full advantage of the opportunities for more sustainable water management offered by NbS, changes are needed. The new paradigm of working with nature and not against it needs innovative approaches from different sectors. Below we make a strong call to various actors in Europe, to take action to foster the implementation of Nature-based Solutions and change the course of Europe's waters.

CALL TO ACTION

The European Commission:

- **Ensure that the EU Biodiversity Strategy for 2030 includes legally binding targets of restoring natural wetlands, peatlands and floodplains** as part of a broader nature restoration target of 15% of EU land area. This would contribute to significantly increasing EU carbon sinks and would also improve resilience to the impacts of climate change.

- **Strengthen and foster the implementation of the EU legal framework for water protection** in order to meet the 2027 deadline, and ensure no weakening takes place. In particular, the European Commission should declare the Water Framework Directive fit for purpose and make sure the third River Basin Management Plans – to be developed by Member States by the end of 2021 – contain guarantees that surface and ground waters will be in good status by 2027. In addition, and as part of the upcoming Water Action Plan, a large-scale deployment plan of NbS for water management should be launched in order to enhance the natural treatment of pollution, sustain biodiversity, and increase resilience to climate change.

European Union Member States:

- **Strengthen the implementation of the EU legal framework** for water protection in order to meet the 2027 deadline, reducing the amount of exemptions and using them only when fully justified.

- **Integrate NbS into third-cycle river basin management plans** (2022-2027), carefully analysing hydromorphology indicators, as well as into both associated programmes to bring all European waters to good status by 2027 and Flood Risk Management Plans.

- **Apply the non-deterioration principle and precautionary approach** to protect remaining free-flowing, unaltered and clean stretches of rivers for their biodiversity and ecological values and not leave them open to further hydropower development and modifications for agriculture and inland navigation.

- **Improve transparency and enable effective public participation** in river basin management planning and application of exemptions (e.g. Article 4.7 WFD).

Private Sector Corporations

- **Engage in Water Stewardship** and begin by assessing water risk across material parts of the value chain and creating a strategy that mitigates risk (WWF Water Risk Filter); and support policy that ensures good governance, such as the Water Framework Directive. Learn more about water risk and water stewardship.

- **Learn more about how NbS can help to solve water challenges** and promote their application where possible.

- **Scale up collective action on NbS** through platforms that allow different companies, even from different sectors, to work together at basin or landscape level to reduce their shared risks. Such a scale may allow for the implementation of Bankable Water Solutions (see case study on Haringvliet and Box 6).

The Financial Sector

- **Understand water risk and how to better account for it when valuing investments.** Learn more about financial value and water risk and check out the Ceres Water Investor Toolkit. In particular, learn more about how investments are already working for NbS and existing structures to support NbS activities. Learn more about the story of the Washington DC Water Bond and Nature Insurance Value: Assessment and Demonstration (NAIAD), and explore how WWF is mobilizing finance for NbS via its Bankable Water Solutions.

- **Engage with existing efforts and start to create offerings that finance NbS**.

- **Implement and support policy that lays the foundation for credible green investments,** such as the upcoming EU taxonomy framework, and a strong EU Water Framework Directive.

Europe's past features a dramatic loss of nature. This has not only diminished the continent's wildlife and biodiversity, but the loss of forests, wetlands and floodplains has also increased risks from flooding, drought, and poor water quality. These risks are projected to further increase in much of the continent – even if we succeed in holding the rise in global temperature to below 1.5 degrees C. Nature-based Solutions have the potential to restore some of the losses of the past while reducing the risks of the future.

LIVING EUROPEAN RIVERS

Living European Rivers is a WWF-led initiative to bring life back to Europe's waters for the benefit of people and nature. Involving other civil society organizations, governments, investors, businesses and communities, the initiative aims to protect rivers, lakes and wetlands that are still in good health and restore the ones that have been degraded - to help build resilience in the face of climate change. To achieve this ambitious goal by 2030, the initiative works to improve water governance, redirect financial flows towards nature-based solutions, remove dams, fight unsustainable hydropower, and raise awareness about the values of freshwater ecosystems.

For more information, please contact:
Eva Hernández
Coordinator of Living European Rivers Initiative, WWF
Email: ehernandez@wwf.es

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