Investing in Nature
for European Water Security

The Nature Conservancy

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Investing in Nature
for European Water Security

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ACRONYMS

APSFR	Areas of Potential Significant Flood Risk
AR	Aquifer Recharge
BOD	Biological Oxygen Demand
CAP	Common Agricultural Policy
CIS	Common Implementation Strategy
EEA	European Environment Agency
EQS	Environmental Quality Standards
EC	European Commission
EU	European Union
FHRM	Flood Hazard and Risk Map
FRMP	Flood Risk Management Plans
GI	Green Infrastructure
GWD	Groundwater Directive
MS	Member State
NbS	Nature-based Solutions
NbS-WS	Nature-based Solutions for water security
NWRM	Natural Water Retention Measures
PAHs	Polyaromatic hydrocarbons
pBDEs	Brominated flame retardants
RBDs	River Basin Districts
RBMPs	River Basin Management Plans
SDGs	Sustainable Development Goals
SuDs	Sustainable urban drainage systems
UNFCCC	United Nations Framework Convention on Climate Change
UWWTD	Urban Wastewater Treatment Directive
WFD	Water Framework Directive
WS&D	Water Scarcity and Drought

Foreword

Marianne Kleiberg
Regional Managing Director Europe
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We all depend on water, the one essential element for humans and nature to thrive alongside one another. Ensuring water security means that water of an acceptable quantity and quality is available for health, livelihoods, ecosystems and the economy, coupled with an acceptable level of water-related risks. Nature can play a significant role to address those challenges and help us restore and maintain the health of European freshwater resources.

Europe is facing many outstanding water security challenges. Our lakes and rivers are under pressure as we struggle to reduce their level of nutrients and sediment load. The quality of our groundwater sources is threatened by intensive agriculture. Disruptive flood events are the costliest natural hazards in the region. Water scarcity is no longer limited to the Mediterranean basin but has also become a significant risk in Central and Northern Europe. With climate change, population growth and increased urbanisation, flood and water scarcity are set to increase over time.

Nature is a powerful tool which, coupled with "manmade" technology, can support us in many ways. Forests can filter water before it percolates into the ground. Wetlands and retention ponds can help treat waste water and recharge aquifers. Restoring the natural course of rivers can slow the flow and limit the catastrophic impact of flood events. Harnessing the power of nature can help keep water treatment costs low and, in some cases, avoid investing in water treatment altogether. Nature-based approaches can also improve health, create sustainable jobs and reduce the threats posed by climate change. But this will only be possible if we mobilise investments in nature for water security on a massive scale.

European actors have harnessed the power of nature for water management for centuries. At the turn of the 21st century, Europe broke new ground with a visionary piece of legislation, the Water Framework Directive, which set out a common framework for all European Union countries to measure the state of European waters and devise ways to improve them. This paved the way for substantial financial resources, mostly public, to be allocated towards attaining these objectives.

Despite such conducive policy framework and substantial investments, progress has been slow. This is a powerful reminder that once pollutants have entered freshwater streams (including nitrates from agriculture causing algae blooms, for example), they are extremely difficult to remove. We need to focus on conserving freshwater resources that have not yet been contaminated as much as on investing resources in cleaning up those that are already compromised.

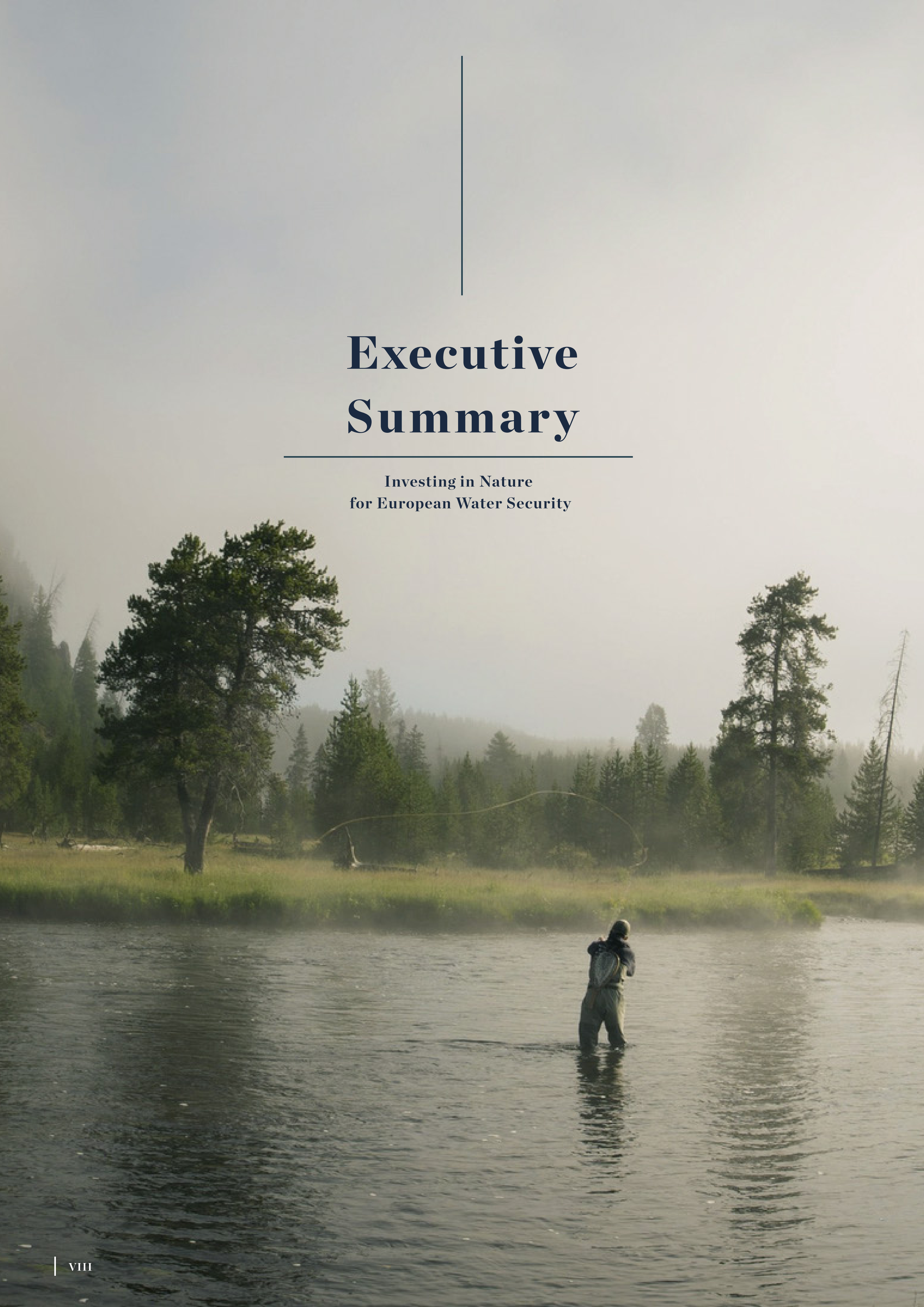
Investing in Nature for European Water Security offers a strategic vision to buck that trend and scale up the implementation of nature-based solutions for water security in Europe. One of the main conclusions of this report is that large amounts of repayable financing from both public and private sources is needed to accelerate the pace of investments in water security.

At The Nature Conservancy, we will focus our efforts going forward on bringing actors together and ensuring that nature finds its place in investment projects for water security. We see this as a critical contribution so that capital looking for sustainable finance opportunities can flow to regenerating and maintaining Europe's precious freshwater natural capital.

Marianne Kleiberg
Regional Managing Director Europe
The Nature Conservancy

Executive Summary

Investing in Nature
for European Water Security



Water security is at the heart of healthy and prosperous societies. European countries' prosperity depends on their ability to maintain the gains they have achieved in water security over centuries and to address new and rising challenges. Even though the vast majority of Europe's population has 24 hours access to reliable water and sanitation services in their home, Europe has many outstanding water challenges.

Ensuring water security requires "the provision of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies" (Sadoff and Grey, 2007). In other words, water needs to be available in the right quantity, at the right quality, at the right time and in the right place. Unfortunately, ecosystems' ability to purify and regulate water flows is greatly eroded by urbanisation, deforestation, relentless increases in artificial ground covering, excessive use of pesticides and fertilisers, and heavy modifications applied to water courses for hydropower production. As a result, the integrity of freshwater ecosystems is seriously threatened and their ability to meet societal and ecological needs compromised.

This report explores how investing in nature at scale could significantly contribute to addressing Europe's water security challenges. It was prepared based on a review of the literature, two workshops convened in London (January 2019) and Madrid (March 2019) and interviews with a wide mix of stakeholders who have had experience in leading some of the existing investments.

The report's main objectives are:

- To identify the roles that nature-based solutions can play to tackle Europe's water security challenges, as part of hybrid (green-grey) water investment strategies;
- To extract learning from on-the-ground experiences with investments in nature for water security in Europe and identify enabling conditions and barriers to scale;
- To formulate recommendations on what needs to be done differently to achieve scale and contribute to boost water security and resilience in the European Union.

Water security in Europe: a ticking time bomb

Almost 20 years ago, the European Union and its Member States (MS) set ambitious goals to achieve good water quality for all water bodies by 2015. The Water Framework Directive, adopted in 2000, broke new ground in European environmental legislation. It built upon and consolidated earlier European water policy and legislation and led to remarkable successes. Europe has achieved exceptional progress in the last few decades to clean up its beaches and upgrade wastewater treatment, improving the ecological status of rivers and other water bodies. Despite this, outbreaks of toxic green algae regularly affect rivers, lakes and coastal waters and are becoming more frequent with temperature increases. Other water challenges grow more pressing by the day, with rising water scarcity due to climate change, urbanisation and economic pressures, frequent (and devastating) floods, and other lingering water pollution issues.

Despite strong policy and regulatory frameworks, robust institutions and ample funding flows (including from the Common Agricultural Policy), European countries have not yet achieved the objectives they had set themselves in terms of sustainable water management. Almost five years past the initial deadline, only 40 percent of European surface waters meet the quality standards that were supposed to be achieved by 2015.

Key water security challenges in Europe fall into four categories:

Surface water quality

Water quality issues persist in the European Union, particularly with respect to high nitrates levels linked to agricultural run-off from fertilisers and pesticides. Contamination with heavy metals, which takes a long time to reverse, is brought about by industrial activity and burning of fossil fuel, with mercury going up into the atmosphere and coming down into freshwater bodies. Emerging pollutants are a growing threat, including from microplastics, antibiotics and endocrine disruptors. These pollutants create dangerous cocktail effects that are difficult to predict and poorly understood. In England and Wales, the National Audit Office estimates the cumulative cost of water pollution to be between £700 million and £1.3 billion a year, and that it is likely to increase with the impact of climate change. In addition, the natural flow of rivers has been heavily modified to respond to economic priorities—for navigation, hydropower production, irrigation or flood risk management. Land management activities can lead to soil erosion and increase fine sediment input into surface waters. Approximately 11.4 percent of the EU territory is estimated to be affected by a moderate to high level of soil erosion.

Groundwater quality

Groundwater is a strategic resource in the European Union as it is the primary source of drinking water for many Member States. Groundwater quality is affected mainly by diffuse pollution, stemming mostly from agricultural sources including nitrates in fertiliser or manure and pesticides. Excessive nitrate concentrations, which can harm humans, affect over 18 percent of the area of groundwater bodies in Europe. Rising nitrate levels in groundwater bodies can reach a tipping point, after which natural denitrification processes no longer occur and aquifers become unusable.

Flooding

The risks and likely impacts of flooding are increasing in Europe. This is due to multiple factors, including the modification of water bodies' natural courses; the transformation of natural surfaces into hard, impervious surfaces; increases in population density, floodplain development and land-use change; and climate change. Flood events have had a significant and rising impact in Europe in the last few decades. From 1980 to 2015, 3,695 distinct flood phenomena occurred in Europe, with the highest number reported in 2010, when 27 countries were affected. Most of these flood phenomena were caused by fluvial flooding. Although European floods have fluctuated throughout the years, they have had a significant and rising impact in the last decades when taking account of physical damages and economic losses. Recent reports on disasters in Europe and their frequency and impact for the period 1998-2009 suggest that floods and storms were the costliest natural hazards in Europe during that period. The overall losses recorded in the study period added up to about EUR 52 billion for floods, compared with EUR 44 billion for storms and EUR 29 billion for earthquakes.

Droughts and water scarcity

Water scarcity is no longer the preserve of Mediterranean areas but affects Northern Europe as well, due to population and economic pressures compounded by the impact of climate change. Once associated mainly to the Mediterranean basin, droughts are now occurring and having devastating impacts in Northern Europe as well, including in countries like Sweden, Finland, the UK, Ireland and Germany. Droughts registered in Europe between 1976 and 2006 affected more than 100 million people and over 37 percent of the continent's land mass, with associated financial losses of EUR 100 billion over that same period. Belgium and the South East of England have been amongst the most water-scarce regions of Europe for some time. In the last few summers, the river Rhine experienced extremely low flows that called into question its ability to remain navigable over time; Ireland's green pastures were no longer able to provide sufficient cattle feed without fertiliser application late in the season. These events are expected to increase in frequency and severity across the whole of Europe due to climate change.

These factors have contributed to a rapid decline in freshwater biodiversity, even more acute in Europe than in other parts of the world. Land and marine biodiversity are also jeopardised by reduced and degraded wet habitats and the contamination of coastal areas from upstream watercourses. Over the last decades, it has become clear that water is not a commodity that can be extracted, transported, used up, polluted and recovered with no visible implications on the natural environment from which it originates.

Why invest in nature to address European water security challenges?

From now on, business as usual will not be sufficient to deliver improvements in line with targets, particularly in areas that are more difficult to tackle, such as diffuse pollution or flood defences. Solving these challenges cannot be done with technical fixes alone and will require a combination of grey and green solutions that will boost resilience, cut costs and deliver real benefits for water security, biodiversity and climate, as well as jobs and social cohesion.

Some water service providers, cities and other European water stakeholders have invested in nature to boost water security. Over several centuries they have bought land and maintained forests in their upstream catchments. For example, Austria's capital of Vienna, with 1.8 million inhabitants, gets natural spring water which originates in the Lower Austrian Limestone Alps. The water supply system, still in operation today, was built in 1873 when the construction of the first of two water mains was completed over a length of 150 kilometres. This went hand in hand with the city's purchase of land in the upstream watershed. It established over time a forest-covered protection zone of approximately 700 square kilometres designated for water resource conservation. Several water service providers around Europe are investing in nature-based solutions alongside their grey infrastructure investment programme, to cut costs and generate additional benefits.

What is needed today is to reconnect water users with their upstream catchments, around joint interests and plans, to boost the resilience of water resources, support biodiversity, adapt to climate change and contribute to its mitigation by investing in less energy-intensive solutions.

NbS-WS are cost-efficient strategies that need to be mainstreamed in any water resource management strategies.

Nature-based solutions are central to boosting European water security

This report argues that greater investments in nature are needed to meet Europe's water security challenges, protect freshwater resources and safeguard nature's integrity. One promising way to do this is through nature-based solutions for water security (NbS-WS). These are "actions to protect, sustainably manage and restore natural or modified ecosystems that address water security challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN, 2019).

A broad spectrum of NbS can be deployed to address key water challenges and enhance water security, alongside grey infrastructure or as self-standing solutions. The range of NbS considered in this report (as shown in Table 2-2) can address four main types of water challenges related to surface water quality, groundwater quality, floods and water scarcity. Some of these measures entail investments in so-called green infrastructure (for example, reforestation or building artificial wetlands), while other solutions consist of improved management practices (such as agricultural practices that reduce fertiliser or pesticides use).

The NbS-WS presented in this report are focused on interventions in land areas that are important for water security and that tend to be outside of a city's boundaries. Such a focus was chosen as watershed interventions for source water protection typically require coordinating multiple actors and handling complex governance and funding issues, a key area in which this report argues more focus is needed.

The report present evidence that NbS-WS can be cost-effective strategies when compared to grey infrastructure investments and need to become an essential aspect of water resource management plans. Investing in NbS-WS can deliver benefits that go beyond water security, including to address climate and biodiversity problems. They could make a significant contribution to reversing the rapid decline in freshwater biodiversity in Europe and to adapt to climate change. Payments for ecosystem services, where downstream users pay upstream users to safeguard or restore the watershed's integrity, can also help address the urban-rural divide and alleviate tensions around who should bear the cost of the ecological transition.

The role of NbS-WS in addressing water security challenges is substantial, but it also varies depending on the type of challenges and the kind of NbS used:

Surface water

Significant role, particularly to deal with excess nutrient and sediment loads in surface water.
Vegetated buffers within riparian zones are amongst the most well-studied and frequently used mitigation measures to reduce nitrogen, sediment and phosphorus losses to surface waters via run-off. Employing NbS to improve surface water quality can significantly reduce the costs of treating drinking water and waste water (for example, using artificial wetlands as alternative treatment "technology"). However, the potential of NbS to reduce concentrations of other chemicals is comparatively less well understood.

Flooding

Significant role to reduce flood risk and the impact of floods, especially for events of higher frequency and lower severity.
NbS can help alleviate flood risk and impacts on floodplains and urban environments. NbS interventions can include restoration of natural river characteristics, afforestation or wetlands conservation.

Groundwater quality

Significant role, particularly to reduce nitrate pollution.
A wide array of NbS are well suited to improving groundwater quality, ranging from improved agricultural practices to land-use changes.

Water scarcity

Significant role to increase resilience to water scarcity and stress.
Aquifer recharge can increase water availability in periods of scarcity and drought while protecting groundwater resources from salinisation. By storing and regulating water flow, restored wetlands can function as important buffers, thereby increasing resilience to droughts, heat waves and wildfires. Wetlands can act as sponges during wet periods, storing water and giving natural aquifers time to recharge, regulating the water cycle and acting as a damper against extreme temperatures.

The EU policy framework is conducive to NbS-WS, although key areas need to be addressed

Several EU policies in the areas of water management, biodiversity and nature protection, agriculture and climate either mention or recommend NbS. The WFD built on several decades of water policy and brought together previously adopted directives on water and waste water into a coherent framework. Implementing earlier directives enabled Europe to achieve remarkable success in reaching very high levels of waste-water treatment. The WFD established the legal framework that committed Member States to achieve good ecological status for all ground and surface waters. It generalised the principle of river basin planning, introduced a focus on outcomes and mandated the prioritisation of measures based on economic analysis as well as the adoption of cost-recovery principles.

Despite efforts in recent years to "green" the EU's main policies and legislative framework, expected water-related outcomes have not come about. One critical reason relates to some fundamental contradictions between the EU Common Agricultural Policy and other policies and directives looking to support investments in nature and biodiversity. The negative impacts of European agriculture on water and biodiversity is a key challenge for EU environmental policy.

Whereas there has been substantial focus on quality aspects in European water policy, and more recently on flood management, the approach towards water scarcity and drought has generally been less elaborate, with much of the focus on crisis management rather than planning for risk reduction. Extreme events that took place over the previous decade, such as the heat wave and drought of 2003, prompted a shift in European drought and water scarcity policy with a clearer focus on planning and risk reduction. But more remains to be done in this area.

Pioneering experiences with NbS-WS exist in Europe, but scale is limited

Despite a common overall water policy framework, European countries have adopted NbS-WS with various levels of enthusiasm and success. Assessing the extent to which European countries have adopted NbS-WS is complicated by the fact that available information is partial and fragmented. Based on a more in-depth review of experiences in five countries (France, Germany, the Netherlands, the United Kingdom and Spain), we found that the first four had on the whole more conducive frameworks and at-scale experience with NbS-WS, which Spain intends to develop further.

The types of NbS-WS in use throughout the EU have tended to mirror the gradual shifts in focus of European water policy, from one centred on tackling pollution to one addressing a greater set of issues in a more active manner, including floods and water scarcity. For example, the Floods Directive (2007) prompted 26 Member States to include NbS (referred to as Natural Water Retention Measures, or NWRM) in some or all of their flood risk management plans (FRMPs).

Over the 2014-2020 period, an average of EUR 5.5 billion per year was committed to restoring and conserving watersheds and to sustainable management activities in Europe. An estimated 99 percent of all funding for watershed investment in Europe comes from public funding sources via multiple channels, mostly from the European Union—in the form of CAP subsidies, regional structural funds or dedicated grant funds—and from national, regional or local governments. Substantial public funding for NbS-WS from the EU comes through dedicated grant programmes, such as Horizon 2020, LIFE or Interreg for specific activities. These programmes have gradually invested more in NbS in line with EU policies.

Public funding also comes directly from national or local budgets. France and the Netherlands are amongst European countries that allocate substantial public funding to water resource management and have recently increased the share of these investments to NbS-WS.

To support the adoption of NbS-WS in a more systematic and targeted way at the local level, some water service providers or large water users have invested in protecting water resources at source. Several such efforts exist in Europe, although they remain limited both in number and in scale. The report examined in more detail 19 cases to better understand the efforts of these actors as well as the challenges they have faced. Annex C showcases those experiences, examining how they were deployed to address water security challenges and enabling factors.

Water service providers and cities have engaged with upstream users to protect their water sources by buying and protecting land, working with land-owners, farmers and forest managers to support change in agricultural and forestry practices, or building artificial wetlands to reduce the costs of waste-water treatment. Many water companies in England and Wales, for example, are collaborating with farmers at catchment level to protect their water sources, with support from Defra (Department for Environment and Rural Affairs) and Ofwat, the economic regulator. Cities can act as catalysers for the adoption of NbS-WS, but often they are not organised to do so. Most NbS-WS investments have been carried out as pilot projects at relatively small scale, with some notable exceptions where the establishment of multi-governance platforms has eased scale-up. Still, many water service providers do not consider investments in nature as central to their investments plans and tend to give greater priority to grey infrastructure investments.

In many countries, despite an overall policy framework conducive to NbS adoption, acquired behaviours are often the strongest barrier to scale and are linked to governance barriers and technical, physical or financial roadblocks. For example, although significant funding has been made available for NbS-WS through CAP, funding streams are complex and fragmented and have not supported meaningful improvements in environmental outcomes at landscape scale. Collective learning across European countries has been limited; this is particularly true when it comes to the potential contribution of NbS-WS to addressing water pressures and generating other benefits, including environmental (climate mitigation and adaptation, biodiversity), social (public health and well-being, social cohesion) and economic (employment or risk reduction).

Transformative ways to accelerate and scale up NbS-WS

Significant changes are underway. Water supply companies are faced with escalating treatment costs and the risk of fines where they are identified as primarily responsible for meeting freshwater quality standards. Both public agencies and private corporations increasingly choose (or are asked) to act as good stewards of water resources and of the life they support. Water users, including corporates, are acutely aware that the unavailability of clean freshwater poses an immediate and long-term risk to the sustainability of their activities. For its 2019 edition, and for the ninth year in a row, the World Economic Forum's Global Risk Report showed that environmental risks are at the top of business leaders' minds, with many such risks arising around water (such as extreme weather events, natural disasters or scarcity).

Momentum is building to accelerate investments in NbS-WS in Europe, and our recommendations point at ways to accelerate and scale these solutions. We present approaches that can be transformative and would allow scaling up NbS-WS further and faster. If these approaches are applied in a well-coordinated manner, they can accelerate the use of NbS-WS to alleviate current and looming water security challenges in Europe.

Recommended pathways to scale are set out here:

1 VALUE
Give natural capital the place it truly deserves in resource allocation

Natural capital should be fully taken into account in investment decisions so that NbS-WS gets comparable consideration with grey infrastructure options. Water sector actors (including national and local governments, water service providers and large water users) should measure the impact of their investment decisions on natural capital and give priority to NbS-WS when they can increase natural capital values. Opportunities for such investments should be clearly articulated and prioritised to generate interest from public and private actors looking for sustainable investment opportunities. This would represent a radical shift in how we measure and track value, so that clean water resources, biodiversity or reduced catastrophic risk from wildfires or floods are fully accounted for in investment and asset allocation decisions.

2 WORK TOGETHER
Harness the power of collective action

Investing in NbS-WS generates multiple benefits for multiple parties. However, it often does not happen because no single actor can derive sufficient benefit to justify making the investment. Beneficiaries should work together at the basin or sub-basin level to build governance and financing structures that enable joint planning, investment, management and maintenance of NbS-WS. Models for such governance platforms already exist throughout the world and in Europe; these demonstrate governance and financing innovation and could be systematically encouraged at national and regional levels. Such multi-partner governance platforms are also a prerequisite to attract funding and financing from varied sources in a seamless way that achieves impact at scale.

3 MOBILISE
Investments through outcome-based blended finance packages

To date, public funding constitutes the lion's share of investments in NbS-WS in Europe. Although significant, these funding streams do not allow for addressing water security challenges at the scale of a given region, or for specific types of investments that can have significant impact if implemented at scale (such as peatland restoration or carbon sequestration). Besides, strong competition regarding the use of public funds for water investments means that NbS-WS are not prioritised. Meanwhile, private investors are actively looking for opportunities to grow their sustainable finance portfolios but lack adequate financial products to channel their investments.

Now is the time for intermediary partners (such as environmental NGOs, consultancies or investment banks with environmental objectives) to play a larger role in packaging water-sector investment needs in a way that can attract repayable financing, as long as reliable and predictable funding streams exist to repay upfront investment. This would speed up investments and prevent further deterioration of water resources and biodiversity. It would also provide access to substantial, liquid and deep financing markets, necessary for scale. Examples of outcome-based blended finance structures for water security have recently emerged in the United States and broken new ground to attract private sector financing for specific water challenges. Private financing is typically provided up front. Clear revenue streams need to be identified to repay those initial investments (plus a return) when target environmental outcomes are reached. Such outcome-based blended finance structures have been applied to a variety of water security challenges. Some examples: managing urban drainage (see Box 8-4 on Environmental Impact Bonds), reducing the risk of catastrophic wildfires (see Box 8-5 on Forest Resilience Bonds) and delivering surface water quality improvements (see Box 8-6 on the Delaware Water Revolving Fund).

4 PRIORITISE
Identify where greatest results can be achieved

In the current approach, diverse funders examine fragmented investment project opportunities with little coordination. To get a mix of private and public funding and financing requires estimating investment needs, identifying where certain types of NbS-WS can work at landscape scale and building pipelines of investable NbS-WS projects. Landing private financing for opportunities where repayment opportunities are greatest would free up public grants. Building shared pipelines of investable projects should be actively encouraged and supported through philanthropic or public funding and potentially through innovation prizes. This calls for identifying water security hotspots across Europe or at country or regional level, making it easier to prioritise resources and make sure the right mix of funding and financing flows where it is needed. This will also require a stronger focus on results (even in investments that are not outcome-based) so that effectiveness and cost-effectiveness are measured on a more reliable basis and can be compared with grey infrastructure solutions. Building joint project pipelines across multiple locations would allow overcoming fragmentation on the supply side of the finance equation. At present, potential funders have limited visibility on where the needs and potential for NbS-WS are, which hinders their ability to innovate and to offer adequate financial products.

5 KNOW YOUR ROLE
Targeted recommendations for different groups

Each actor has a role to play to scale-up NbS-WS in Europe:

Table ES-1 *Key recommendations for scaling up NbS-WS by types of actors*

Actors	Key recommendations for each type
European Union institutions	• Maintain high level of ambition in terms of water security outcomes: do not extend deadlines but rather bring forward investments in water security • Fund the development and application of strong monitoring frameworks for NbS-WS, with a focus on data on their effectiveness and cost-effectiveness • Clarify the legal framework for payments for environmental services so that a variety of actors (water service suppliers, large water users) have a clear framework to make such payments where these can reduce their total costs over time (investment costs, operations and maintenance costs)
National governments	• Identify water security hotspots and potential for NbS-WS to address them • Help build project pipelines by organising national-level innovation prizes
Local governments	• Reach out to stakeholders in the basin or sub-basin to strengthen collective action for water security • Review policies across all sectors where local government can play a strong role to incentivise NbS-WS adoption. • Include NbS and their co-benefits for multiple sectors whenever reviewing options and planning investments for enhancing urban water security • Define water service contracts based on outcomes rather than specifying technologies or outputs • Promote NbS-WS in relevant interactions with the city's hinterland/relevant urban-rural interactions
Water service providers	• Systematically consider NbS-WS as options in investment planning and programming to minimise overall costs • Collaborate with other actors on regional water resource planning and implementation • Systematically monitor effectiveness and cost-effectiveness of NbS-WS they implement to build evidence base
Water users (corporations)	• Join multi-sectoral governance platforms for water management • Contribute funding for NbS and other investments that contribute to overall water security • Consider NBS as an attractive way to deliver on multiple objectives, including water stewardship, biodiversity and carbon neutrality targets
Farmers	• Adopt improved farming practices to reduce pressures on water resources • Embrace NbS-WS as a way to get a just retribution for land stewardship services they can provide, with benefits in terms of income and recognition • Seek facilitated access to credit to help with the transition
Public financiers	• Provide grants for innovative projects and seek to de-risk private financing • Move towards a loan-based model for NbS-WS with clear revenue streams
Private financiers	• Engage with water actors, public funders and intermediaries to better articulate what sustainable finance opportunities they are looking for • Seek returns on multiple fronts: financial, environmental and social
Intermediaries (NGOs, consultancies, academic institutions)	• Bridge information and knowledge gap between water sector actors and providers of funding and financing • Perform a brokering role, by helping identify and match project pipelines and funding and financing sources • Innovate and develop outcome-based blended finance vehicles

1. Introduction

This report aims to provide a strategic vision for mobilising greater investments in nature for water security in Europe, based on practical experiences. It includes:

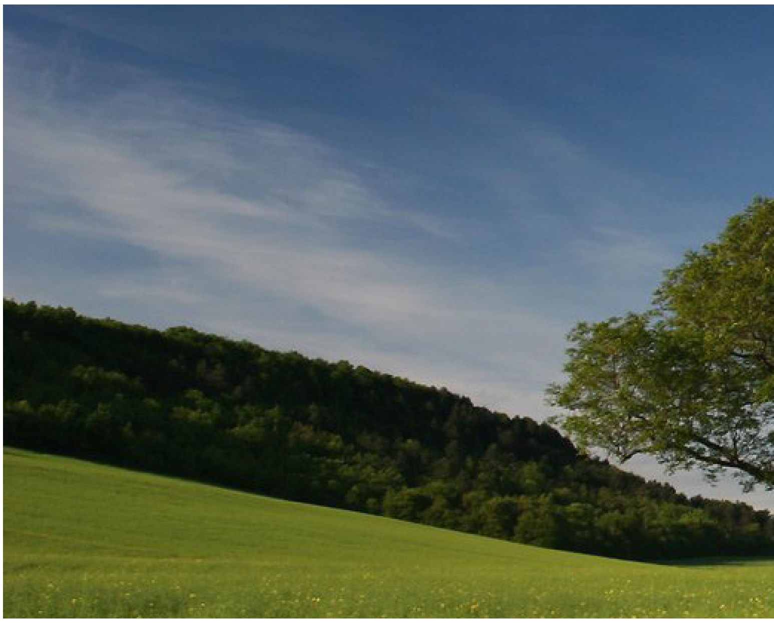
- An overview of water security challenges faced by European countries and a continent-wide perspective on the scale of these challenges
- Evidence that investing in nature can increase water security, by lowering costs (when compared to investing in grey infrastructure alone) and bringing many additional benefits in terms of biodiversity, climate, jobs and social cohesion
- Examples of pioneering European experiences with investing in nature for water security
- Recommendations on what is needed to significantly increase the pace of investment in nature for water security in Europe

For centuries, European countries have built their economic prosperity on dompting and managing nature, building aqueducts to bring water from kilometres away, draining wetlands and marshes to gain farmland, building dykes and levees against floods, channelling rivers to allow navigation and power production. With economic development came industrial contamination, intensive agriculture, urbanisation and other land use changes that have put increasing pressure on water resources. European countries, for the most part, have long been able to deliver safe drinking water and sanitation to their population. But they face many other water security challenges, related to water pollution, floods and, more recently, water scarcity.

Since the late 1960s, European countries have started to legislate and put in place governance frameworks for more integrated and sustainable management of their water resources. Although water legal and governance frameworks differ widely from one European country to another, European Union Member States, home to just over 510 million people (Eurostat, 2019b), operate under a common policy and legal framework for water management, that include the Water Framework Directive (WFD) and other directives.[1] Since its adoption in 2000, the WFD has provided a solid framework for managing water resources at river basin level against well-defined outcomes, including for the environment. This common framework has enabled large-scale data gathering using consistent indicators, analysed and reported upon centrally by the European Environment Agency (EEA, 2018a). Water professionals and policymakers have worked together across borders, supported by numerous EU-funded projects that enable peer-to-peer exchanges and joint work to tackle similar, although very local, water security challenges. The European Union has also channelled considerable financial resources to help latecomers in the EU, such as Bulgaria, Romania or Croatia, to bring their water systems in line with other European countries.

Despite significant progress decades down the line, many of the objectives that were set by the WFD in 2000 have not been met. A recent stock-taking report by the EEA (EEA, 2018a) showed that only 40 percent of surface water bodies had reached good ecological status and good chemical status (as defined in the WFD), when the initial objective was to reach 100 percent by 2015 (the deadline was later pushed back to 2027). As presented in this report, European waters remain under significant pressure from diffuse pollution (from agriculture or roads), point-source pollution (from industry or energy production), over-abstraction and hydromorphological changes. All these pressures from human activities, combined with the rising incidence of floods and water scarcity caused by climate change, lead to rising water security challenges.

European water supply and waste-water services are particularly vulnerable to climate change impacts. While climate risks related to infrastructure and activities that depend on water have been identified, it is also critical to consider the strong interdependencies that the water sector has with agriculture, forestry and biodiversity. The *European Environment State and Outlook 2015* report highlighted that to achieve the vision of the 7th Environment Action Programme (EAP), fundamental transitions in land use and urban development are needed across these sectors (EEA,2015b). Climate adaptation opens the door to systemic progress by increasing resilience, avoiding harm to ecosystems through precautionary and preventive action and by restoring and enhancing natural resources.



1 As of November 2019, the European Union was composed of 28 countries, with uncertainty looming on the future status of the United Kingdom.

In 2019, the world's attention sharply turned to climate adaptation, in addition to mitigation.

Across the world, investing in nature is increasingly seen as a key way to adapt to climate change, build water security and boost resilience. IIn the last decade, the world's attention has turned to climate adaptation, in addition to mitigation. The United Nations General Assembly and associated Climate Action Summit that took place in September 2019 highlighted that rising concerns around climate change and biodiversity collapse are inextricably linked and that investing in nature lies at the heart of reversing both trends. The Global Commission on Adaptation set up by the United Nations, the World Bank and the Bill and Melinda Gates Foundation highlighted the critical importance of water systems for climate adaptation. Its flagship report, released before the UN Climate Action Summit, stated, "Climate change is integrally connected to water systems and resources. Successful adaptation will require scaled-up investments in healthy watersheds and water infrastructure, dramatic improvements in efficiency of water use and the integration of new climate risks, such as floods and droughts, at every level of planning and operation" (Global Commission on Adaptation, 2019).

Moving beyond the calls for investments in nature, it is essential to delve deeper into how nature-based solutions can be used in specific contexts. Factors such as geographical characteristics, governance and policy settings vary for each location and these differences influence the way these solutions can be applied and can deliver results. This report aims to explore these specificities in the European context, with a focus on addressing European water security challenges.

1.1 Report objectives

The main objectives of this report are:

- To identify the roles that nature-based solutions can play to tackle Europe's water security challenges, as part of hybrid (green-grey) water investment strategies;
- To extract learning from experiences with investments in nature for water security in Europe and identify enabling conditions and barriers to scale;
- To formulate recommendations on what needs to be done differently to achieve scale and boost European Union economies' water security and resilience.

Water is the lifeblood of our economies. Investing in nature for water should not be a priority for water sector managers alone. This report aims to make understanding water challenges accessible to a broader audience, including decision makers in the public and in the private sector across several sectors. In particular, we unpack water sector challenges and associated investment needs in NbS-WS to make them intelligible for public and private financiers, particularly those who are actively looking for sustainable finance opportunities. They hold the keys to unlocking significantly greater resources than what we have seen up to this point.

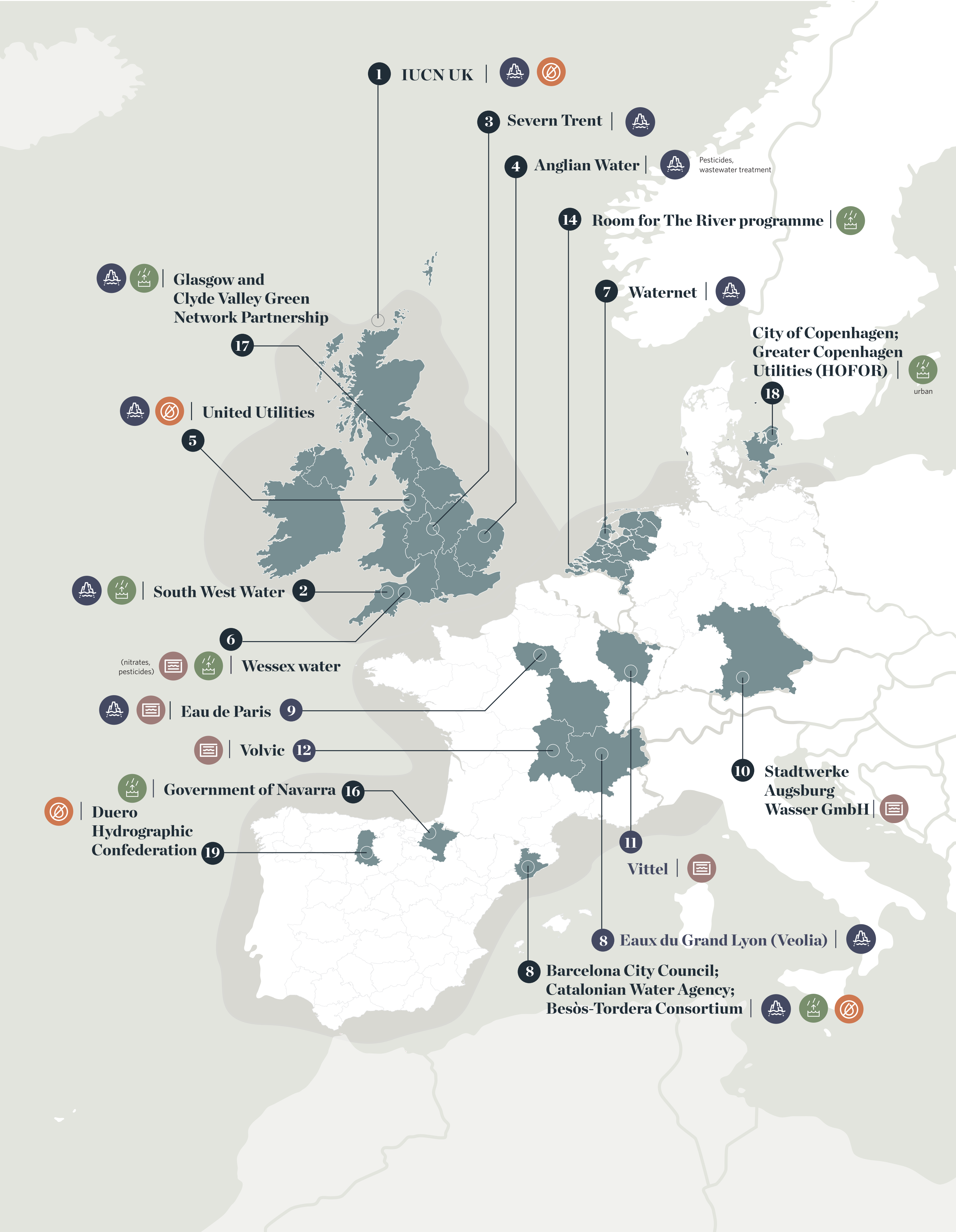
Pioneer examples of at-scale investments in NbS-WS in Europe can serve as a foundation for innovation and future scaling. The report presents in more detail 19 European case studies of NbS-WS that were implemented and the water security challenges they address. These cases analyse the different contexts and motivations that enabled the decisions to support NbS investments and overcome barriers. Examples come from a range of European countries, as shown on the map below.

Figure 1-1 *Case studies: water user-led initiatives to invest in NbS-WS in Europe*

Water Security challenges

- Surface water quality
- Scarcity
- Flooding
- Groundwater

Source: Authors



1 IUCN UK
3 Severn Trent
4 Anglian Water
Pesticides, wastewater treatment
14 Room for The River programme
Glasgow and Clyde Valley Green Network Partnership
17
7 Waternet
City of Copenhagen; Greater Copenhagen Utilities (HOFOR)
urban
18
United Utilities
5
South West Water 2
6
(nitrates, pesticides)
Wessex water
Eau de Paris 9
Volvic 12
Government of Navarra 16
Duero Hydrographic Confederation 19
10 Stadtwerke Augsburg Wasser GmbH
11
Vittel
8 Eaux du Grand Lyon (Veolia)
8 Barcelona City Council; Catalonian Water Agency; Besòs-Tordera Consortium

Our analysis is far from being comprehensive, however, and suffers from a number of limitations. The European Union has funded numerous research projects on nature-based solutions over the years through its Framework Programmes for Research and Technological Development, particularly through the seventh programme (FP7), which ran from 2007 to 2013, and Horizon 2020 (FP8), which runs from 2014 to 2020. Other grants have come through LIFE or Interreg, among others. Despite significant investments, information on NbS-WS remains relatively difficult to access for non-water specialists. It tends to be hidden away in water companies' and municipalities' annual reports, consultant reports, project implementation reports and academic articles. Sometimes they go by another name, such as Natural Water Retention Measures, green infrastructure or ecosystem-based adaptation. Due to resource constraints, we were able to conduct detailed analysis of policy and governance frameworks in only five countries, including France, Germany, the Netherlands, Spain and the United Kingdom.

We hope that the report will help inform the definition of upcoming European Union policy frameworks in the areas of water and sustainable agriculture. In the wake of European Parliament elections in May 2019, a new European Union strategic agenda was defined for the next five years (2019-2024). One of the four key pillars of this agenda is to "build a climate-neutral, green, fair and social Europe" (European Council, 2019). This will include new and hopefully more ambitious policies for the environment, water and sustainable agriculture. At the time of this writing, the WFD and daughter directives were undergoing a fitness check: results were expected by end of November 2019, with follow-up discussions in early 2020. Several civil society actors have joined together to restate their attachment to the WFD and declared it "fit-for-purpose", ahead of the official review by the European Commission (WWF & et al., 2018).

We hope that lessons from what is happening on the ground and our specific recommendations for going to scale can help inform the definition and improvement of European broader policies, governance structures and practices so that NbS-WS becomes mainstream at the urban level and feeds into the European Union's future research agenda, through its upcoming Horizon Europe programme (FP9, 2021-2027). In particular, we hope that by elevating the need to improve metrics and accountability through monitoring and evaluation, we will strengthen existing efforts to assess effectiveness and cost-effectiveness of NbS-WS.

We hope that our recommendations to mobilise and combine European and national financial resources are seen as a way to maximise funding opportunities and to help reduce the barriers for NbS-WS. In a forthcoming report by TNC, we will highlight the potential for targeted landscape-scale investments in NbS-WS to advance water security so as to help identify where NbS-WS can make the greatest contribution.

We expect that learnings and recommendations from this report will be applicable to other geographies facing similar or related challenges. Europe has been leading the way in integrated water resource management for several decades: how European water service providers and local governments choose to tackle their water security challenges can generate learnings and impact much beyond the continent's borders.

Europe has been leading the way in the area of integrated water resource management for several decades

1.2. Report structure

The remainder of this report is structured as follows:

Section 2 provides an overall introduction to nature-based solutions for water security (NbS-WS) and how they can substitute or complement grey infrastructure to address key water sector challenges. We show that, thanks to a conducive European water policy context, NbS-WS can be used in Europe to address common water challenges and generate additional benefits, particularly for biodiversity, climate, jobs and social cohesion.

The next sections examine four main water challenges affecting European water security: improving surface water quality **(Section 3)**, improving groundwater quality **(Section 4)**, dealing with floods **(Section 5)** and dealing with water scarcity **(Section 6)**. In each case, we identify what the scale of the challenge is and where it manifests itself in Europe with greatest acuity, now and in the future. We then set out how NbS-WS can or cannot contribute to addressing this challenge, and we identify the most promising applications of such approaches, with illustrative examples from European experiences. In doing so, we highlight pioneering experiences led by a wealth of European actors, including water service providers, local governments, large water users, civil society organisations and academia.

Section 7 sets out how European stakeholders have adopted NbS-WS. We examine key enablers and barriers to accelerate investments in NbS-WS in Europe, to help address the water security challenges identified in earlier sections. In many countries, despite an overall policy framework that is conducive to change, mentalities can be the strongest barrier, due to technical and physical barriers, governance barriers or financial barriers. We review what has worked well in some countries and what has proven harder to shift in others, to produce the basis of our recommendations for incremental change.

Section 8 formulates recommendations for accelerating take-up of NbS-WS in Europe, clearly outlining roles and responsibilities for a range of actors that need to be involved.

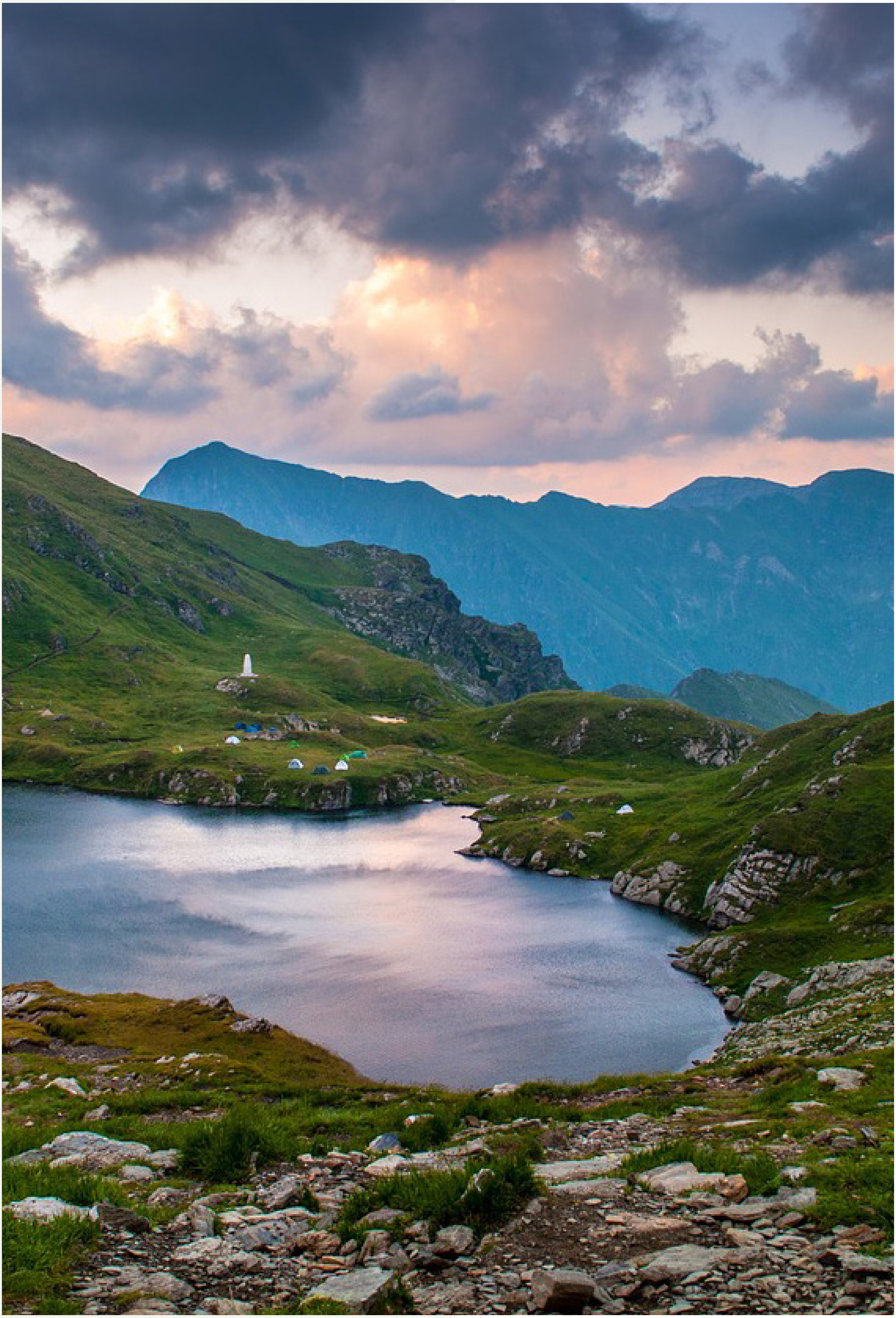
In addition:

- **Annex A** contains 19 case studies of NbS-WS in Europe, showing where the activities took place, the types of NbS-WS that were implemented and the water security challenges they addressed;
- **Annex B** presents summaries of the main European policies and financial instruments that exist and can contribute to supporting investments in NbS-WS in Europe;
- **Annex C** contains a list of databases with useful information on NbS-WS in Europe;
- **Annex D** contains a glossary of key terms used in this report, both technical terms relative to NbS-WS and financial terminology;
- **Annex E** contains a list of general references. References for case studies in Annex A are included in the case studies.
- **Annex F** acknowledges the numerous contributions that have been gratefully received for the preparation of this report.

2. European Water Security
How Investing in Nature Can Help?

Increasing the pace and scale of investment in nature-based solutions is an important tool to boost Europe's water security and to deliver other critical environmental improvements. These include climate (both adaptation and mitigation) and biodiversity as well as jobs and social cohesion.

Investing in nature for water security fits well with the European Union overall policy framework. However, as follow-up sections will show, such investments have remained relatively limited when compared to what is needed to achieve all of these mutually reinforcing objectives.



2.1. Why is it important to invest in nature for water security?

Ensuring water security is critical to achieving sustainable development. Sadoff and Grey (2007) define water security as "availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies". In that study, the authors highlighted how developing and managing water resources to achieve water security is essential for sustainable economic growth.

Water security can be threatened in multiple ways. Available **water quantities** are threatened by rising demands for water from multiple sectors (human consumption, agriculture, industry, the environment) and a changing climate. When the **quality of surface water and groundwater** is affected by pollution, ecosystems lose their ability to sustain life and water becomes unfit for human consumption, thereby increasing the cost of water treatment. Without water of an acceptable quantity and quality, the vast majority of human activities, including food and energy production are affected—and so is the ability of ecosystems to function.

In the pre-industrial era, water security challenges were tackled through working with nature, rather than against it. But with technological progress, humans have increasingly relied on "grey infrastructure" solutions: pipes and concrete, dams, levees and water treatment plants that manage and dompt nature to bring water from far distances, treat it, protect communities against floods, drain wetlands and regain territories over former marshlands or the sea. These solutions have delivered remarkable advances in terms of public health, irrigation and navigation. But this did not come without a cost. Nature and biodiversity suffered with a loss of natural habitats, changes in natural flows and pollution. The importance of protecting water at source has long been front of mind for managers in charge of delivering clean water. But they have increasingly relied on grey infrastructure at the expense of green infrastructure, for a number of reasons explored in Section 7. They have used NbS solutions wherever possible, but on a relatively small scale out of the mainstream.

Over the last decades, a number of high-level policy statements have brought the importance of investing in natural systems to the fore. These international statements are fully reflected in EU legislation and policy, as shown in Table 2-1. In 2018, the United Nations World Water Development Report focused on nature-based solutions for water. It highlighted opportunities to harness natural processes to regulate the water cycle. The report stressed the importance of nature-based solutions, emphasising that they are "an essential step to ensuring the long-term sustainability of water resources and of the multitude of benefits that water provides" (WWAP /UN-Water, 2018).

Today, despite recent advancements in the use of green infrastructure solutions, water resource management in Europe and elsewhere remains highly reliant on grey infrastructure. While the U.N.'s World Water Development report did not suggest a replacement of grey infrastructure with nature-based solutions, it urged to "identify the most appropriate, cost-effective and sustainable balance between grey infrastructure and NbS considering multiple objectives and benefits". This was echoed in a recent report by the World Bank and World Resources Institute (2019), *Integrating Green and Gray: Creating Next Generation Infrastructure,* in which the authors called for the "next generation of infrastructure", characterised by projects that can tap natural systems and integrate both types of solutions and thus "can help drive economies and strengthen communities and the environment".

Table 2-1 *International policy statements impacting EU policy on nature-based solutions*

Brief overview and impact on EU policies	Brief overview and impact on EU policies
Convention on wetlands or Ramsar Convention **(1971)**	Targeted the maintenance of wetlands' ecological character through implementing ecosystem approaches within the context of sustainable development. → Ratified by all EU Member States. Its implementation is aligned to the Birds and Habitats Directives and the creation of the Natura 2000 Network. It is supported by the EU Biodiversity Strategy targets.
International Convention on Biological Diversity – CBD **(1992)** and the Aichi Targets, **(2010)**	Adopted the ecosystem approach and focused on the integrated management of land, water and living resources to promote conservation and sustainable use of resources in an equitable manner. Adopted the Strategic Plan for Biodiversity, including the 20 Aichi Biodiversity Targets. These will be revised in the upcoming COP 15 in Kunming, China, in 2020. → The EU Biodiversity Strategy was developed to comply with the CBD and Aichi Target commitments and sets the EU biodiversity targets, which include the full implementation of the Birds and Habitats Directives, maintaining and restoring ecosystems and their services, and others.
Millennium Ecosystem Assessment – MEA **(2005)**	Assessed the consequences of ecosystem change for human well-being and referred to the global condition and trends in the ecosystems and the services they provide. → Target 2 under the EU Biodiversity Strategy aims to maintain and enhance ecosystem services in Europe. A dedicated Working Group advancing the Mapping and Assessment of Ecosystems and their Services (MAES) delivered the fifth MAES Report in 2018. It proposed ways to measure the condition of terrestrial, freshwater and marine ecosystem types based on a selection of indicators.
Agenda 2030 Sustainable Development Goals - SDGs **(2015)**	Included biodiversity and ecosystems throughout the SDG framework, not only in Goals 14 (Life Below Water) and 15 (Life on Land), but in targets in many other goals, including 2 (Zero Hunger), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities) and 12 (Responsible Consumption and Production). In addition, Goal 13 (Climate Action) related to water in terms of adaptation and links to policies within the UNFCCC framework. → Three main EU communications indicated that 1) EU political priorities contribute to implementing the UN 2030 Agenda for SDGs in the future; 2) a new European Consensus on Development has a shared vision and framework for development cooperation aligned with Agenda 2030; and 3) a renewed partnership with African, Caribbean and Pacific (ACP) countries focuses on a new, sustainable phase in EU-ACP relations after the Cotonou Partnership Agreement expires in 2020.
Sendai Framework for Disaster Risk Reduction **(2015)**	Voluntary international framework with four priorities for action: understanding disaster risk, strengthening disaster risk governance to manage disaster risk, investing in disaster risk reduction for resilience, enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction. This document underlined ecosystem-based solutions for reducing disaster risk. → The EU played a key role in the negotiations process and supports EU Member States and non-EU countries in achieving the seven Sendai targets. The Commission published an Action Plan to translate the Sendai priorities into EU policies and funding instruments. It proposes concrete activities to: include risk knowledge in all EU policies (e.g., collection/sharing loss and damage data, scenarios risk assessments, management of information); improve governance to risk management; promote risk-informed investments; and develop a holistic disaster risk management approach for disaster preparedness and resilience. The Floods Directive is a key component.

International policy	Brief overview and impact on EU policies
Task Force on Climate-related Financial Disclosures – TCFD (2016)	Developed voluntary, consistent climate-related financial disclosure recommendations by request of the G20's Financial Stability Board. → The European Commission published new guidelines on corporate climate-related information reporting to ensure that the financial sector can play a critical role in transitioning to a climate-neutral economy and in funding investments at the scale required.
Paris Agreement of the UNFCCC (2015)	Set out a global action plan to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. Of 167 Nationally Determined Contributions (NDCs) submitted under the Paris Agreement, more than 100 countries included actions referred to as nature contributions (for example, conservation activities, Ecosystem based Adaptation-EbA and NbS). → The EU has played a leading role in international efforts to fight climate change. Its NDC commitments focus on mitigation efforts (40 percent GHG reduction). The EU Adaptation Strategy aims for a climate-resilient Europe and provides examples of NbS to be used. Three objectives include: adaptation in cities supported through the Covenant of Mayors for Climate and Energy initiative; climate proofing of investments; and improving knowledge through the adaptation platform (Climate-ADAPT).

2.2. What are nature-based solutions for water security?

Broadly defined, nature-based solutions (NbS) involve working with nature and functioning ecosystems to help address diverse environmental, social and economic challenges. The International Union for Conservation of Nature (IUCN) coined the term and adopted a resolution at the World Conservation Congress in 2016 that defines NbS as *"actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"* (IUCN, 2019).[2] The European Union defines NbS in a broader manner as "solutions which are inspired by, supported by or copied from nature" (EC, 2015a). The European Commission website also states: *"These solutions can simultaneously provide environmental, social and economic benefits and help build resilience; as a result, they can be cost-effective and sustainable".*

The European Union has committed significant resources, through successive research programmes, to raise awareness to the fact that nature can provide viable solutions that use and deploy the properties of natural ecosystems and the services that they provide in a smart, "engineered" way. The objective of these projects is to demonstrate that "nature-based solutions provide sustainable, cost-effective, multi-purpose and flexible alternatives for various objectives". The European Commission has argued that "working with nature, rather than against it, can further pave the way towards a more resource-efficient, competitive and greener economy. It can also help to create new jobs and economic growth, through the manufacture and delivery of new products and services, which enhance the natural capital rather than deplete it". [3]

In line with the definitions above, we define nature-based solutions for water security (NbS-WS) as actions to protect, sustainably manage and restore natural or modified ecosystems that address water security challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. A broad spectrum of NbS can be deployed to address key water challenges and enhance water security, alongside grey infrastructure or as self-standing solutions.

2 The IUCN has identified the lack of clarity with respect to NbS definition as an issue and is currently in the process of defining a global standard for the design and verification of nature-based solutions, which will be launched at the next World Conservation Congress in Marseille in June 2020.

3 Speech by Kurt Vandenberghe, Director for Climate Action and Resource Efficiency at the European Commission at the 2015 European Conference on Biodiversity and Climate Change (ECBCC).

Table 2-2 below presents the range of NbS that can be deployed to address four main types of water challenges, including surface water quality, groundwater quality, floods and scarcity. The European Union typically refers to those measures as Natural Water Retention Measures (NWRM), defined as "multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes". The NWRM platform provides a comprehensive database presenting these solutions, with technical specifications and examples of where they have been applied throughout the EU.[4] This goes into a lot more technical detail than this report and can be used as a useful reference guide for practitioners involved in the design of NbS-WS. By contrast, this report aims to place those solutions into a broader framework of analysis and identify where they can be of help.

The solutions presented in Table 2-2 group different approaches to invest in nature. Some of these solutions, such as forests and wetlands, entail investments in "green infrastructure", which could potentially be treated as a capital asset of a water service provider, in the same way that a water treatment plant or a waste-water treatment plant would do. Green infrastructure provides a series of services in the same way that built infrastructure does. A forest can treat water percolating into the ground, as shown in Lyon, France, where maintaining a healthy forest helped Eau du Grand Lyon achieve full compliance with drinking water standards at about half the annualised costs if it had had to build a water treatment plant (see Case Study 8 - Eau du Grand Lyon). A constructed wetland can contribute to treat waste water before it returns in the environment. For example, in Eastern England, Anglian Water built an artificial wetland next to one of its waste-water treatment plants at the Ingoldisthorpe Water Recycling Centre (see Case Study 4 - Anglian Water). The wetland filters water after it has passed through the existing treatment plant to ensure it meets high quality standards, thereby replacing the need for conventional, energy-intensive, waste-water treatment infrastructure. The report Green Infrastructure: *Guide for Water Management* (UNEP-DHI et al., 2014), jointly prepared by UNEP-DHI, IUCN and TNC, provides more detail on the role and potential costs of green infrastructure.

Other solutions presented in the table fall in the category of "improved management practices". For example, improved agricultural practices leading to reduced fertiliser or pesticides use, or planting of catch and cover crops, sustainably manage or restore modified ecosystems, so as to reduce water pollution at source, rather than having to invest in expensive water treatment down the line. Many of the experiences in Europe detailed in the present report have entailed downstream water users engaging with farmers or forest managers upstream to change their practices to ensure a more sustainable use of natural assets. The case studies in this report show that there are many ways for this engagement to take place: when land is purchased and then leased back to farmers with specific conditions on their sustainable use, when subsidies are provided to facilitate transitioning to organic farming or creating river strips to stem the flow of leaching nutrients into water bodies.

One important clarification is that the NbS-WS presented in Table 2-2 are focused on interventions in land areas that are important for water security and that tend to be outside of a city's boundaries. This focus was chosen for the report as a whole because watershed interventions for source water protection typically require the coordination of multiple actors and therefore complex governance and funding issues, which is one of the key focus areas for the present report. Other NbS—such as Sustainable Urban Drainage Systems (SuDs), green spaces (for bioretention and infiltration) and permeable pavements—are also very relevant in cities to reduce volumes of rainwater going into the drains, the risks of combined sewers overflows (where such systems are in place) or the risks of urban flooding everywhere else. They have been well studied and documented elsewhere and are not the focus of this report. (See EC, 2015a, and Brown and Mijic, 2019, amongst other sources.)

As the table shows, one NbS-WS can impact various water security challenges. In the table, the cells marked in green indicate that which challenges these NbS-WS can address. For example, either reforestation or afforestation, or both, can have beneficial impacts on multiple water challenges (in terms of water quality, floods and water scarcity), but there is no solid evidence as yet that it can help with removing chemicals or emerging pollutants from surface waters. Additional evidence for the impact that these solutions can have in addressing each of the four main challenges is provided in Sections 3 to 6.

NbS-WS need to be considered as complementary to grey infrastructure solutions. In a number of geographies and particularly in the European context, they are unlikely to provide a comprehensive solution to the water security

4 We do not use the NWRM terminology in the present report as it is intended for a broader audience, beyond the European Union, and this term is not commonly used in other geographies.

challenges, for reasons analysed in more detail in Section 7. For example, the land that is available to be either protected or repurposed is relatively limited, and there might be difficulties in repurposing the land that is already farmed, as this usually requires agreeing with farmers to limit cultivation.

From an economic point of view, combining NbS-WS with grey infrastructure is often more cost-effective than grey infrastructure alone. Protecting surface waters at source rather than relying exclusively on expensive water treatment can generate significant savings, in terms of both avoided investment costs (not having to build a water treatment plant) and reduced or avoided operating costs (such as reductions in chemicals and energy consumption).

The *Beyond the Source* report, published by The Nature Conservancy (TNC) in 2017 (Abell R. et al., 2017), presents the findings of seven studies of U.S. cities that maintain high-quality water due to protection or restoration of their source watersheds. One of the most well-known examples this report highlights is that of New York City, home to the largest unfiltered water supply in the United States. The City combined investments in a water source protection programme for its watersheds forested areas with an already existing agricultural best management practices programme. These interventions were developed as an alternative to building a water treatment plant for an estimated US$8-10 billion and save the City more than US$300 million a year on water treatment operation and maintenance costs (Abell et al., 2017).

Table 2-2 *Nature-based solutions for water security: potential solutions and links to water sector challenges*

Water challenges	Surface water quality				Groundwater quality		Floods	Water scarcity		
Nature-based solutions	Nutrients	Sediments	Pesticides	Other chemicals & emerging pollutants	Nitrates	Pesticides	Upstream watershed	Lower river flows	Lower groundwater levels	Droughts
Reforestation/afforestation	●	●	●		●	●				
Targeted land protection (including forest protection)	●	●	●		●	●				
Land-use change from farmland to pasture land	●	●	●		●	●	●	●	●	●
Riparian buffer strips/Riparian zone restoration	●	●	●				●	●	●	●
Aquifer recharge	●	●								
Reconnecting rivers to floodplains	●	●								
Establishing flood bypasses							●			
Wetlands restoration/conservation	●	●						●	●	●
Construction of artificial wetlands	●	●		●			●	●	●	●
Ponds and basins	●	●		●	●		●			
Forestry Best Management Practices (BMP), including forest fuel reduction	●	●			●		●	●	●	●
Improved agricultural practices:										
Catch crops/Cover crops	●	●	●		●		●			
Crop rotation	●	●	●			●	●	●	●	
Conservation tillage	●	●			●					
Reduced fertiliser use	●				●					
Alternative plant protection			●			●				

Source: Authors

In addition, NbS-WS can generate many additional benefits that go beyond water security. Potential advantages from NbS-WS are summarised in the table below.

Table 2-3 *Potential benefits from NbS-WS*

WATER SECURITY	CLIMATE CHANGE ADAPTATION	BIODIVERSITY CONSERVATION
1 Maintain or improve water quality 2 Maintain or improve river flows and aquifer recharge 3 Reduce impact of flooding	1 Reduce soil erosion 2 Soil quality improvement 3 Reduce frequency and intensity of forest fires, flooding and droughts	1 Landscape diversity 2 Protect and expand natural habitats 3 Limit expansion of invasive species
CLIMATE CHANGE MITIGATION	**HUMAN HEALTH AND WELL-BEING**	**JOBS AND SOCIAL COHESION**
1 Reduce greenhouse gases emissions 2 Carbon sequestration	1 Improve food security 2 Reduce exposure to polluting substances 3 Amenity value and recreational benefits	1 Create jobs particularly in rural areas 2 Promote urban-rural solidarity

Potential advantages from NbS-WS are very intervention- and context-specific, however. Their deployment as part of an integrated programme of measures to address specific water security challenges requires specific assessments in every case. (Abell et al., 2017) found that four out of five cities analysed (out of a sample of more than 4,000 cities with a population of more than 100,000 people) could improve water quality from upstream forest protection, reforestation and improved agricultural practices, and that one out of six of the large cities could pay for these natural solutions through savings in water treatment alone (Abell et al., 2017). This means that in a few cities, NbS-WS for source water protection may not have a significant impact (either because the watershed is too large, or because these cities rely mostly on groundwater sources which are more challenging to protect). In the majority of cases, although operating cost savings may be significant, it is essential to take account of other benefits (in terms of biodiversity, climate or social cohesion) to make a convincing business case for investing in NbS-WS to address water security challenges facing those cities.

2.3. European policy context: mostly conducive, although issues remain

The WFD and other related directives provide, on the whole, a conducive framework for investing in nature for water security. Several EU policies in the areas of water management, biodiversity and nature protection, agriculture and climate either mention or recommend NbS. On paper, these policies provide a conducive framework for a massive adoption of NbS-WS. Such impetus has sometimes been at loggerheads with EU agricultural policy, however, which has historically driven a shift towards intensive agriculture and is responsible for many of the challenges that EU countries face today, in terms of both water quality and quantity. A comprehensive list of European policies and legal provisions that have an impact on the adoption of NbS-WS are set out in Annex B.

A conducive European policy framework for NbS-WS.

When the EU adopted the Water Framework Directive in 2000, it was a visionary piece of legislation with the purpose of protecting and enhancing the status of all water bodies in Europe, including groundwater and surface waters.

The WFD built on several decades of water policy and brought together previously adopted directives relative to water and waste water into a coherent framework. The implementation of earlier directives (such as the Urban Wastewater Treatment Directive, 1991) had enabled Europe to achieve remarkable success in reaching very high levels of waste-water treatment. The WFD established the legal framework that committed EU Member States to achieve good ecological status for all ground and surface waters. Even though the WFD was adopted before the concept of NbS-WS (or NWRM as they are known in the EU) was coined and widely used, key aspects of the WFD are conducive to investments in such solutions, as set out in Box 2-1 below.

Box 2-1 *Key aspects of the Water Framework Directive (WFD) that are conducive to investing in nature for water*

RIVER BASIN PLANNING

The WFD sets out an integrated and coordinated approach to water management by considering the river basin as the natural geographical and hydrological management unit. In order to make WFD implementation and monitoring operational, the concept of "water bodies" has been introduced as the key unit to which a number of the WFD requirements are related. For example, a body of surface water means a discrete and significant element of surface water such as a lake, reservoir, stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water. A groundwater body is defined in the WFD as a distinct volume of groundwater within an aquifer or aquifers, whereas an aquifer is defined as a geological layer with significant groundwater flow. An important innovation relates to the creation of River Basin Districts throughout the European Union, with the responsibility to prepare River Basin Management Plans (RBMPs) in consultation with all actors in the River Basin District. These RBMPs were first prepared by 2009 and subsequently updated in 2015. These two planning cycles have led to the identification and hierarchisation of potential measures to reach "good status" (see next point), including NBS measures to help improve quality status. The RBMPs were prepared on a collaborative basis to foster public participation, improve governance and to decentralise policy-making.

FOCUS ON OUTCOMES

The WFD sets out key outcome objectives relative to improving the overall quality of water bodies, as opposed to an exclusive focus on the attainment of specific technical norms which was the approach of earlier water directives, such as the Urban Wastewater Treatment Directive (1991) or the Nitrates Directive (1994). The environmental objectives of the WFD include the achievement of good ecological and good chemical status of surface water bodies across Europe by 2015. The goal of good ecological status is based on the status of key biological elements such as fish, macrophytes, phytoplankton and benthic invertebrates, which need to be supported by good physico-chemical and hydromorphological conditions. The good chemical status objective is defined by limits on the concentration of certain pollutants that are relevant across the EU, known as priority substances. Good chemical status means that the concentrations of all priority substances and certain other pollutants do not exceed defined environmental quality standards (EQSs). These quality objectives were initially expected to be achieved by 2015. Failure to do so (by a wide margin) meant that the deadline had to be extended to 2027. These deadlines have been the topic of an intense discussion and were interrogated as part of the overall fitness check of the Directive.

ECONOMICS AND COST RECOVERY

The WFD was the first directive to place economic analysis at the heart of water sector policy-making, by insisting on water pricing that covers all costs of producing water (including internalisation of environmental and resource costs). The recommended approach for prioritising measures to be included in the RBMP is to conduct a cost-effectiveness analysis. Aside from water quality, the directive called for bringing "heavily modified water bodies" back to their natural state, except when the costs of doing so significantly outweigh the benefits after a full cost-benefit analysis. Reliance on economic analysis was intended to provide a stronger case for justifying the costs of restoring aquatic ecosystems and enhancing opportunities for participation. However, economic analyses conducted at MS level were of varying levels, and several countries still have not adopted tariffs that allow adequate incentives for water conservation.

INTERDISCIPLINARY AND HOLISTIC

The WFD takes account of the complexities and system interactions of ecological processes by considering all aspects of water management and the need for multi-sectoral integration. It refers to functioning ecosystems requiring the protection, enhancement and restoration of water bodies and acknowledges the potential of multiple ecosystem services derived by a healthy river basin. This would in theory provide a strong basis for the adoption of NbS-WS.

Following the assessment of the first RBMPs and based on a fitness test of European water legislation, the European Commission published "The Blueprint to Safeguard Europe's Water Resources" in 2012 to address obstacles for EU water legislation (EC, 2012d). This document provides a long-term framework for EU water policy and fosters integration with other policies objectives. It emphasises key themes which include: improving land use, addressing water pollution, increasing water efficiency and resilience, and improving governance by those involved in managing water resources, as per the EU's 2020 Strategy up to 2050 and the Roadmap to a Resource Efficient Europe (2011). In addition to the WFD and the Blueprint, there are six key water directives to ensure the good status of Europe's waters: the Urban Waste Water Treatment Directive (1991), the Nitrates Directive (1991), the Drinking Water Directive (1998), the Bathing Water Directive (2006), the Groundwater Directive (2006) and the Floods Directive (2007).

Other critical pieces of European legislation provide a strong framework for investing in nature for water security. Key ones are presented here:

- The **Habitats Directive (1992) and the Birds Directive (2009)** form the main legal framework for the protection of nature and biodiversity in the EU and provide the legal framework for a comprehensive system of protected natural areas across the EU, called the Natura 2000 network. Other aspects of biodiversity are addressed through policy documents, in particular the EU Biodiversity Strategy, which runs to 2020. It supports the expansion of NbS by calling for the restoration of at least 15 percent of degraded ecosystems in the EU.
- The **Seventh Environment Action Programme (7th EAP) (2013)** is the main policy document intended to help guide EU action on the environment and climate change up to 2020 and beyond based on the following vision: "Living well, within the limits of our planet". It supports NbS measures to enhance ecological and climate resilience, such as ecosystem restoration.

- The **European Commission Strategy on Green Infrastructure (2013)** emphasised that green infrastructure contributes to effective policy implementation when objectives can be achieved fully or partially via nature-based solutions. It also places green infrastructure firmly in the context of the Europe 2020 Growth Strategy, which relates to smart, sustainable and inclusive growth across the EU.
- The **EU Strategy on Adaptation to Climate Change (2013)** calls on Member States to make Europe more climate resilient by deploying ecosystem-based approaches to adaptation. It calls for the integration of adaptation into EU policies—such as the Cohesion Policy and the Common Agricultural Policy (CAP), below—and encourages Member States and regions to use these funding sources to address knowledge gaps and to invest in the analyses, risk assessments and tools required to improve capacities for adaptation.

Two main EU policy instruments have significant implications for funding environmental management and nature protection and are funded in the European Union: the Cohesion Policy, which governs the European Structural and Investment Funds (ESIF), and the Common Agricultural Policy (CAP), as further described below:

- The **Cohesion Policy** represents the largest share of the EU budget. Approximately 32.5 percent of the EU budget 2014-2020 (approximately EUR 351.8 billion over seven years at 2014 prices) is allocated to financial instruments that support cohesion policy. Funds are managed and delivered in partnership by the European Commission, MS and stakeholders at the local and regional level, with the purpose of supporting job creation and a sustainable and healthy European economy and environment. In particular, the Cohesion Policy supports regions to preserve and ensure sustainable development of their natural environment and to finance water and waste-water infrastructure. During the 2014-2020 financing period, although the bulk of funding went to grey infrastructure investments, a greater share of Cohesion Policy resources for the water sector went to catchment management compared to previous periods. Funding is channelled through five European structural and investment funds (ESIF); one of them is the European Agricultural Fund for Rural Development (EAFRD), worth EUR 100 billion for the period 2014-2020.
- The **Common Agricultural Policy,** the main EU funding for agriculture development, consists of two pillars. CAP Pillar I provides direct payments to farmers to help them keep the land in good agricultural and environmental condition via good soil management. CAP Pillar II complements these payments by supporting rural areas to meet economic, social and environmental challenges. It includes payments to cover WFD measures to improve water management and support protected areas. Two instruments are used to integrate the EU's water policy objectives into the CAP: the cross-compliance mechanism, which links certain CAP payments with specific environmental requirements, and the EAFRD. More detail on how successive attempts to "green the CAP" have generated limited environmental outcomes so far is provided in Box 7-4.

In addition, the European Union has adopted policies to increase the share of private financing for sustainable investments in Member States' territories. In March 2018, the Commission released an Action Plan on Sustainable Finance with three main objectives: reorient capital flows towards sustainable investment to achieve sustainable and inclusive growth; manage financial risks stemming from climate change, environmental degradation and social issues; and foster transparency and long-termism in financial and economic activity. In June 2018, the Commission set up a technical expert group on sustainable finance to develop a unified classification system for sustainable economic activities, an EU green bond standard, methodologies for low-carbon indices, and metrics for climate-related disclosure.

Taken together, these policies provide a conducive environment for investing in nature for European water security. As discussed below, however, key outcome targets have not been met, which means that a different approach is needed to deliver significant improvements.

With a number of key gaps and areas for improvement

Mainstreaming water policies into sectoral policies has not been optimal. The EU's water policy objectives require action in different policy areas. This means intervention by a range of authorities and stakeholders, which may pursue different and potentially contradictory interests in competing sectors (such as agriculture, urban, fisheries, transport, waste sector, tourism).

Despite efforts in recent years to "green" the EU's main policies and legislative framework, expected water-related outcomes have not been achieved. As subsequent sections set out in more detail, substantial challenges persist in the status of European waters. For example, as of 2018 only about 40 percent of Europe's surface waters reach good ecological status and 38 percent good chemical status (EEA, 2018a). As shown in Section 3, a major contributor to such failure to achieve outcomes is diffuse pollution, largely from agriculture. Many European countries have made substantial progress in terms of reducing point-source pollution with waste-water treatment as required under the Urban Waste Water Treatment Directive (UWWTD). The situation with ground water was comparatively less alarming, with 74 percent of groundwater bodies in good chemical status and 89 percent in good quantitative status. Still, hidden in these averages are groundwater challenges that are particularly acute in specific geographical areas.

One critical reason for failing to achieve expected outcomes relates to some fundamental contradictions between the EU CAP and other policies and directives looking to support investments in nature and biodiversity. For many years now, the CAP has supported intensive agriculture, including the use of fertilisers and pesticides, resulting in agricultural practices that lead to greater run-off and diffuse contamination of water sources. Although the WFD has been partially integrated into the CAP, a mismatch exists between policy objectives and the instruments used to effect change. The European Court of Auditors found that the use of CAP funding to support WFD measures has been very limited compared to other CAP funding that targeted environment and climate measures (ECA, 2014).

The negative impacts of European agriculture on water and biodiversity are a key challenge for EU environmental policy, as noted in several EU documents. Agriculture covers about half of the European Union's total land area. The EEA noted that "agricultural production is a major source of diffuse pollution, mostly as a result of excessive emissions of nutrients and chemicals such as pesticides" and that "agriculture is the main cause of groundwater's failure to achieve good chemical status, due to nitrates as well as other agricultural chemicals" (EEA, 2018a). The report also noted that agricultural run-off also affects surface waters that can be used for drinking water supplies. In Member States facing greater problems with water scarcity and drought—an issue especially in southern European countries such as Spain—agricultural abstractions also compete with drinking water needs and other uses for scarce water resources. Over-abstraction from groundwater aquifers impacts the river basin flow regime and groundwater levels. Efforts to solve over-abstraction and secure long-term sustainability remain inadequate in southern Europe.

In some cases, failure to achieve expected WFD outcomes is linked to the need to "catch up" in terms of point source pollution or maintaining existing infrastructure, which can require substantial investment.[5] The proportion of the population connected to urban waste-water treatment in southern, south-eastern and eastern Europe is generally lower than in other parts of Europe, although it has increased over the last 10 years with levels now at about 70 percent (EEA, 2017c). Inadequate waste-water treatment also remains a challenge in Spain: the country was fined by the Court of Justice of the European Union in 2018 for failing to comply with the UWWTD and was required to immediately close the gap in terms of waste-water investments (EC, 2019c). In addition, many European countries need to make substantial investment to renew old assets, some of which have been in place since the late 19th century. For instance, the *Assises de l´Eau* in France (a multi-stakeholder platform set up at the initiative of President Macron to assess investment needs in the water sector) announced that boosting investment in renewing infrastructure is urgently required and will translate in EUR 41 billion in investments over the period 2019-2024 (Assises de l'Eau, 2018).

Whereas there has been substantial focus on quality aspects in European water policy, the approach towards water scarcity and drought has generally been less elaborate. Much of the focus has been on crisis management rather than a proactive plan for risk reduction. In part, this has been due to the observation that until recent years "most Europeans have been insulated from the social, economic and environmental impacts of severe water shortages" (EEA, 2009). Extreme weather events that took place over the previous decade, and specifically the heat wave and drought of 2003, prompted a shift in European drought and water scarcity policy with a clearer focus on planning and

5 A forthcoming study by the OECD has estimated the water sector investment needs for all European countries. It will be released in 2020.

risk reduction. Nevertheless, this change of paradigm has exposed a lack of institutional capacity across many EU Member States, and progress has been slow (Tsakiris, 2015).

Finally, challenges exist on effective implementation of water-related monitoring and evaluation systems, resulting in limited policy feedback and uptake. The assessment and management of freshwater systems requires a holistic approach to monitoring, reflecting interconnected systems at the catchment level. Local and regional stakeholders face challenges in setting up efficient monitoring systems and facilitating effective enforcement. Results from monitoring systems deliver partial, fragmented and in some occasions delayed information.

The European water sector will need to continue to invest in the billions to meet WFD objectives, renew assets and make them more resilient in the face of climate change. This creates an opportunity to channel investments into a combination of green and grey infrastructure so as to lower the costs of the overall package and reduce the overall financing gap.

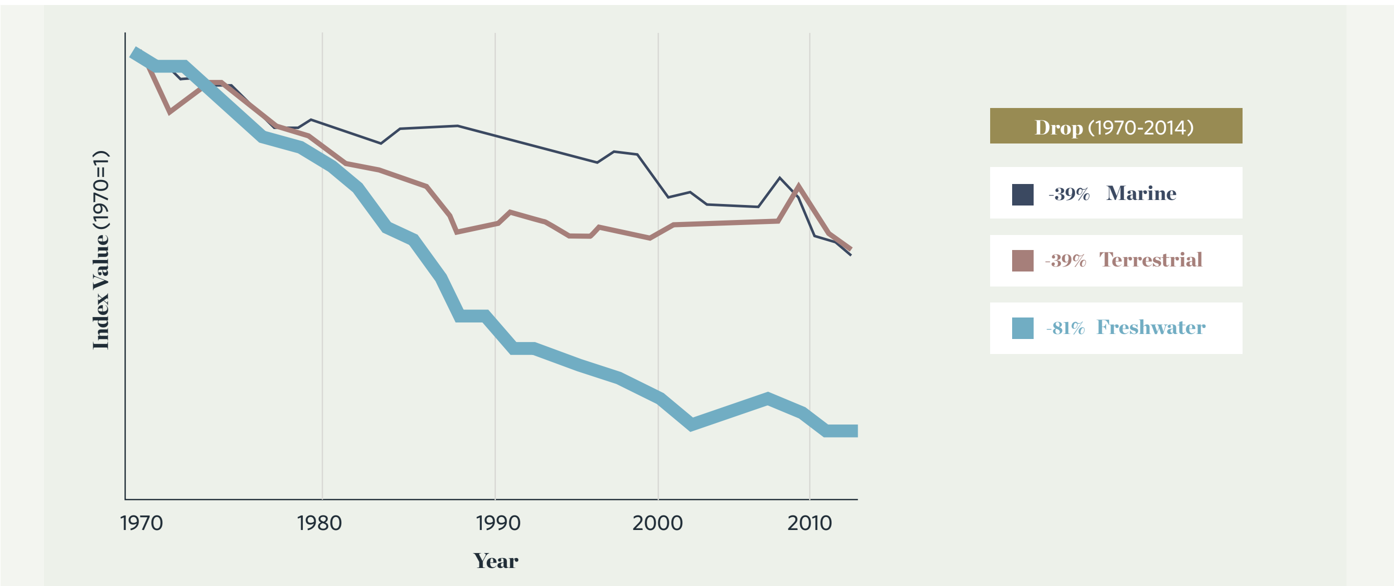
2.4. Why a step change in the pace of investments in NbS-WS is needed now

Investing in nature for water security can deliver impacts much beyond water security. It can address other pressing environmental challenges of our times, including collapsing biodiversity and climate change. These pressures are rapidly coming to the forefront of citizens' and politicians' minds in Europe and are therefore making it even more critical to identify practical solutions to accelerate investments in NbS-WS. In the face of these twin emergencies, business as usual will not be sufficient and accelerating investments in NbS-WS is critical.

2.4.1. For biodiversity

Global freshwater biodiversity has seen a massive 81 percent decline in the last 50 years—the equivalent of a 4 percent decline every year between 1970 and 2014, as shown in Figure 1 (WWF, 2018).[6] Freshwater biodiversity has declined at twice the rate of other forms of life, such as marine and terrestrial life; the latter two also are affected by the way we manage our rivers, lakes, wetlands and estuaries.

Figure 2-1 *Freshwater biodiversity has collapsed much faster than marine or terrestrial*



Source: *Adapted from WWF Living Planet Index 2018*

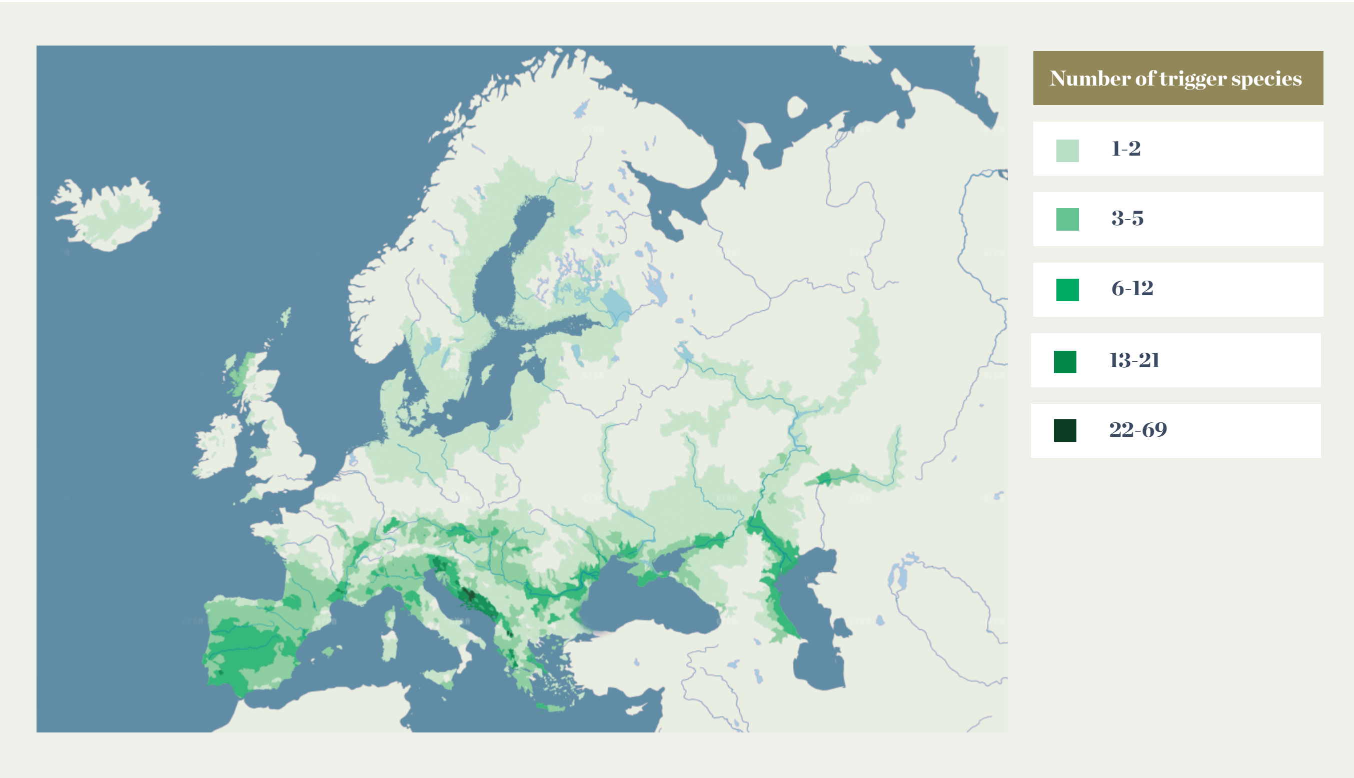
6 This data is published in WWF Living Planet Report and is based on 3,358 populations, representing 880 species of mammals, birds, amphibians, reptiles and fishes worldwide (Living Planet Index).

Despite covering less than 1 percent of the Earth's surface, freshwater ecosystems are home to at least 126,000 species of fishes, molluscs, reptiles, insects, plants and mammals, corresponding to more than 10 percent of known animal species and one third of all vertebrates (Visconti P. et al., 2018; WWF, 2018). Freshwater habitats such as lakes, rivers and wetlands are the most accessible water resources to humans. Their biodiversity provides a wide range of income sources and ecosystem services, including from food (fisheries, aquaculture) and as water quality and quantity regulators (plants). Many rivers, lakes and wetlands are also highly valued for recreational and cultural benefits, some of which generate substantial tourism revenues. In Europe, large rivers such as the Rhine, the Danube, the Ebro and the Rhone, wetlands such as the Doñana in Spain or the Camargue in France and thousands more are a powerful reminder of the importance of freshwater bodies in our daily lives and our economies.

The quantity and quality of habitats and abundance of many species is declining in Europe. Europe, jointly with Central Asia, is the region where freshwater biodiversity is most threatened (Vörösmarty et al., 2010). General threats to inland water ecosystems include water pollution, flow modification, habitat degradation, invasive alien species and salinisation. Overexploitation of water resources and agricultural activity are the dominant causes of current species loss.

Analyses of data on freshwater biodiversity show that more than 75 percent of Europe's catchment areas are subject to multiple quality and quantity pressures and have been heavily modified, in seriously threatening their biodiversity (Tockner et al., 2008). A study conducted in 2017 (Carrizo et al., 2017) identified the most important catchments for the conservation of freshwater biodiversity in Europe (see Figure 2-2). This map shows the results of the prioritisation of 18,816 river and lake catchments in Europe based on their importance for conserving freshwater biodiversity. According to this study, while critical catchments for freshwater biodiversity cover almost half of Europe, priority catchments are mostly located in southern and eastern Europe, where current levels of protection are not sufficient. As the proportion of threatened species is higher at lower latitudes in Europe, so is the overall diversity of freshwater species (Visconti P. et al., 2018).

Figure 2-2 *Critical catchments for freshwater biodiversity conservation per number of trigger species*



Source: *Freshwater Biodiversity Data Portal*

Note : Critical catchments contain sites likely to qualify as freshwater "key biodiversity areas", with 706 catchments shaded by the number of distinct trigger species (species that are globally threatened, have restricted ranges or have high endemism). This map was published on the Freshwater Information Platform as a continuation of the EU-funded project Biofresh (ended in 2014). It was the first programme to establish a platform bringing together information and data on freshwater biodiversity.

This map shows that the critical basins for freshwater biodiversity include some of the main river basins in Spain and Portugal (Duero, Tajo, Guadalquivir, Guadiana), the Danube in the Balkans and the Rhône in southern France.

Significant examples in species decline have been registered in Europe, including in protected areas. For example, many species of dragonfly have shown a steep decline in their population numbers and distribution since the 1950s, particularly in the south due to droughts and poor water management. While 24 percent of assessed dragonfly populations are still declining, some species have been recovering following improved water management practices (Visconti P. et al., 2018). In general, of known freshwater animal and plant species, 13 percent of those with known conservation status are at high risk of extinction in Europe (including in Central Asia).[7] Particularly threatened are mosses and liverworts: 50 percent of species are endangered. Freshwater fishes follow, with 37 percent of species in danger, freshwater snails (45 percent), vascular plants (33 percent) and amphibians (23 percent). Of all species endemic to Europe, 30 percent are threatened. Central and Western Europe has the highest percentage (35 percent) of threatened endemic species (Visconti P. et al., 2018).[8] In addition, pressures on freshwater resources do not only influence freshwater biodiversity directly but also indirectly threaten terrestrial species that depend on freshwater resources, such as terrestrial migratory birds and mammals.

On a positive note, conservation efforts in the region have produced a number of success stories. For example, the European sturgeon has made a remarkable comeback in the river Rhine. The species had almost disappeared following deterioration of water quality in the catchment, dam construction and excessive exploitation of its caviar. In 2019, the European Commission and experts from EU Member States endorsed a continent-wide plan to save the eight European sturgeon species from extinction under the EU Habitats Directive. This will be the first action plan for a fish species implemented under this EU directive (WWF, 2019). Another recent success story comes from England, where beavers were reintroduced in the forest of Dean in Gloucestershire in 2018, 400 years after disappearing from the region. Besides the positive impact on biodiversity, the reintroduction was also intended as a nature-based solution to reduce downstream flood risk: dams built by beavers help hold larger volumes of water higher upstream in natural pools and wetlands. As they are permeable, they gradually release water downstream and slow the flow (University of Exeter, 2018). This could be replicated in other areas if successful (Morris, 2018).

Protecting freshwater and terrestrial biodiversity is tightly linked to activities to protect water resources. If actions to protect source water are designed with a view to mitigate and minimise threats to biodiversity, they can contribute to conserving large numbers of species (Abell et.al 2017). The restoration or rehabilitation of native habitats through revegetation can be an important strategy for supporting biodiversity conservation in watersheds with medium and high levels of human modification, for instance.

Source water protection programmes with a positive impact on biodiversity have already been implemented in Europe. An example can be found in Lyon, France (see Case Study 8 - Eau du Grand Lyon). The benefits of introducing NbS for source water protection led to the creation of a natural habitat reserve at the heart of the metropolis, a migration corridor and a reproduction site for birds that also hosts 32 percent of the local flora and sensitive heritage species. In England, multiple water companies in partnership with other actors (such as the Moors for the Future programme) have taken steps designed not only to address water discolouration but more importantly to restore peat bogs and associated species as well as to reduce carbon emissions from degraded peatland (see Case Study 1 – IUCN UK). And in North West England, a catchment approach was developed by the local water company, United Utilities, and the Royal Society for the Protection of Birds (RSPB) to help protect and improve water quality and enhance and protect the natural environment (see Case Study 5 – United Utilities).

To reach the best outcomes in biodiversity conservation, planned activities for water source protection need to include the best information on species' locations, habitat requirements and threats, alongside information on where water security benefits can best be achieved. This information can further help identify locations where targeted land protection is most needed (Abell et al., 2017).

7 The two regions are here considered together as they are part of the same biogeographic realm (or ecozone) - the Paleartic. Biogeographic realms are broad divisions of the Earth surface which are defined according to the distributional patterns of plant and animal species.

8 Historical information and long-term data series are rare for tracking freshwater biodiversity. As a result, patterns of species richness across countries and time are known with much less confidence than for terrestrial systems (Carpenter et al., 2009; Strayer & Dudgeon, 2010; Tockner et al., 2008; Tockner et al., 2011 in Visconti P. et al., 2018). In Europe, a high proportion of freshwater species have unknown current population trends. This highlights the urgent need for further monitoring and data collection across the region (Visconti P. et al., 2018).

2.4.2. For climate

Climate change in Europe will continue to manifest itself through an increase in extreme weather events, with projected changes in temperature and rainfall that will vary from one region to another. This will result in increased droughts and floods, with potentially catastrophic consequences. Floods in Central Europe have caused deaths and widespread property damage across parts of the Czech Republic, Germany and Austria. Recurrent flooding events are also a growing issue in Spain, France and the UK. Whereas water scarcity had long been an issue limited to Southern Europe, in countries such as Spain, Greece and Malta, the last few summers have been the hottest on record. A global database of meteorological drought events from 1951 to 2016 has shown that progressive temperature increases outbalanced the increase in precipitations in central Europe causing more frequent and severe droughts (Spinoni et al., 2019). Droughts have affected northern and central European countries such as Germany, the Netherlands, Sweden, Ireland and Poland in ways not seen before. Such droughts affect both surface and groundwater availability and have had important economic consequences for several sectors, particularly agriculture, forestry and water service. Stressed wetlands and aquatic ecosystems have affected the sectors that depend on the resources and functions they provide (such as food, water, fibre, fuel, recreation, flood control, storm protection). Subsequent sections provide more detail on how floods (Section 5) and scarcity (Section 6) are affecting European countries and on how the situation is expected to evolve in future.

Nature-based solutions as a whole are increasingly seen as a fundamental tool for climate mitigation and adaptation. Their use, however, is still very limited compared to the potential they offer—even though NbS for mitigation and adaptation have both economic and practical advantages and can be used to address a wide range of climate hazards. Awareness of NbS solutions and their application has been growing around the world in recent years, but not fast enough. A study led in 2017 by TNC and 15 other institutions, published in *Proceedings of the National Academy of Sciences* (PNAS), concluded that nature-based solutions can provide over one third of the emission reductions needed by 2030 to keep global temperature increases under 2°C. This study stated: "Alongside aggressive fossil fuel emissions reductions, Natural Climate Solutions (NCS) offer a powerful set of options for nations to deliver on the

Protecting freshwater and terrestrial biodiversity is tightly linked to activities to protect water resources.

Paris Climate Agreement while improving soil productivity, cleaning our air and water, and maintaining biodiversity" (Griscom et al., 2017).[9] This means that conservation, restoration and improved land management are necessary steps for a transition to a carbon neutral global economy and a stable climate. Despite these findings, the Nature4Climate website indicates that nature-based solutions receive less than 3 percent of climate mitigation funding.

NbS-WS will be key tools going forward to adapt to climate change. As the World Bank puts it, "climate is water". Adaptation to climate change will require investments that can strengthen resilience and enable societies to deal with extreme events, such as floods and droughts. In its 2019 flagship report, the Global Commission on Adaptation stated that the Commission will "galvanise national, local and private sector leadership for nature-based solutions" and "will seek to strengthen the resilience of natural freshwater and critical human water systems to reduce risks for billions of people facing high water stress and for those whose lives are impacted by floods and droughts" (Global Commission on Adaptation, 2019). A recent background paper

9 Natural Climate Solutions are a subset of Nature-based solutions that are deployed to reduce carbon emissions and store more carbon in the landscape. More information can be found in the Nature4Climate website, an initiative that aims to increase investment and action on natural climate solutions in support of the 2015 Paris climate agreement.

commissioned by the Global Commission on Adaptation to inform its flagship report provides examples of NbS for adaptation. These include the restoration of upland forests and watersheds to reduce peak flows and stabilise soils, as well as increased infiltration and groundwater recharge to reduce drought impacts (Kapos, V. et al., 2019).

Continuously rising temperatures and heat waves are also intensifying fire risks across Europe, especially in central and southern countries. Many examples of watershed disruption caused by wildfires have been documented in the U.S., but this is also the case in Europe. Examples to note are the Devil Canyon catchment in Southern California (Jung, H.Y. et al., 2009) and the Beça River basin in Northern Portugal (Santos, R. M. B. et al., 2015). Catastrophic fires can increase sediment flows and affect river water quality, particularly in the Mediterranean mountain regions where autumn rain storms often follow summer wildfires, causing soil run-off. Investing in forest management and protection can reduce fire risk and, as a result, sediment flows in rivers. Examples from around the globe illustrate potential benefits on water supplies. In the United States, catastrophic burns led to significant increases in sediment load in the Rio Grande, the main river from which the New Mexico state capital of Albuquerque gets its water. In 2004, TNC established a water fund that supports activities such as tree thinning, stream restoration, flood control and wildfire management on 688,000 hectares of land in the area. To secure sustainable financing from water users, government, investors and stakeholders, payments for ecosystem services (PES) were established to upstream land managers (Abell et al., 2017). And a new vision set out by the European Commission is shifting the focus from reactive fire suppression to long-term proactive fire prevention and forest management at the landscape scale (Faivre, 2018). Because PES are recognised as an important implementation tool and are promoted in the EU Biodiversity Strategy (2011) and their potential is highlighted in the Roadmap for a Resource Efficient Europe (2011), there are opportunities to further their adoption for a broad range of NbS, including fire risk protection.

NbS-WS can play a key role to mitigate climate change. For example, the IUCN Peatland Restoration program in the UK was established to restore degraded peat, given its extremely important role in carbon storage and water management (see Case Study 1 - IUCN UK). Through restoration and land management activities, as well as awareness campaigns across the country, the program scope covers 2 million hectares of peatland across the UK. Finally, many NbS-WS allow to save on energy-intensive (or waste-water) treatment activities and sharply reduce the need for concrete and other building materials. This in turn reduces the need for energy to produce such materials. Anglian Water, one of the largest water utility in the UK, sees the adoption of NbS-WS as an important contributor to its goal to become carbon neutral by 2050 (Anglian Water, 2017) (see Case Study 4 - Anglian Water).

3. Improving Surface Water Quality

Increased waste-water treatment and point source emission controls have improved surface water quality in Europe in recent decades, but surface water bodies continue to face significant challenges. The environmental objectives embodied in key EU legislation, such as the WFD, the UWWTD and the Nitrates Directive, have yet to be fully met. Outstanding challenges in this area relate to nutrient enrichment (mainly nitrogen and phosphorus), sediment loads and chemical pollution.

Diffuse pollution from agriculture remains a major cause of poor water quality currently observed in parts of Europe. Many land management practices (linked to agriculture, livestock, forestry) also lead to soil erosion and sedimentation of surface waters, and more targeted work is needed to improve the understanding of the role and impacts of sediment run-off on water quality. Concerning chemicals, even though some key issues with the most hazardous substances have been and continue to be addressed, there are major concerns with emerging pollutants (e.g., pharmaceuticals) and other chemicals (e.g., pesticides not regulated under the WFD) entering freshwater resources.

NbS can play a clear role too address surface water quality challenges, particularly those stemming from excessive nutrient and sediment loads. Vegetated buffers within riparian zones are amongst the most well studied and frequently used mitigation measures to reduce sediment and phosphorus losses to surface waters via run-off. Employing NbS to improve surface water quality can greatly reduce the costs of drinking water treatment or waste-water treatment (e.g., via the use of artificial wetlands as alternative treatment technology), and generate additional benefits, particularly in terms of biodiversity. However, the potential of NbS to reduce concentrations of other chemicals is comparatively less understood.

3.1 What are key challenges in Europe?

The main challenges with regard to surface water quality in Europe relate to nutrient enrichment (mainly nitrogen and phosphorus), sediment loads and chemical pollution. Substances causing nutrient pollution derive from agricultural and industrial activities as well as household use. The main sources of nutrient enrichment with nitrogen and phosphorus include point source emissions from urban waste-water treatment plants and industry and diffuse emissions from agricultural production and atmospheric depositions (EEA, 2018a; EEA, 2015a).

Nutrient enrichment causes eutrophication, which occurs when a body of water becomes overly enriched with minerals and nutrients that induce excessive growth of algae. Decomposition of the algae lowers oxygen levels and creates turbid waters, resulting in loss of aquatic biodiversity and reduced fish stocks. For example, nutrient pollution and resulting eutrophication have caused a rapid loss of whitefish species from lakes in the Alps; whitefish species are keystone species in alpine lakes, and their loss has had wider impacts on these ecosystems (Vonlanthen, et al., 2012). Excessive nutrient enrichment can also be dangerous for human health; toxic algal blooms that may form can impair the use of water for drinking, bathing and fishing. For example, in 2013, blue-green algal blooms appeared in some European lakes due to warm weather, relatively calm conditions and a considerable level of nutrient pollution in some areas. When levels of blue-green algae are dangerously high, authorities must inform swimmers because they can cause rashes after skin contact and illnesses if swallowed (EEA, 2013).

Algal bloom on Loch Leven in Scotland

Excessive sediment loads can also impair the quality of surface waters. Sediment is an essential and integral natural element of the hydromorphology of rivers, lakes, and estuarine and coastal systems. It is also vital to the ecology of these systems, providing and supporting habitats as well as nutrients for aquatic plants, invertebrates, fish and other organisms. However, some land management activities can lead to soil erosion and thus increase the supply of fine sediment into the receiving surface waters (EC, 2019d).

Chemicals in surface waters present risks to plants and animals in freshwater ecosystems, as well as to the animals eating them. Chemicals can enter surface waters in different ways. They may have been released into the air, returning later to the Earth's surface in the form of rain or dust (atmospheric deposition). They may have been directly discharged into water from industry or urban waste-water treatment plants or from agricultural run-off. Risks presented by some chemicals, like metals and persistent organic pollutants such as the pesticide lindane, have been recognised for decades. However, new risks linked to other chemicals, such as some newer pesticides or pharmaceuticals, either alone or in combination, are continually being identified (EEA, 2019a). Another key concern involves micropollutants and the so-called cocktail effect: mixtures of single chemical substances that may be present at harmless concentrations (when considered individually) can pose a risk to health when combined (EEA, 2018c). The detection of several hundred organic chemicals at low concentrations in a single freshwater sample is common, and the level of risk that this might present is insufficiently understood (EEA, 2019a).

Source: *The Freshwater blog website. Photo by Laurence Carvalho*

In many cases, it is difficult to impossible to clearly attribute harmful ecological impacts with the presence of specific chemicals. EEA (2018c) concludes that it is rarely possible to explain observed effects in ecosystems based on the presence of individual chemicals alone. Instead, multiple lines of evidence are needed. EEA (2018c) reviews the sources and toxicity of the main chemical pollutants in European surface waters. For example, DEHP, a phthalate widely used as a plasticiser in the manufacturing of PVC, causes endocrine disruption to aquatic organisms, adversely affecting reproduction and growth. Severe examples can also occur following industrial accidents: for example, following an accident at a gold mine in Romania in 2000, a dam near Baia Mare holding 100,000 cubic metres of water contaminated with 100 tonnes of cyanide spilled into the Someș River. The spill is estimated to have killed over 1,200 tonnes of fish (UNEP/OCHA, 2000).

Nutrient enrichment, sediment loads and chemical pollution of surface water can have **significant economic impacts.** The World Bank stated in a recent report "Although many water quality parameters may affect growth, BOD (biochemical oxygen demand) is perhaps the most appropriate measure to use to test the relationship between upstream water quality and downstream GDP, given its ability to proxy a wide array of pollutants. When the BOD level of surface water is at a level at which rivers are considered heavily polluted (exceeding 8 milligrams per litre), GDP growth in downstream regions is lowered by a third" (Damania et al., 2019). In England and Wales, it has been estimated that the cumulative cost of water pollution is between £700 million and £1.3 billion a year and that it is likely to increase due to the impact of climate change (Ofwat, 2011). In southern Europe, the economic cost of algal blooms (marine and freshwater ecosystems) in Greece, Italy and Spain was estimated to cost over EUR 300 million per year (Glibert, et al., 2014).

EU Member States have made **substantial progress** in the last 30 years to improve the quality of Europe's freshwater bodies, thanks to EU policies—in particular, the Water Framework Directive (WFD), the Urban Waste Water Treatment Directive (UWWTD) and the Drinking Water Directive (DWD), as well as national policies. The goal of these key EU policies is to significantly reduce the negative impacts of pollution, over-abstraction and other pressures put on water and to ensure that a sufficient quantity of good-quality water is available for both human use and the environment (EEA, 2018d).

In 2015 only around 40 % of EU surface waters were in good ecological status.

As mentioned in Section 2.3, the WFD was conceived as an umbrella directive which encompasses all older EU water directives as part of its "basic measures". Reducing pollution to meet the objectives of the WFD requires Member States to correctly implement and enforce several other directives and regulations, including basic measures and other texts that have been adopted subsequently: the UWWTD (1991), the Nitrates Directive (1991), the DWD (1998), The Bathing Water Directive (2006), The Pollutant Release and Transfer Register Regulation (2006), the Environmental Quality Standards Directive (EQSD) (2008), the Plant Protection Products Regulation (2009), the Directive on Sustainable Use of Pesticides (2009), the Industrial Emissions Directive (2010) and the proposal for a regulation on minimum requirements for water reuse (2018). These texts are briefly summarised in Annex B, with a particular focus on how they impact surface water quality regulation.

The environmental objectives of the WFD include the achievement of good ecological and good chemical status of surface water bodies across Europe by 2015. [10] The goal of good ecological status is based on the status of key biological elements such as fish, macrophytes, phytoplankton and benthic invertebrates, which need to be supported by good physico-chemical and hydromorphological conditions. The good chemical status objective is defined by limits on the concentration of certain pollutants that are relevant across the EU, known as priority substances. Good chemical status means that the concentrations of all priority substances and certain other pollutants do not exceed defined environmental quality standards (EQS).

Despite improvements achieved in surface water quality in recent decades, Europe's surface water bodies continue to face significant challenges. The environmental objectives of key EU legislation, such as the WFD, the UWWTD and the Nitrates Directive have yet to be met fully.

As of 2015, **only around 40 percent of EU surface waters were in good ecological status (or good ecological potential), and 38 percent were in good chemical status** (EEA, 2018a) (see Figure 3-1).[11] The main significant pressures affecting the status of surface water bodies include hydromorphological pressures (affecting 40 percent of water bodies), diffuse sources (38 percent), point sources mainly from urban waste water (18 percent) and water abstraction (7 percent) (EEA, 2018a).

Hydromorphological pressures comprise all physical alterations to water bodies that modify their channels, shores, riparian zones and water levels/flows, such as dams, embankments, channelisation and flow regulation. These activities may cause damage to the morphology and hydrology of water bodies, interrupt the continuity of river systems and result in altered habitats, with significant impacts on ecological status (EEA, 2018a). For example, the construction of dams and weirs has been estimated to account for 55 to 60 percent of the known causes that lead to freshwater fish decline in Europe (Birnie-Gauvin et al., 2017).

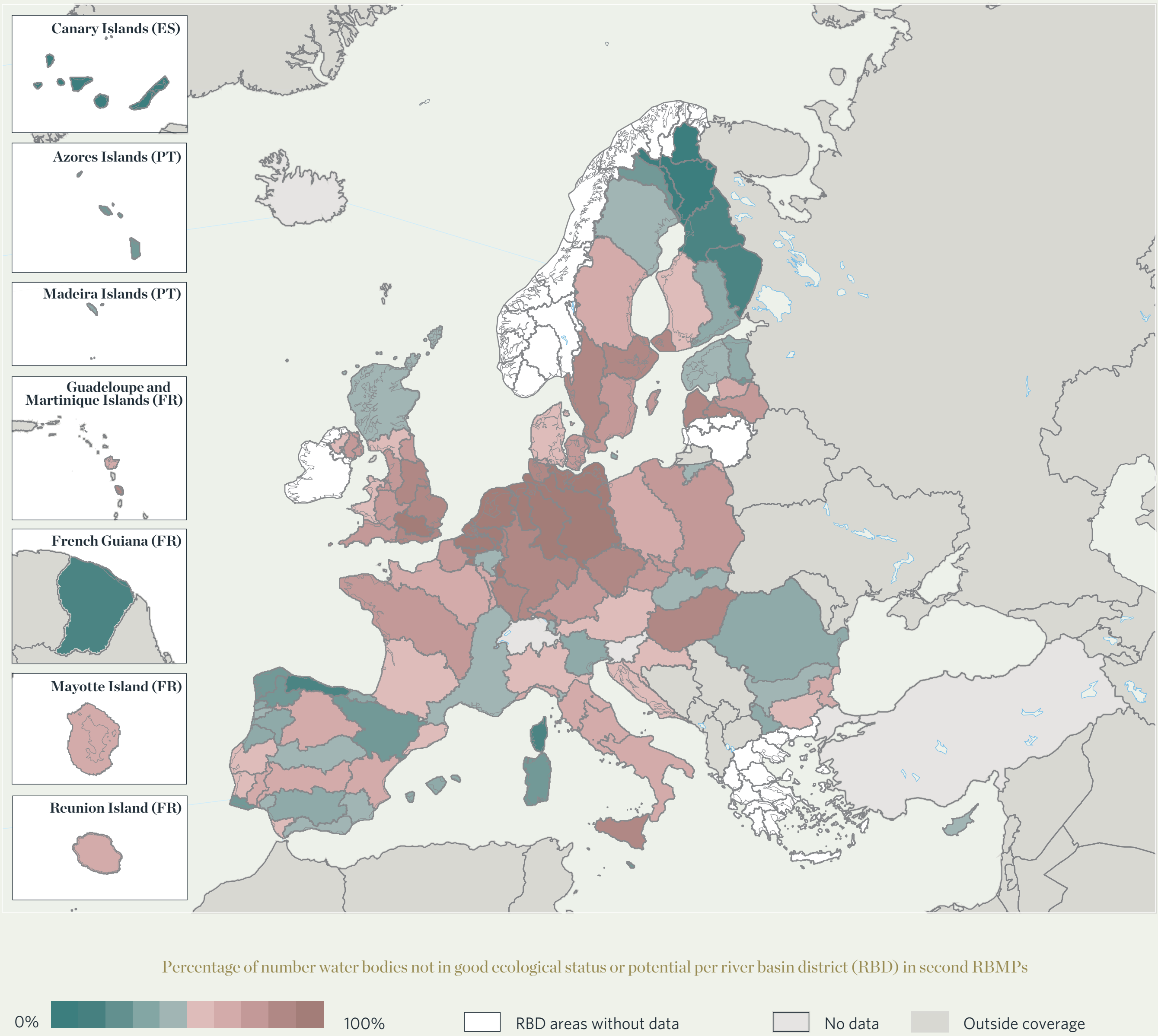
Diffuse emissions have many smaller sources spread over a large area. Diffuse pollution is due mostly to excessive emissions of nutrients (nitrogen and phosphorus), atmospheric deposition (mainly of mercury) and diffuse pollution from chemicals such as pesticides. Other drivers are rural dwellings (emissions from households that are not connected to sewerage systems) and run-off from urban areas and forested land (EEA 2018a).

Point sources refers to emissions that have a specific discharge location. The main driver of point source pollution pressures is urban waste-water treatment (when inadequately treated water is discharged back into watercourses), followed to a lesser degree by industrial plants and storm overflow (EEA, 2018a).

10 In order to make WFD implementation and monitoring operational, the concept of "water bodies" has been introduced as the key unit to which a number of the WFD requirements are related. A body of surface water means a discrete and significant element of surface water such as a lake, reservoir, stream, river or canal; part of a stream, river or canal; a transitional water; or a stretch of coastal water.

11 Good ecological status is the environmental objective of natural water bodies, while good ecological potential is the environmental objective for heavily modified and artificial water bodies. As per the WFD, heavily modified and artificial water bodies are those with substantial changes in their hydromorphology to serve specific uses, such as navigation, flood protection and hydropower generation.

Figure 3-1 *Percentage of water bodies in Europe's RBDs that are not in good ecological status or potential*



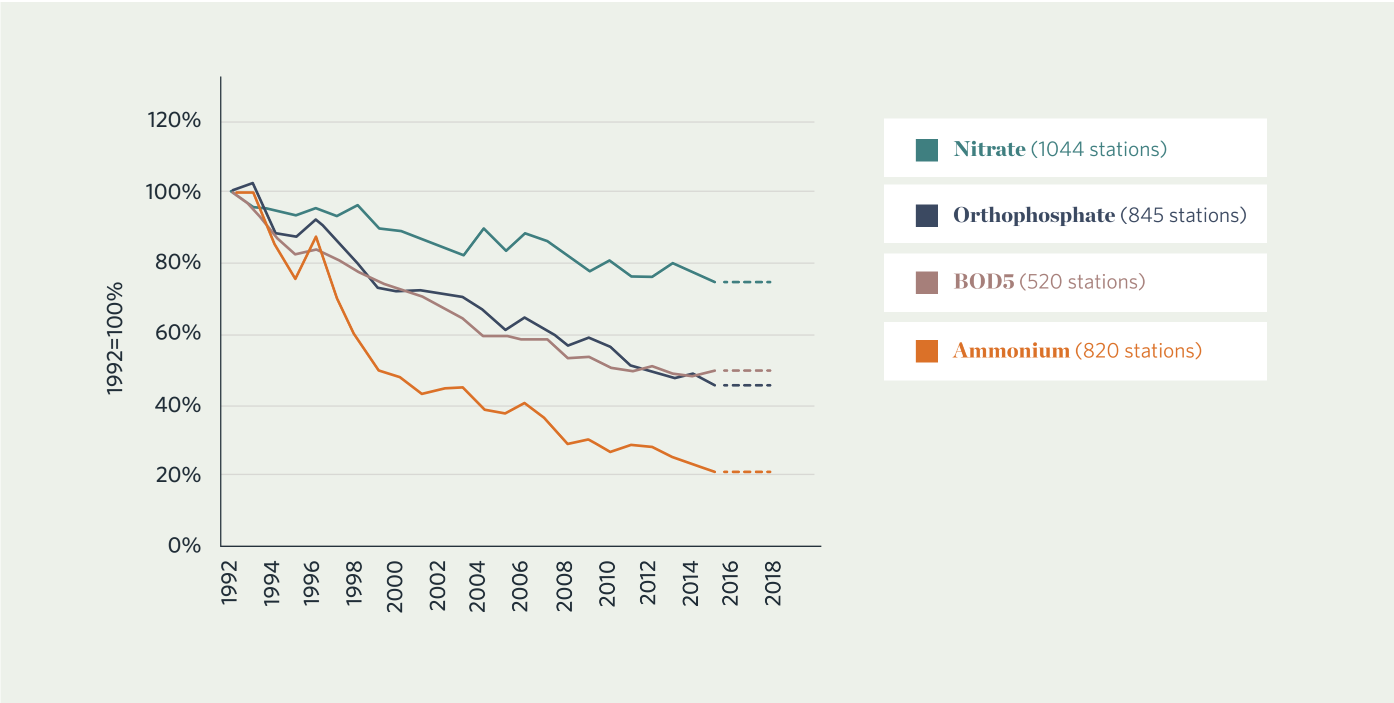
Source: *EEA, 2018a.*

The following sections describe the main challenges with surface water quality in Europe according to their relevance at European scale and the potential for NbS to tackle them.

3.1.1. Nutrients

Improved waste-water treatment (both urban and industrial) and reductions in the agricultural use of nitrogen and phosphorus have led to significant improvements in water quality in Europe in recent decades (EEA, 2018d). In European rivers and lakes, concentrations of pollutants associated with waste-water discharge (point sources), such as ammonium and oxygen consuming substances (measured BOD), have decreased markedly over the last 25 years as shown on Figure 3-2, because of general improvements in waste-water treatment (EEA, 2018a). The average orthophosphate concentration in European rivers has decreased markedly over the last two decades, reflecting both improvements in waste-water treatment and the reduction of phosphorus in detergents. However, in the same period total nitrate levels, which are closely related to diffuse pollution from agriculture, have declined only modestly, indicating that diffuse pollution from agriculture remains a significant challenge.

Figure 3-2 *Trends in European river water quality*



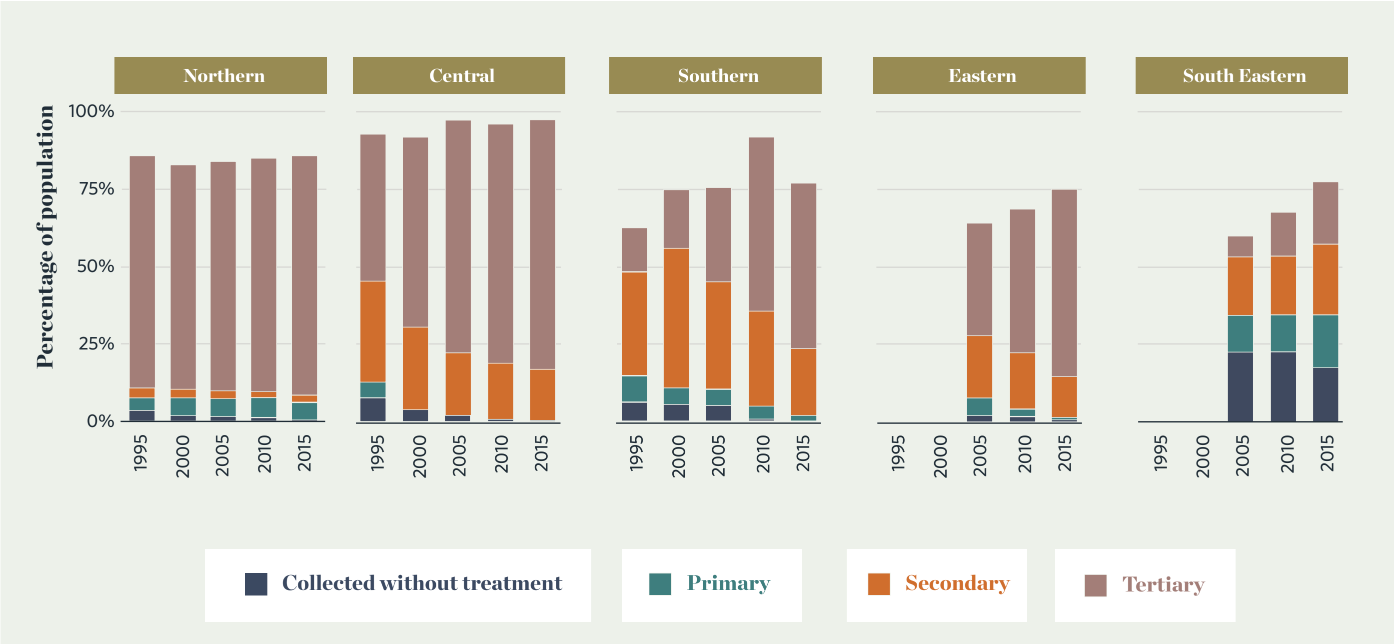
Source: *EEA data reported by countries to WISE-4 Water quality, 2016 (from Kristensen, 2018).*

Notes: Percentage changes refer to changes in substance levels compared to the 1992 level (100%). Orthophosphate is the main type of phosphorus that can be measured directly in water. BOD5 is the five-day biochemical oxygen demand.

The implementation of the Urban Waste Water Treatment Directive, together with national legislation, has led to significant improvements in waste-water treatment across much of the European continent. These positive trends are due to increased connection rates to sewers, improvements in wastewater treatment and a reduction in the use of polluting substances at source, such as lowering the phosphate content in household detergents (EEA, 2018a). Figure 3-3 shows the changes in urban waste-water treatment in Europe since 1995.

12 Biochemical oxygen demand (BOD) is the most widely used criteria for assessing water quality. It represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter in the presence of oxygen. BOD is used as an index of the degree of organic pollution in water.

Figure 3-3 *Changes in urban waste water treatment in Europe*



Source: *OECD/Eurostat, 2019*

Notes: Northern Europe: Norway, Sweden, Finland and Iceland. Central: Austria, Belgium, Denmark, Netherlands, Germany, Ireland, Switzerland, Luxembourg and United Kingdom. Southern: Cyprus, France, Greece, Italy, Malta, Portugal and Spain. Eastern: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. South Eastern: Bulgaria, Croatia, Romania and Turkey.

Collected waste water can be treated to different levels: Primary treatment temporarily separates heavy solids and liquid. Secondary treatment removes dissolved and suspended biological matter. Tertiary treatment is anything more than primary and secondary treatment to allow ejection into a highly sensitive or fragile ecosystem.

Despite decades of efforts and European and national policies to reduce nutrient emissions from both point and diffuse sources, nutrient enrichment of Europe's freshwaters is still a significant concern.

Diffuse pollution from agriculture, in particular, remains a major cause of poor water quality (EEA, 2015a). Overall levels of fertiliser use associated with intensive agriculture remain high, especially in some intensive agricultural areas such as the Netherlands, Belgium, Germany, France and Northern Italy. Large variations exist among Member States in terms of nitrogen and phosphorus surplus. Of great concern is the growing use of fertiliser in the last few years (EEA, 2018a) because of a slight growth in usage amongst Member States who most recently joined the EU. In 2007-2017, the highest increases in nitrogen consumption per hectare were reported for Bulgaria, Hungary, Romania and Latvia (EC, 2019a; Eurostat, 2019a).

In 2012, the EU countries with the highest nitrate concentrations in rivers were Luxembourg, the United Kingdom, Belgium and Denmark. Germany and Denmark also had the highest proportion of stations showing significantly decreasing trends from 1992 to 2012 (EEA, 2015a).

Big challenges remain to ensure compliance with the Nitrates Directive action programmes, with a particular focus on compliance with the limits on application rates for manures and fertilisers (EEA, 2015a). In spite of several tools used in Member States to reduce fertiliser inputs from agriculture, the European Commission has concluded that compliance will require further efforts to adapt measures to regional pressures (EC, 2018a).

With regard to point sources, despite high levels of compliance achieved in many countries with the Urban Waste Water Treatment Directive, some countries are still far from reaching full compliance, including Ireland, Italy, Spain and Portugal (EC, 2017).

Pressure from point source pollution on surface water quality is expected to decline due to further improvement in waste-water treatment, while projections on the extent of diffuse pollution from agriculture at EU level are difficult to make.

Concerning point source pollution, further surface water quality improvements are expected due to the expansion of urban waste-water treatment. The EU-28 Member States have reported detailed information about the ongoing and planned 11,500 projects to comply with the requirements of the UWWTD, based on data collected in 2014. Among them, at least 6,000 treatment plants are expected to be built or renovated, with a total capacity of about 94 million population equivalent (PE) (EC, 2017).

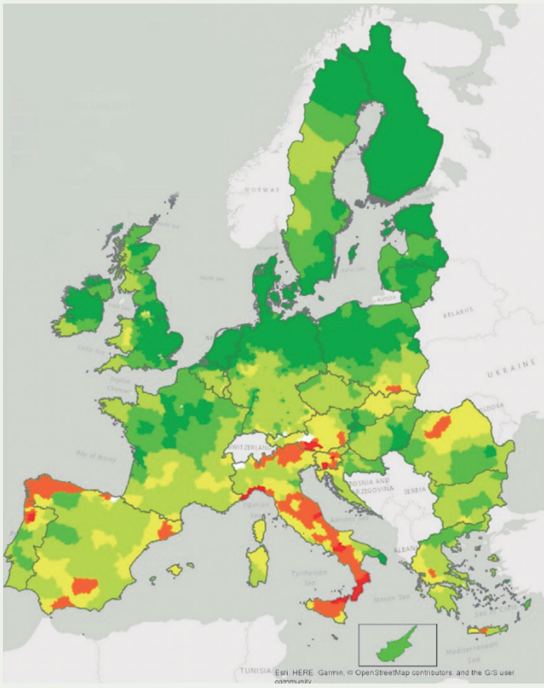
Concerning diffuse pollution from fertilisers, future trends in the development of the nitrogen balance for agricultural land will depend on a number of factors, including area of arable land, types of crops produced, biofuel production, livestock numbers, agricultural practices, technologies and types of management, markets and trade patterns, and food choices (Winiwarter, et al., 2011, cited by EEA, 2018e). While making overall predictions for the development of the nitrogen balance presents a challenge, it is noted that an increase in demand for nitrogen fertiliser is predicted for Europe up to 2020. Increases are expected for central and eastern Europe, whereas a decrease is anticipated for western Europe (FAO, 2017, cited by EEA, 2018e). An increase in fertiliser use may also be expected for Europe up to 2050 (Bruinsma, 2012, cited by EEA, 2018e). Nevertheless, this does not necessarily mean an increase in the surplus of nitrogen from agricultural land, as fertilisers may be applied more efficiently in the future.

When reporting on the Nitrates Directive, approximately 12 Member States predicted a decrease in nitrate concentration in surface and groundwater, partly due to changes in agricultural practices and agri-environmental measures. Remaining Member States came to no conclusion on a possible trend, did not report a forecast or indicated that a forecast would not be possible (EC, 2018, cited by EEA, 2018e).

3.1.2. Sediments

Land management activities can lead to soil erosion and increase fine sediment input into surface waters. Approximately 11.4 percent of the EU territory is estimated to be affected by a moderate to high level of soil erosion (more than five tonnes of sediment per hectare per year). Agricultural areas— including arable lands, permanent crops, grasslands and heterogeneous agriculture lands—cover 51 percent of the EU surface area and account for 69 percent of total soil losses (Eurostat, 2018).

Figure 3- 4 *Mean soil erosion rates at NUTS 3 level for arable lands (tonnes per hectare per year), 2012, EU-28*



Soil loss rates in arable lands

- Very Low (<1)
- Low (1-2)
- Moderate Low (2-5)
- Moderate
- Moderate High (10-20)
- High (>20)
- No arable lands

Source: *Joint Research Centre, European Commission, from Eurostat, 2018*

Impacts from elevated sediment export into surface waters range from damage to the health of aquatic ecosystems to poor quality water for abstraction in drinking water protected areas. Increased siltation can directly impact river habitats by clogging up the interstices on river beds, which prevents or reduces fish spawning and egg survival, especially for sensitive species such as salmon. Sediment can also transport contaminants in sediment particles, such as chemicals, nutrients and faecal indicator organisms (EA, 2015b).

Many land use activities can lead to soil erosion and sedimentation: harvesting timber, especially through clear felling; allowing livestock to have unrestricted access to rivers; late harvesting, causing soil compaction; or over-grazing in upland areas. Industry may cause associated problems: contamination of sediment (and transport of such contaminants) or colour problems through mining activities, industrial discharges (suspended solids from sewage treatment works), or atmospheric deposition of industrial pollution (EA, 2015b). The degradation of peatland—including through the use of open ditches for drainage—leads to organic carbon loss and water discolouration, which is impossible to reverse via water treatment. This issue is highlighted in three case studies in Annex A (see Case Study 1 – IUCN UK; Case Study 3 – Severn Trent; and Case Study 5 – United Utilities).

Sediment is one of the least defined pressures in the context of EU water legislation. Unlike nitrate concentrations, there is no in-river WFD sediment standard, and sediment pressures are assessed by linkages to biological element failures (EA, 2015b). Sediment run-off or in-river siltation is not routinely monitored across the EU, which further obscures the extent of the problem.

The few references to sediment in the WFD generally concern chemical quality, especially environmental quality standards for "materials in suspension" on the indicative list of main pollutants in Annex VIII (SedNet, 2009). However, the Environmental Quality Standards Directive, amended in 2013, does not consider pollutants within the sediments. The main focus across the majority of Member States is on water (that is, dissolved) contamination rather than on sediment-associated contamination (EC, 2019d).

Despite the lack of an EU-wide overview of the problem, soil erosion is included in the list of challenges that can give rise to possible actions in the WFD. The reporting of key measures under the WFD foresees the inclusion of key measures "to reduce sediment from soil erosion and surface run-off" to tackle diffuse pollution (e.g., from agriculture). In addition, sediment quantity is a crucial element of hydromorphological quality elements that are tracked under the WFD, such as river continuity and morphological conditions.

To date, most European countries do not have sediment management plans in place (Dworak & Kampa, 2019). Some major European river basins commissions have taken up the challenge to work towards transboundary sediment management plans as part of river basin management planning, such as the Rhine and Danube commissions (Brils, 2008). At a recent workshop[13] of European national experts, the consensus was that to better understand the role of sediment would require more targeted work. Experts need additional guidance on the management of sediment quantity and quality to support the delivery of WFD objectives (EC, 2019d).

Because the EU lacks overview data on sediment pressures on surface water, there are no European projections of how this challenge is likely to develop in the future. However, a recent IPBES report on land degradation showed that land degradation (partly caused by sediment run-off) is a significant problem worldwide, one that is likely to worsen unless adequate measures are adopted (IBPES, 2018).

13 Sediment management in support of achieving GEP. WFD CIS ECOSTAT Workshop, 1-2 April 2019, Dubrovnik

3.1.3. Chemicals

Europe-wide action to prevent some of the most hazardous chemicals from making their way into Europe's many surface waters—and to reduce existing levels—has been successful over the past decades (EEA, 2019a). Due in large part to EU rules on emissions controls since the first cycle of reporting of RBMPs, Member States have made progress in tackling priority substances and in significantly reducing the number of water bodies failing the standards for substances such as several priority metals (cadmium, lead and nickel) and pesticides (EEA, 2018c).

The chemical status of surface waters under the WFD is assessed against a relatively short list of historically important pollutants known as priority substances. In most Member States, a few priority substances account for poor chemical status; the most common are mercury and, to a lesser extent, pBDEs (brominated flame retardants) (see Box 3-1). If mercury and other so-called ubiquitous priority substances were omitted from the chemical status evaluation, only 3 percent of surface water bodies would fail to achieve good chemical status (see Figure 3-5) (EEA, 2018a).[14]

Box 3-1 *Mercury and pBDEs: Priority substances mainly responsible for poor chemical status in the EU*

MERCURY

Mercury can enter the environment from coal burning and industrial processes, the largest release being into the air from the energy sector. Mercury has also had many historical uses (e.g., thermometers, dental amalgam and hat making), which have since been phased out. The concentrations of mercury in water depend on geology, historical pollution in sediments, concentrations in precipitation and industrial emissions. Mercury can enter surface waters through direct emissions, such as from UWWTPs and industry. It is readily released as a vapour, so it can be widely distributed through atmospheric deposition in dust and rain. The Environmental Quality Standard (EQS) for mercury is defined to protect predators such as sea eagles or otters from secondary poisoning through eating contaminated fish. In particular, it protects against methyl mercury, which accumulates in the food chain. Fish consumption can be an important source of mercury to humans, when fish plays a significant role in the diet (EEA, 2018c). Chronic exposure to methyl mercury can adversely affect children's development, particularly in the womb.

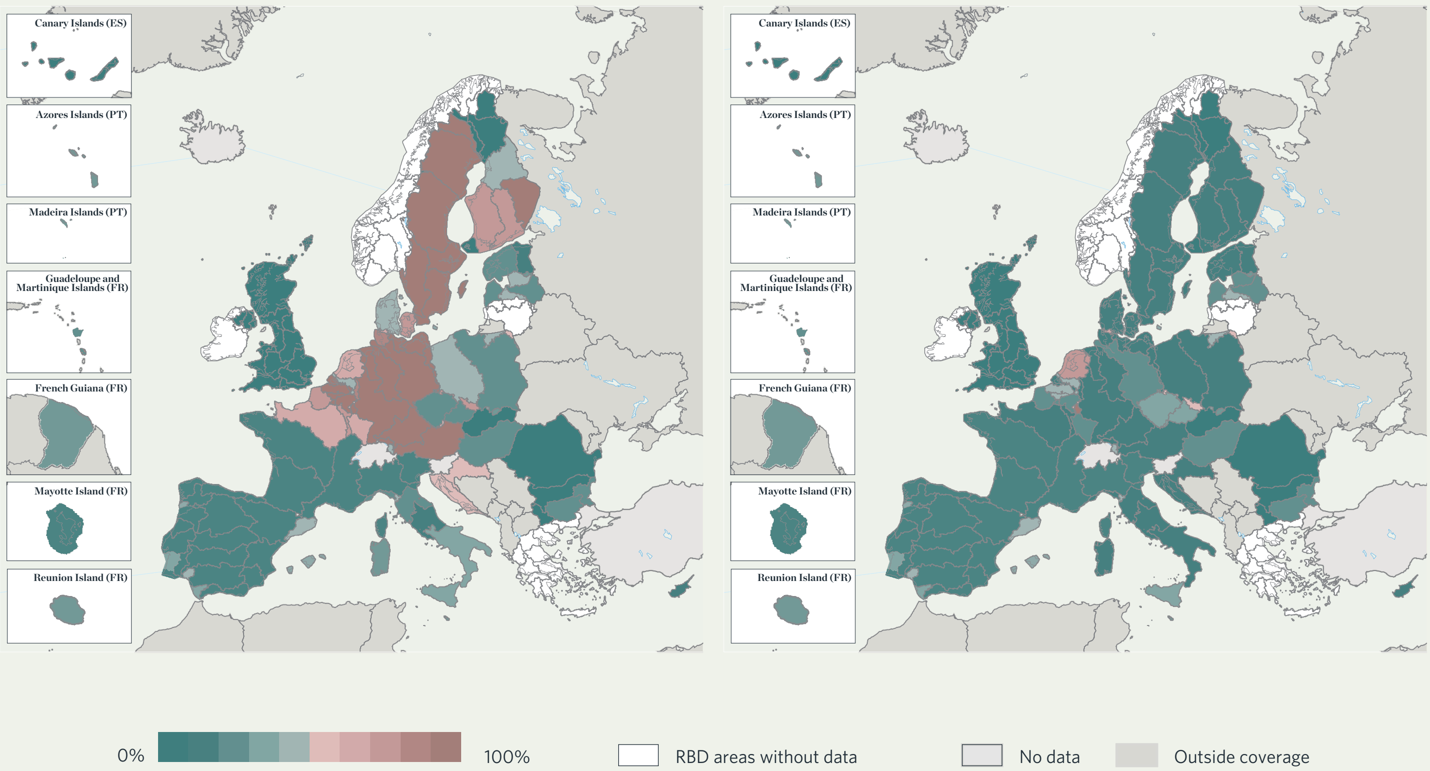
BROMINATED DIPHENYL ETHERS

Brominated diphenyl ethers (pBDE) are used in many household goods—from cushions to computers—to prevent the spread of fires. Treated items shed particles that mix into household dust, and most of this is thought to reach the environment through drainage from washing machines to sewers, or by mixing with rainfall.

Source: *EEA, 2018a*

14 The ubiquitous priority substances (uPBTs) are mercury, pBDEs (polybrominated diphenyl ethers), tributyltin and certain PAHs (atmospheric pollutants with multiple sources, resulting from the burning of organic matter).

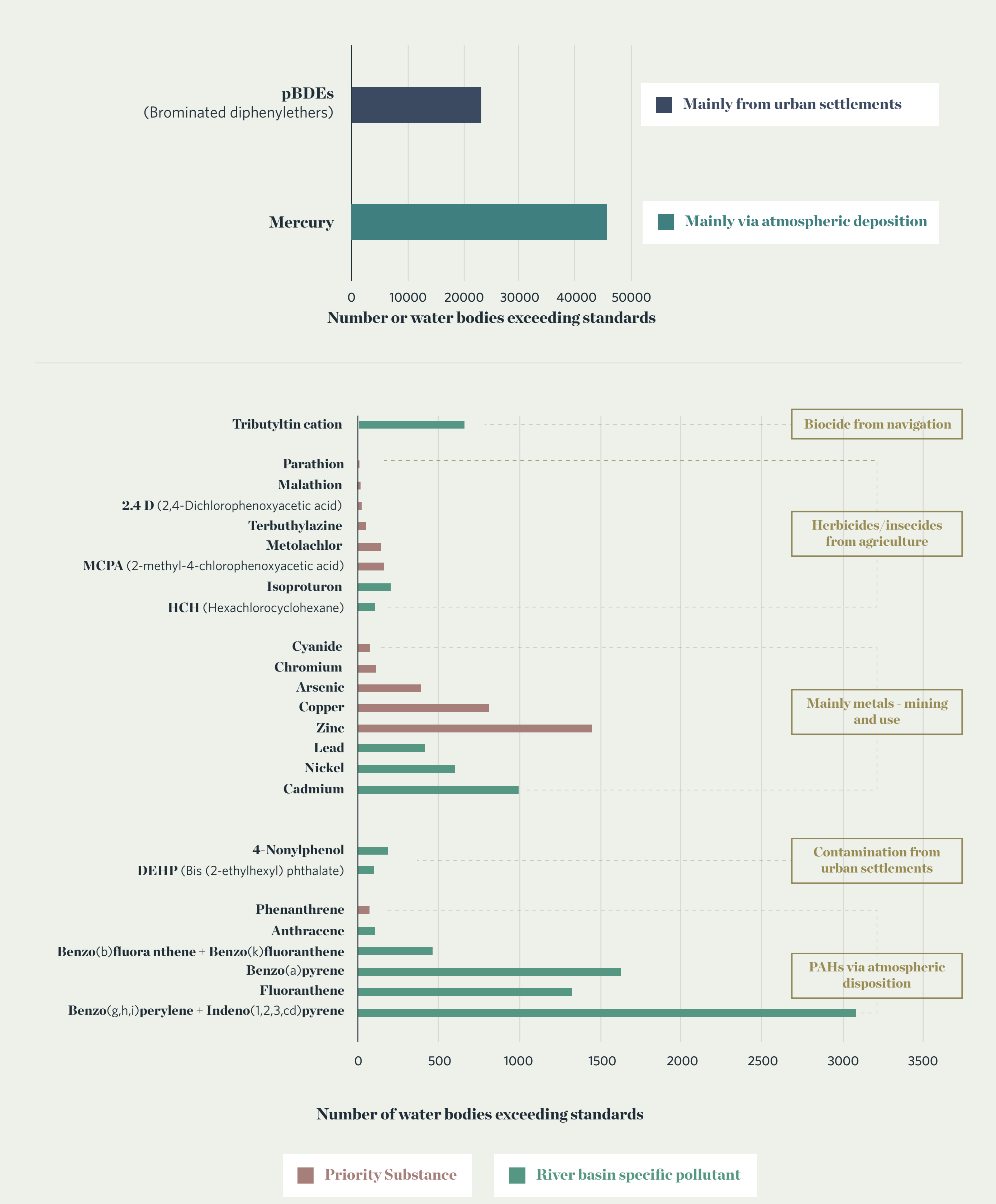
Figure 3-5 *Percentage of water bodies in Europe's RBDs that are not in good chemical status, with uPBTs (left map) and without uPBTs (right map)*



Source: *EEA, 2018a*

The main pressures leading to failure to achieve good chemical status are atmospheric deposition and discharges from urban waste-water treatment plants. Atmospheric deposition leads to contamination with mercury in over 45,000 water bodies failing good chemical status. Inputs from urban waste-water treatment plants lead to contamination of over 13,000 water bodies with polyaromatic hydrocarbons (PAHs), mercury, cadmium, lead and nickel (EEA, 2018a) (see Figure 3-6).

Figure 3-6 *Pollutants most frequently exceeding environmental quality standards (EQS) in surface water bodies in the EUW*



Source: *Numerical information from EEA (2018c)*

Notes: Graphs based on 25 Member States that reported under the WFD by February 2018 (total of 111,105 water bodies). Under the WFD, EU-wide standards apply for priority substances, while national or river basin standards apply for RBSPs.

Of the thousands of chemicals in daily use, relatively few are tracked and reported under the WFD.

Even though some key issues with the most hazardous chemicals have been and continue to be addressed, there are major concerns with emerging pollutants and other chemicals entering water that can significantly affect surface water quality.[15] Challenges remain especially with regard to many harmful chemicals that have not been prioritised for monitoring under the WFD (EEA, 2019a). Of the thousands of chemicals in daily use, relatively few are tracked and reported under the WFD. There is a gap in knowledge at the European level over whether any of these other substances presents a significant risk to the aquatic environment, either individually or in combination with other substances.

In addition, information on the sources and emissions of many pollutants remains incomplete, limiting the ability to identify and target appropriate measures (EEA, 2018a). For instance, most pesticides are not regulated under the WFD and are therefore not reported at the EU level. Whole classes of pesticides—fungicides and bactericides—are omitted (EEA, 2018c). However, there are specific EU provisions for pesticides in drinking water. [16] In England, pesticides are the biggest reason surface drinking water protected areas are rated "at risk" of not meeting their objectives (for 122 out of total 486 drinking water areas); metaldehyde, found in molluscicide used in farming, is the primary cause of exceedances (EA, 2015a).

Metaldehyde is a highly soluble, organic compound commonly used in pellets against slugs and snails.[17] Although believed to be harmless to humans at the levels currently detected, it is very difficult to remove at water treatment works and meeting the EU targets is not possible using conventional water treatment technology (Castle et al., 2017). More information on this topic is provided in Annex A, where two case studies present examples of programmes that tackle these issues. The water company Severn Trent in England has been engaging with farmers to address water pollution from metaldehyde as 11 catchments in its service area were affected by this issue. Severn Trent has engaged with over 2,000 farms and makes payments of up to £8 per hectare to help farmers switch from metaldehyde to ferric phosphate (see Case Study 3 – Severn Trent). Anglian Water launched the "Slug it Out" campaign in 2015 with the aim of reducing metaldehyde levels at source. To encourage farmers to change their practices, "Slug it Out" pays them the cost difference between metaldehyde and the ferric phosphate alternative (see Case Study 4 – Anglian Water).

Looking forward, we expect improvements in the chemical status of EU surface waters due to the continued implementation of the WFD and the UWWTD. At the same time, concentrations of certain chemical pollutants may also increase due to demographic changes and the impact of climate change on agricultural production systems.

Since 2015, stricter standards for some priority substances have been coming into force, and new substances will be added to the reported priority substances list for the third RBMP (EEA, 2018a). Directive 2013/39/EU (amending the EQSs Directive) identified 12 additional priority substances with associated environmental quality standards (EQSs). The directive also updated the EQSs for seven of the existing priority substances in line with the latest scientific and technical knowledge concerning their properties. Good status should be reached by 2021 for the seven substances with updated standards, and by 2027 for the 12 new substances.

Concentrations of certain chemical pollutants, including emerging pollutants, are expected to increase in the future. For instance, environmental concentrations of pharmaceuticals are likely to increase as the population ages and grows (EC, 2019a).

Climate change also has a likely role in future surface water quality. For example, it is likely to extend the seasonal activity of pests and diseases and the risks associated with these effects (EEA, 2019b). As a result, this may lead to an increase in the spraying of pesticides.

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15 In addition to chemical compounds that generate well-established risks to living organisms, experts have insufficient knowledge of the risks posed by an array of other emerging pollutants. Among those pollutants are several pharmaceutical substances such as certain painkillers, antimicrobials, antidepressants, contraceptives and antiparasitics that are commonly found in surface and groundwaters, soils and animal tissues. Traces of some pharmaceuticals have also been found in drinking water (EC, 2019a). To address such emerging pollutants, the 2013 amendment of the Environmental Quality Standards Directive foresees a Watch List of a limited number of such substances which would be monitored across the EU for up to four years. The current Watch List includes eight substances or groups of substances, mainly synthetic and natural hormones, antibiotics and other pharmaceutical substances and pesticides (JRC, 2018).

16 The Drinking Water Directive sets a concentration limit of 0.1µg/l for individual pesticides, and of 0.5µg/l for the total sum of pesticides.

17 The maximum concentration stipulated by the European Union's Drinking Water Directive (DWD) for metaldehyde is 0.1 microgram per litre (or parts per billion) in treated water. This is the equivalent of one drop in an Olympic-sized swimming pool.

3.2. What role can NbS play to alleviate surface water quality challenges?

There is evidence that NbS can play a significant role to address surface water quality challenges, particularly those relative to excessive nutrient and sediment loads in surface water. By contrast, there is a lack of available knowledge on the potential of such measures to reduce concentrations of chemical substances that lead to failure of good chemical status of EU surface waters. Conventional approaches to dealing with poor surface water quality in Europe include investing in wastewater treatment, reducing pollution at source (by lowering the phosphate content in detergents and phasing out particularly harmful chemicals) and adopting targeted measures under the Nitrates Directive to reduce the use of mineral fertiliser and manure in agriculture (e.g., general binding rules, taxes, manure surplus management). In addition to these strategies, Member States have also been using NbS-WS to address issues of poor surface water quality. Several Member States are supporting investments in targeted green infrastructure that can impact surface water quality, such as constructed wetlands and run-off ponds that capture and retain nutrients and reduce losses through agricultural drainage. River restoration and less intensive land uses, such as afforestation, are also increasingly recognised as effective means to tackle diffuse pollution pressures, as they increase nutrient retention and recycling (EEA, 2018a).

Effective NbS to address surface water quality challenges are presented in more detail below.

Riparian buffers (vegetated and woodland) in and around cropped fields and alongside watercourses are amongst the most well studied and frequently used mitigation measures to reduce sediment and phosphorus losses to surface waters via surface runoff (Kronvang, et al., 2015a). In Europe, riparian buffers are commonly used in response to the Nitrates Directive's requirement to reduce diffuse pollution. (EC, 2012b). Existing research supports their role to reduce sediment and especially particulate-bound phosphorus. However, existing studies show that their efficacy for reducing dissolved phosphorus and nitrogen is more variable (Kronvang, et al., 2015a). Nutrient removal efficiency depends on the width of buffer strips, with retention rates for sediment and total phosphorus being as high as 98-99% for a width of 30 metres. Efficiency and lifetime of buffer strips can be improved when the width is adjusted according to local conditions (Kronvang, et al., 2015b).

Restoring or conserving wetlands and wet woodlands help remove nitrogen, phosphorus and pesticides as well as reduce sediment erosion and delivery before entering water bodies (EC, 2012c). The retention of nutrients (nitrogen and phosphorus)[18] depends on the wetland's size, location and the vegetation it contains (NWRM, 2015c).

18 Dissolved phosphorus is the phosphorus that remains in water after the water has been filtered to remove particulate matter. Phosphorus attached to the particulate matter that remains on the filter is called particulate phosphorus. Together these two forms of phosphorus make up the total phosphorus concentration in a water sample.

As an example, in a Swedish catchment (Tullstorpsån), the average concentrations of phosphorus decreased by 30 percent thanks to wetland restoration (NWRM, 2015c).

Artificial (constructed) wetlands can function as biological wastewater treatment "technologies", either as a supplement or a substitute to conventional treatment plants. While wetlands restoration aims to renew their natural functions, wetlands can be created artificially to support the improvement of surface water quality. Constructed wetlands can also be used to reduce flow velocity, remove nutrients and sediments and mitigate surface water runoff from agricultural and livestock fields (UNEP, 2014). Their effectiveness as a solution to surface water quality problems is illustrated in several case studies in Annex A (see Case studies 3 – Severn Trent; 4 – Anglian water 6 – Wessex Water, 13 – Barcelona; 17 – Glasgow and Clyde valley, Scotland). Recent findings also show that constructed wetlands show high potential for treatment of pharmaceuticals; however, relevant research is still limited and requires further work (Li, et al., 2014).

Run-off ponds can be used to capture nutrients before they enter surface water. Detention basins and ponds are water bodies storing surface run-off. A detention basin is free from water in dry weather flow conditions, whereas a pond (e.g. retention ponds, flood storage reservoirs, shallow impoundments) contains water during dry weather and is designed to hold more water when it rains. Detention basins and ponds can be effective at pollutant removal (e.g. suspended solids, nitrogen, phosphorus, metals), as a result of settling of particulate pollutants and uptake by vegetation (NWRM project, 2015a). Case 8 on Eau du Grand Lyon in Annex A describes the use of artificial ponds (pollution barrier) along with other NbS to protect water resources (see Case study 8 – Eau du Grand Lyon)

Less intensive land uses, such as afforestation, are increasingly recognised by EU MS as effective means to reduce diffuse pollution. Afforestation is the process of establishing forests in areas that have not been forested before, while reforestation is the restoration of forests in areas where forests were removed or destroyed. Woodland creation is taking place across Europe on grassland and, less frequently, on former arable land in order to deliver multiple benefits (Bastrup-Birk and Gundersen, 2004; Hyytiäinen, et al, 2008). The conversion of managed grassland and arable land to forests reduces the level of nutrient inputs from fertilisers and organic amendments and increases the net capturing of nitrogen from the ground via tree nutrient uptake and removal in harvested biomass, thereby decreasing nutrient leaching to groundwater and surface water (BioIntelligence, 2006; Rosenqvist, 2007).

Improved agricultural practices can also reduce pollution from agriculture. Examples of improved agricultural practices to tackle nutrient pollution include using farm-level nutrient planning (e.g. on timing of application), using conservation tillage, using nitrogen-fixing catch crops (grown in the period between two main crops in order to retain nutrients in the root zone) and cover crops (grown to protect the soil against erosion and minimise the risk of surface runoff by improving the infiltration) and using crop rotation. Other measures include livestock management through improved feeding (reduced phosphate compounds, which are mainly used in the poultry and swine sectors), reduced grazing, as well as optimised manure management (increased manure storage, reduced use) and manure surplus management. Manure storage, in particular, can improve the timing of application to minimise the risk of excessive leaching into the water environment (EEA, 2018a).

Ample evidence exists on the effects of improved agricultural practices on surface water quality, such as:

- For catch crops, an average reduction in nitrogen-leaching of 48 percent and a range of zero to 98 percent has been identified. Cover crops have been very successful at reducing sediment losses; studies report 7 to 87 percent, with an average reduction of 52 percent (Stevens and Quinton, 2009). According to a Finnish study, plant cover in winter can reduce erosion by 10 to 40 percent and reduce nitrate leaching by 10 to 70 percent (Helsinki Commission, 2007).

- The EU project ENDURE considered agronomic and technological tools for reducing pesticide use. One of the project results suggests a pesticide reduction potential for changed crop rotations ranging from 6 to 25 percent (Ferguson & Evans, 2010).

- Conservation and management measures (reduced tillage, management of plant residues and winter crops, contouring, stone walls, grass margins) have also had a significant impact on reducing soil loss (9.5 percent on average) in the EU during the last decade (Eurostat, 2018).

Several case studies in Annex A show how improved agricultural practices are improving surface water quality across Europe. See Case Study 2 – South West Water; Case Study 3 – Severn Trent; Case Study 4 – Anglian Water; Case Study 9 – Eau de Paris; Case Study 10 – Augsburg; and Case Study 11 – Vittel).

A switch to organic farming can also have significant benefits in terms of water quality. In the EU, the positive contribution of organic farming to meeting key EU environmental objectives of the WFD and Nitrates Directives is recognised in the Action Plan for the future of Organic Production in the European Union (EC, 2014). Sustainable water management is a fundamental part of organic production, ranging from the use of agronomic practices such as crop rotation, use of green manure, and catch and cover crops. Organic farming also protects water by significantly reducing synthetic pesticide and fertiliser use (IFOAM

EU, 2019). Organic farming has developed rapidly during the past fifteen years; the area cultivated using organic farming practices more than doubled in EU-28 between 2002 and 2015 (EC, 2016a). Despite such a substantial increase, the whole area dedicated to organic farming represents only 6.2 percent of the total used agricultural area in Europe (EC, 2016a).

Most of the land farmed organically (78 percent) and most organic farms (81 percent) are situated in EU Member States that joined the EU before 2004, where national and European legislation had helped stimulate the development of this sector early on. Countries that joined the EU since 2004 are rapidly expanding the organic sector as well; for example, the sector has developed extremely fast in terms of Utilised Agricultural Area (UAA) in the Czech Republic, Estonia, Latvia, Slovenia and Slovakia. With an organic sector share of about 19 percent of total land under cultivation in 2015, Austria led Member States, followed by Sweden, Estonia, Czech Republic and Latvia (EC, 2016a). Two examples of investment supporting organic farming can be found in Annex A (Case Study 9 – Eau de Paris and Case Study 10 – swa Augsburg). Eau de Paris, provider of water services to the French capital, has begun an initiative to protect its critical water resources in a sustainable manner over the long term. The initiative includes selective land acquisition as well as financial support and technical assistance to farmers. Since 2008, the water provider has provided financial assistance programs to help farmers reduce fertiliser and pesticide use and adopt organic farming practices.

In addition to water quality improvements, other significant benefits can be gained from investing in NbS to address surface water quality challenges. These include reducing the costs of treating waste water and drinking water. For example, the Exmoor Mires project of peatland restoration (part of a wider Upstream Thinking programme of the water company South West Water, UK) indicated that reduced silt level in water due to peatland restoration could reduce treatment costs for drinking water by 20 percent (NWRM project, 2015b). Lessons learned from the catchment management scheme Upstream Thinking are illustrated in Annex A (see Case Study 2 – South West Water).

Other benefits from NbS include greater biodiversity and habitat diversity, landscape diversity, increases in the recreational values of areas where NbS are implemented, water storage, contribution to more natural flood control, carbon sequestration and improved soil structures.

4. Improving Groundwater Quality

Groundwater is a strategic resource in the European Union and is the primary source of drinking water in EU Member States. Around one quarter of all water abstracted annually in Europe and half of all drinking water comes from groundwater sources in Europe. Groundwater quality is a critical issue across Europe, as it is often used untreated, particularly when extracted from private wells.

In the EU, groundwater quality is affected mainly by diffuse pollution, primarily from agricultural sources including nitrates in fertiliser or manure and pesticides. Nitrates are particularly challenging due to their potential impact on human health.

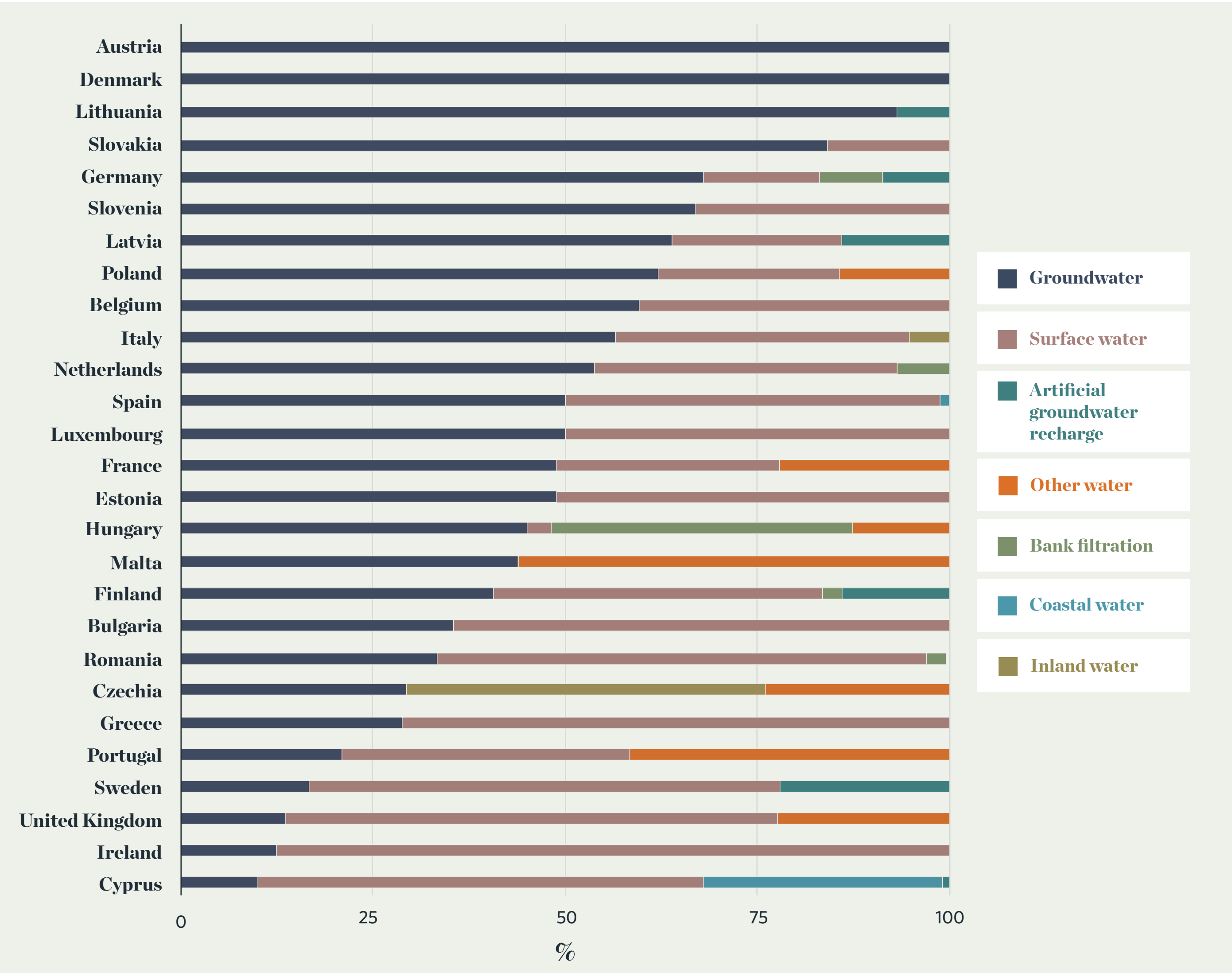
NbS can play a leading role in protecting groundwater quality, particularly from nitrate pollution. A wide array of NbS can be deployed to address groundwater quality, ranging from improved agricultural practices to land-use changes. Options available in a particular region are strongly contingent on local crops, the structure of the region's agriculture, weather conditions and other factors. Options have to be tried and tested in the region, and farmers need to be convinced of their benefits. Successful uptake of these NbS requires long-term involvement, combined with dedicated advisory services.

4.1. What are key challenges in Europe?

Availability of enough good quality groundwater is of vital importance to our social and economic well-being. Groundwater is fundamental for the health of some aquatic ecosystems (e.g., wetlands, lakes, springs) as well as some terrestrial ones (woodlands, riparian forests). It is key for water storage and retention as well as sub-surface stability. Section 4 focuses on challenges relative to groundwater quality. Section 6 examines groundwater quantity challenges alongside other problems related to droughts.

Around 23.6 percent of all water abstracted annually in Europe comes from groundwater sources (EEA, 2010). Groundwater is particularly important for drinking water supply, as it is the source of 50 percent of drinking water in EU Member States, compared to 36 percent coming from surface water (EC, 2016b) and the rest from desalination, bank filtration or other forms. The extent to which Member States depend on groundwater for their drinking water supply varies as shown in Figure 4-1.

Figure 4-1 *Sources for drinking water in Member States 2011 to 2013*



Source: *European Commission, 2016*

Groundwater is essential for agriculture as well. In southern Europe, for example, it represents more than 33 percent of the water used for irrigation (EASAC, 2010).

Groundwater chemical quality in the EU is affected mainly by diffuse pollution from agricultural sources, which originate from the application of fertilisers, manure and pesticides. Nitrates are the predominant groundwater pollutant in the EU (EEA, 2018a) and pose a direct hazard to human health when consumed from contaminated drinking water.[19] Nitrogen pollution can also occur in areas where there is no sewerage system. In addition, pesticides are important pollutants found in groundwater, but limited information is available on pesticide contamination, and reliable and comparable data on the types of pollutants and their concentrations is lacking.

Once pollutants have made their way into groundwater resources, recovery can take years or even many decades. The time to recovery depends on many factors, such as the nature of the hydrogeological conditions, the rate of groundwater recharge and the properties of the pollutant (EEA, 2018a). Current groundwater quality often reflects conditions of years or decades ago. Similarly, present-day pollution may not be relevant for several years or even decades. Removal of nitrates (also referred to as denitrification) occurs naturally both in soil and groundwater bodies under certain chemical conditions. If the sediments through which the groundwater flows have sufficient amount of organic carbon or pyrites, microbes break down nitrate molecules to their component elements, nitrogen and oxygen. This can create low levels of nitrate in groundwater wells. However, this process can happen only whilst organic carbon or pyrites are available: once these are used up, denitrification can no longer occur, and groundwater bodies may become unusable as, for example, a source of drinking water.

The EU Drinking Water Directive sets a maximum allowable concentration for nitrate of 50 milligrams per litre. The Nitrates Directive requires Member States to identify groundwaters that contain more than 50 milligrams per litre of nitrate—or could contain if preventive measures are not taken. Removing nitrates from groundwater at the level of water treatment plants is complex and expensive. For example, in Germany, where groundwater accounts for 61 percent of drinking water, the quality of many groundwater resources is now so poor that it is difficult to use for water production or has even been banned as a water source (DVGW, 2019).

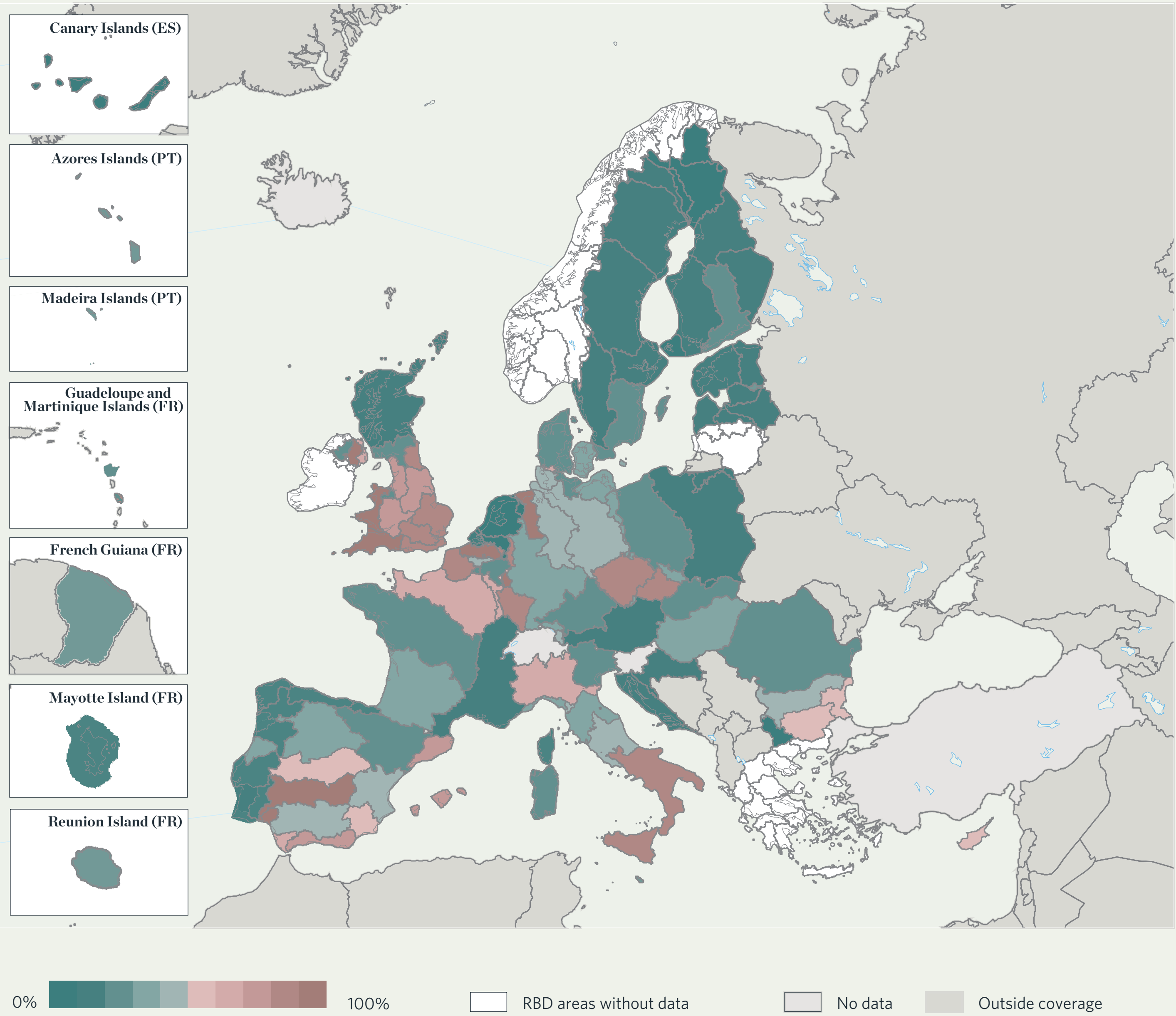
Industrial sites, waste sites and old mines can contribute contamination from organic pollutants and metals such as arsenic, lead and copper. Contaminating substances may also be of natural origin—for example, when the bedrock contains high concentrations of metals and salts such as sulphates and fluorides. In coastal areas, saltwater may intrude into the groundwater aquifers from which freshwater is abstracted, causing salinisation and rendering the aquifers unusable as a drinking water supply (EEA, 2018a).

In view of these challenges, the concept of groundwater protection has been fully integrated into the basic measures of the Water Framework Directive. The WFD established the objective of reaching good groundwater chemical status across Europe. The requirements of the WFD are complemented by those of the Groundwater Directive (GWD) adopted in 2006. The two directives work in conjunction and in a complementary way to other EU legislation, such as the Drinking Water Directive and the Nitrates Directive. The GWD provides EU-wide groundwater quality standards for nitrates and pesticides (individual and total) and requests Member States to establish further national groundwater quality standards (referred to as threshold values) for all substances causing risk of failure to meet good chemical status objectives (EC, 2019a).

In spite of the strong policy elements within EU directives, protecting groundwater quality remains a major challenge in Europe. The latest assessment of WFD implementation found that 74 percent of EU groundwater bodies (by area) are in good chemical status, 25 percent are in poor chemical status, and 1 percent are of unknown status (Figure 4-2). The highest percentage of groundwater bodies not in good chemical status are found in England and Wales, parts of Germany, France, Spain and Italy. Nitrates and pesticides from agriculture have been confirmed as the main pressures causing failure to achieve good chemical status in groundwater in the latest WFD RBMPs (EEA, 2018a).

19 Their presence in groundwater is problematic as nitrates can be converted into nitrosamines in the human body. This can result in disruption to the oxygen transport in infants (methemoglobinemia) (Umweltbundesamt, 2019).

Figure 4-2- *River basin groundwater chemical status*



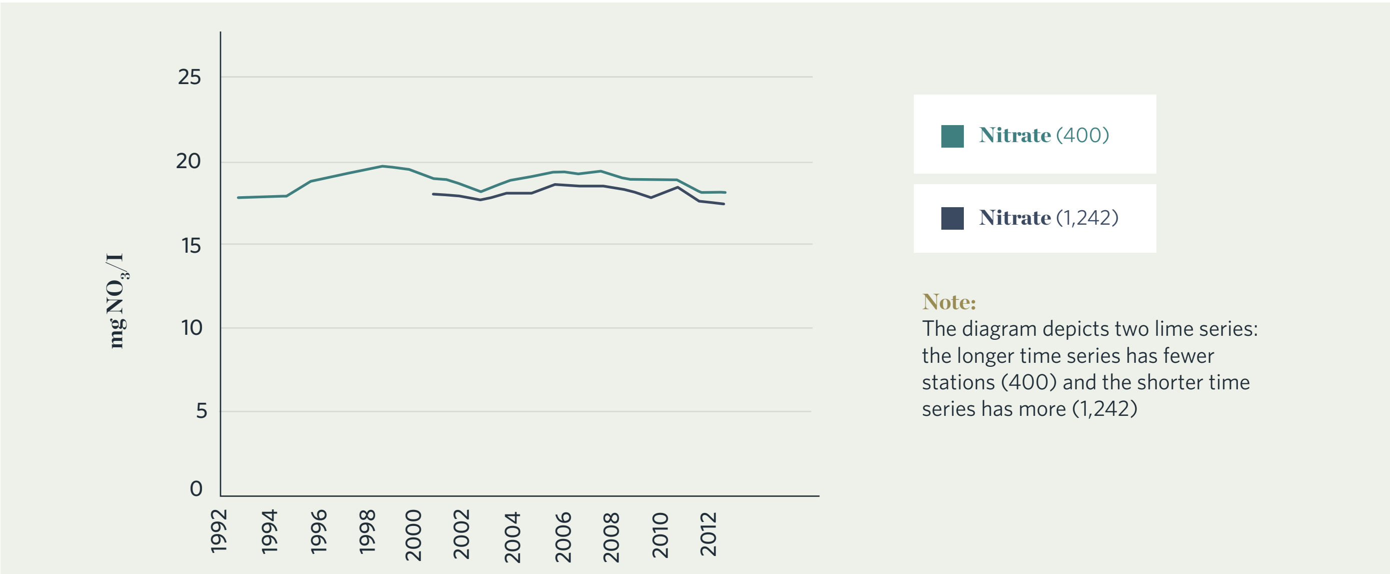
Source: *EEA, 2018a.*

Groundwater chemical status improved only slightly between the first reporting cycle for RBMPs in 2009 and the second in 2015. According to the RBMPs, not much improvement is expected before 2027 for most of the groundwater bodies, due to the long time lag between the implementation of measures and their effectiveness on groundwater quality (EC, 2019a). The following sub-sections discuss in more detail the impact of different polluting substances.

4.1.1. Nitrates

Excessive nitrate concentrations affect over 18 percent of the area of groundwater bodies in Europe. Nitrates in groundwater are attributable primarily to agricultural sources (EEA, 2018a). Average nitrate concentration levels in groundwater bodies have slowly declined in the last few years, after a worrying increase in the early 1990s. By 2011, they had almost returned to their 1992 levels, as shown on Figure 4-3. The decline in nitrate concentration reflects measures to reduce agricultural emissions of nitrates, as well as improvements in waste-water treatment. Measures under the Nitrates Directive have resulted in a reduction in the use of mineral fertiliser, and nutrient surpluses of agricultural origin have progressively decreased in the EU. Between 2000 and 2013, agricultural nitrogen surplus fell by 7 percent, while phosphorus surplus decreased by 50 percent (EEA, 2018a).

Figure 4-3 *Trend in groundwater nitrates*



Source: *EEA, 2018a.*

National averages for nitrate concentrations in groundwater are all well below the Nitrates Directive and Drinking Water Directive limit of 50 milligrams per litre. National aggregation, however, masks considerable variation among groundwater monitoring stations, with approximately 13 percent of the stations across Europe exceeding the limit in 2009.[20] The highest proportion of failure to meet the EU threshold level was observed in Belgium, Denmark, Spain and Cyprus (Eurostat, 2012).

Overall, the lack of coordinated action towards the reduction of diffuse sources of nutrient pollution is hampering progress towards improving the quality of groundwaters in Europe. As noted in section 3.1, significant challenges still remain to ensure compliance with the Nitrates Directive action programmes, particularly with the limits on application rates for manures and fertilisers (EEA, 2015a).

The implementation of groundwater-related environmental legislation in the EU shows results that can best be described as a mixed bag. Mmber States that have been ambitious in terms of applying the Nitrates Directive have seen success. For example, Denmark started adopting legislation on nitrates before the Nitrates Directive came into force in 1991. The country has seen impressive improvements in groundwater nitrates levels since the 1980s. However, other Member States have been less ambitious. The European Commission is taking legal action against some Member States for failing to protect their water against pollution linked to nitrates from agriculture. In many regions in the EU, nitrate levels in groundwater have remained the same. In some areas with intensive agriculture, these levels are even increasing.

Furthermore, the comparatively long residence time of groundwater can delay recovery for years to decades, between applying nutrient control measures and observing measurable improvements in water quality (EEA, 2018a).

20 Their presence in groundwater is problematic as nitrates can be converted into nitrosamines in the human body. This can result in disruption to the oxygen transport in infants (methemoglobinemia) (Umweltbundesamt, 2019).

4.1.2. Pesticides

Pesticides are another major source of groundwater pollution, causing poor chemical status in 6.5 percent of groundwater bodies (by area) (EEA, 2018a). Several countries in Europe report that groundwater has concentrations of pesticides that exceed the quality standards. About 7 percent of the groundwater stations used in an assessment by Eurostat (2013) reported excessive levels for one or more pesticides. Atrazine, which has been severely restricted for plant protection in the European Union since 2004, and its metabolite desethylatrazine are the pesticides most frequently detected above the quality standard throughout Europe (Eurostat, 2013)—illustrating the long lag between the time a product is restricted and when it effectively degrades in the environment.

Monitoring of pesticides in groundwater is a considerable challenge. Even though groundwater is used as a drinking water source, there is limited information available on pesticide contamination and a lack of reliable and comparable data (Eurostat, 2013). Although nitrates (NO3-) and their associated nitrogen compounds—nitrite (NO2), ammonia (NH3) and ammonium (NH4+)—are comparatively easy to measure in water samples, pesticides and their metabolites are extremely numerous and can be complicated and costly to test for. Sampling needs to be performed during periods of application and use, and under various weather conditions. Due to the complexity of monitoring pesticide contamination, it is possible that this problem is underreported. Extensive data sets of high quality are often missing (Eurostat, 2013).

Groundwater aquifers at risk are located in areas used intensively for agriculture, the greatest contributor to pesticides found in European groundwaters. As agricultural production has become increasingly intensive, higher inputs of fertilisers and pesticides lead to the emission of large amounts of pollutant loads into the water environment (EEA 2018a). Further intensification of agriculture down the road could lead to increased groundwater pollution from pesticides. For groundwater bodies to achieve good status, Member States will need to address agricultural pressures while maximising the beneficial effects of good land management (EEA 2018a).

4.1.3. Other groundwater pollutants

Other pollutants can affect groundwater quality in important ways in certain areas of Europe. Saltwater intrusion (e.g., chloride) affects a number of regions throughout Europe. Groundwater areas with serious chloride problems are located in Cyprus, Denmark, Estonia, Germany, Greece, Latvia, the Republic of Moldova, the Netherlands, Poland, Portugal, Romania, Spain, Turkey and the United Kingdom. Many of these areas are located near the coast, and saltwater intrusion due to overpumping of groundwater is likely to be the main cause for the high chloride content in these groundwaters (EEA, 1999).

Industrial chemicals also contribute to poor chemical status, including tetrachloroethylene and metals (such as arsenic, nickel and lead) which may arise from mining or waste water (EEA, 2018a). Chlorinated hydrocarbons (such as tetrachloroethylene) are widely distributed in groundwater aquifers of Western European countries. These come from old landfills, contaminated industrial sites and industrial activities. Petrochemical activities, as well as military sites, are mainly responsible for groundwater pollution by hydrocarbons, and mostly cause local problems (EEA, 1999). Some of these can be very severe, particularly in Eastern Europe.

Some emerging pollutants (e.g., pharmaceutical substances and personal care products) are not regulated in the EU and therefore not well monitored.[21] Groundwater monitoring for these pollutants is very limited or not carried out at all. Europe lacks a coordinated approach to identify, monitor and characterise priority substances, or groups of substances, that have the potential to pollute groundwater. The European Commission highlighted this as a need during the review of the EU Groundwater Directive Annexes in 2014, when it established the requirement to develop a Groundwater Watch List. A voluntary initiative as part of the EU CIS Working Group on groundwater has developed an approach to establish a voluntary EU Groundwater Watch List (Lapworth et al., 2019).

21 See explanatory footnote in section 3.1.3. on emerging pollutants.

4.2. What role can NbS play to alleviate groundwater quality challenges?

This section presents examples of NbS that can address two of the main groundwater challenges, nitrates and pesticides. These solutions consist mostly of disseminating improved agricultural practices. Several of these NbS are already required practice in some EU Member States, while other Member States are following suit. These interventions are not applicable in every area: they are all highly context-specific, depending significantly on a given region's current and historical agricultural context (e.g., crop types, rotation patterns, organic fertiliser availability). Additionally, in the case of pesticides, applicable approaches to pest management depend upon the presence or absence of specific pest types, as well as the legacy of agricultural production in the area.

NbS for groundwater protection have some overlaps with those for surface water protection, but some measures that are relevant for surface waters are not as relevant for groundwater protection. Riparian buffers, for instance, specifically address run-off to surface water bodies. Wetlands are also mainly relevant for surface water pollution and managed aquifer recharge. Where wetlands address groundwater directly, it is predominantly for water quantity reasons, with very few exceptions. This is discussed further in Section 6-

Improved agricultural practices that tackle groundwater quality challenges are described below:

Catch crops

Catch crops are one tactic to reduce the amounts of nitrates that can thus leach into the ground. In most of the EU, the lion's share of groundwater recharge occurs in late autumn and winter months, when there are higher levels of precipitation and low evapotranspiration (low temperatures and no or little uptake of water by plants). As opposed to nitrogen that is bound in organic matter (e.g., roots and other plant residues, soil organisms including bacteria, humus), soil nitrogen that is mineralised and in the form of nitrate is highly soluble and can leach into groundwater. In usual conditions, a high percentage of nitrates that can be found in a farmland's soil in autumn and winter will leach through the soil during winter, as part of the process of groundwater recharge, and reach the groundwater table.

Catch crops are sowed after the main harvest (e.g., after a cereal harvest in July or August). When they grow over the last few weeks of the season, they take up the available mineralised nitrogen in the soil, binding it in organic matter.

In some regions and for some catch crops, these are harvested in the spring (e.g., for feed purposes), but most catch crops are incorporated into the soil. Catch crops have benefits for soil and crop yield (e.g., improved soil structure, increased humus content), and can thus be per se interesting to farmers. However, they imply time-intensive additional work steps in a farm's agricultural cycle. Farmers will often want to rely on some form of previous experience (either their own or from neighbours or advisory services) with a particular catch crop in their region. Catch crops have to be compatible, from a pest-control perspective, with the farmer's crops. A farmer with no previous experience with a certain catch crop and without access to advisory services will thus usually be reluctant, at least at first, to cultivate it.

Catch crops are sown after the summer harvest, but have enough time on the field only if the next crop is a summer season crop—that is, when the next crop is sown out in early or late spring (maize, potatoes, sugar beets, summer cereals).[22] In some cases, it is not possible to sow catch crops if the previous crop's harvest date is too late (e.g., maize in Germany). This means that the extent to which catch crops can be cultivated in a certain region will vary, depending on the region's agriculture and on the crop rotation pattern. Catch crops can typically be sown for 25 to 50 percent of the winter seasons.

Studies aiming to quantify the impact of catch crops on nitrate leaching have shown an average reduction in N-leaching of 48 percent (and a range of 0 to 98 percent) (Stevens and Quinton, 2009). The winter soil cover provided by catch crops also reduces soil erosion. According to a study in Flanders (Belgium), calculations based on detailed scientific knowledge indicate that green cover of the soil reduces soil erosion by at least 50 percent.

22 There are some exceptions to this rule. In Germany, some drinking water companies support the sowing of a "60-day catch crop", for example, a catch crop that is sown out between two winter season crops.

Conservation tillage

Reduced soil tillage, also referred to as conservation tillage, has less negative impact on soil biodiversity and overall soil health than standard tillage practices and is thus good for soil productivity. from the perspective of the farmer, soil tilling plays a wide array of functions and has a significant number of associated impacts and trade-offs. For instance, and in simplistic terms, deep ploughing not only loosens but also turns the soil. It provides many benefits from the view of pest control and plant growth and eases the farmer's work in later working steps. However, soil tillage tends to be bad for soil biodiversity and overall soil health therefore also for soil productivity in the long run. Tilling a soil increases a soil's free surface and the availability of oxygen, which leads to more nitrogen contained in soil organic matter being mineralised (passing from bound organic matter to a mineralised, soluble nitrogen).

Adjusting soil tillage is necessary to reduce nitrate availability for leaching, while keeping in mind other factors relevant to pest control and soil productivity. Possible actions include reducing the depth of soil tillage, changing the type of soil tillage (turning versus non-turning tillage systems), optimising tillage dates, and changing the number of times a soil is tilled (e.g. no post-harvest tillage for maize fields in autumn, with focus on spring tilling instead).

Once again, the suitability of a certain change will depend on a region's agriculture and its related structures, such as the existence of service providers or machinery cooperatives capable of providing low-till, no-till or strip-till services for different crops. Regional knowledge has to be developed through practical experience. This can be based on trial and error, thus taking a few years to yield satisfactory results. This knowledge then needs to be disseminated to farmers throughout the region to reduce potential resistance linked to a fear of reducing soil productivity.

Reduced fertiliser use

Nutrient availability is a key factor determining crop yield, and fertilisers are a comparatively low-priced input. As a result, farmers usually try to be on the safe side when fertilising their crops, which means that they tend to apply more nutrients than what is strictly needed. However, excess fertiliser is problematic from a groundwater perspective, because fertiliser that is not taken up by crops will stay in the soil and can leach into groundwater during late autumn and winter, with groundwater recharge.

Different approaches improve on more traditional approaches used by farmers to estimate their fertiliser needs, as they often include a safety factor due to uncertainty. **Improved accuracy and/or certainty of estimations can lead to a fertilisation that is more in line with actual plant requirements, thus reducing excess fertilisation.** For instance, farmers can improve their estimate of soil nitrogen supply by measuring in springtime the amount of mineralised nitrogen available in soil for plant uptake. This allows them to determine with a good degree of precision how much additional nitrogen is required through fertilisation to cover the crop nitrogen demand. For crops with several rounds of fertiliser application, tests can be performed on plants (e.g., chlorophyll levels in leaves) to establish its nitrogen provision and, based on the results, reduce the amount of fertiliser in later applications. Farm advisors with expertise in nitrogen management can, if given access to a farm's documentation, identify crops and fields for which a farmer could reduce nitrogen application.

Farmer advisory services can also help reduce fertilisation by highlighting that the economic optimum for their crop often lies below their maximum possible yield. The price of the fertiliser required for raising the yield from 90 to 100 percent of the maximum possible yield can be higher than the additional income that comes with the 10 percent increase in yield.

It is also possible to set up schemes in which farmers fertilise their crops at a level that is even lower than the economic optimum for the particular crop. Farmers receive compensation for lost income in these arrangements.

Another way to reduce nitrogen fertilisation is through nitrogen accounting methods. These approaches control, either on a farm or on a field level, the inputs and outputs due to fertilisation and their impact on yield. A wide array of approaches exists and are often part of the nutrient control policies implemented in the EU Member States.

Alternative pest plant protection

In certain cases, it is possible to find alternatives to pesticide spraying therefore reducing their impact on groundwater quality.

As with other factors influencing agricultural practices, pest prevalence and available techniques for pest control vary widely by region. Different crops are affected by different pests or weeds, some of which may have become resistant to certain plant protection products in the region. **Nature-based alternatives to chemical-based pesticides are thus very location-specific; identifying viable options requires long-term, in-depth practical knowledge of the local agriculture.**

For particular weeds affecting certain crops, it can be possible to replace pesticide spraying with one or more additional tilling procedures, carried out at the right moment. The superficial tilling uproots the weeds and thus impedes them from establishing themselves on the field. However, this can be more labour-intensive than spraying a crop and can also negatively affect crop yield. For these reasons, this kind of measure is often compensated economically.

Changes to crop rotation patterns can also reduce the need for plant protection. A good crop rotation scheme, which includes a higher rather than a lower number of crops, can be optimised to reduce phytosanitary risks. More complex crop rotation schemes also have additional benefits—for soil biodiversity, for instance. However, a farmer's crop rotation scheme typically reflects the most profitable crop rotation pattern available to him, and changes to rotation could lead to income loss for which the farmer would need to be compensated. Research suggests a pesticide reduction potential for changed crop rotations ranging from 6 to 25 percent (Ferguson & Evans, 2010).

In some cases, biological control of pests is an option (e.g., releasing wasps that are natural predators of a certain pest), reducing the need to apply insecticide. For example, in France and other areas small wasps are released against the European corn borer (O. nubilalis) on about 150,000 hectares per year. Cardboards with parasitised eggs are attached to the maize plants at the beginning of the egg-laying period. Efficacy (more than 75 percent destroyed pest eggs) and price (EUR 35 to 40 per hectare for the first generation) are comparable to insecticides, unless the pest pressure is very high.

Transition to organic farming

A transition to organic farming can also have a positive impact on nitrates and pesticide levels in groundwater bodies. Organic farming in the EU needs to fulfil EU requirements for organic food/other agricultural products. Farmers can choose to go beyond this minimum standard and comply with a series of self-organised organic standards, such as Bioland and Demeter. All these standards implement restrictions on fertilisation and on the use of plant protection products. They typically result in very significant reductions in the input of nitrates and pesticides into groundwater.

Not all organic farms are as profitable as their conventional counterparts—the premium that consumers are willing to pay for organic products can sometimes, but not always, make up for the reduction in crop yields and the additional work load. The process of transitioning from a conventional farm to an organic one is also costly. According to EU requirements, a farm needs to have been producing organically for five years before its products can carry an organic label: during this transition period, the farm's yield may go down, but the farmer does not receive an economic benefit to compensate for it.

Some existing schemes help support the transition of a farm from conventional to organic farming; others compensate an organic farmer permanently over time, to ensure the farm does not change back to non-organic forms of production. (See Case Study 12 – Augsburg in Annex A.)

In the drinking water protection zones of Leipzig, Germany, a reduction in groundwater nitrate concentration from 40 to 20 milligrams per litre was achieved by offering incentives to adopt organic farming and use hydrological measures (BMUB/UBA, 2016, from EEA, 2018a).

Land-use change, including transition from farmland to pasture land and revegetation

Different kinds of agricultural land use generate strongly differing inputs of nitrate and pesticides into the environment. Pasture land, for instance, is very good at binding nitrogen in organic form in its root system, and so it typically leaches significantly lower amounts of nitrate to groundwater than farmland. The use of pesticides is also typically much lower on pasture land than farmland.

For this reason, numerous schemes support the transition of farmland to pasture land, compensating the farmer economically for this change. Another common approach is for a non-farming actor, such as a drinking water company, to buy the farmland and then lease it back to farmers, subjecting its use to a number of restrictions. For example, this approach was used by Eau de Paris in France. (See Case Study 9 – Eau de Paris.)

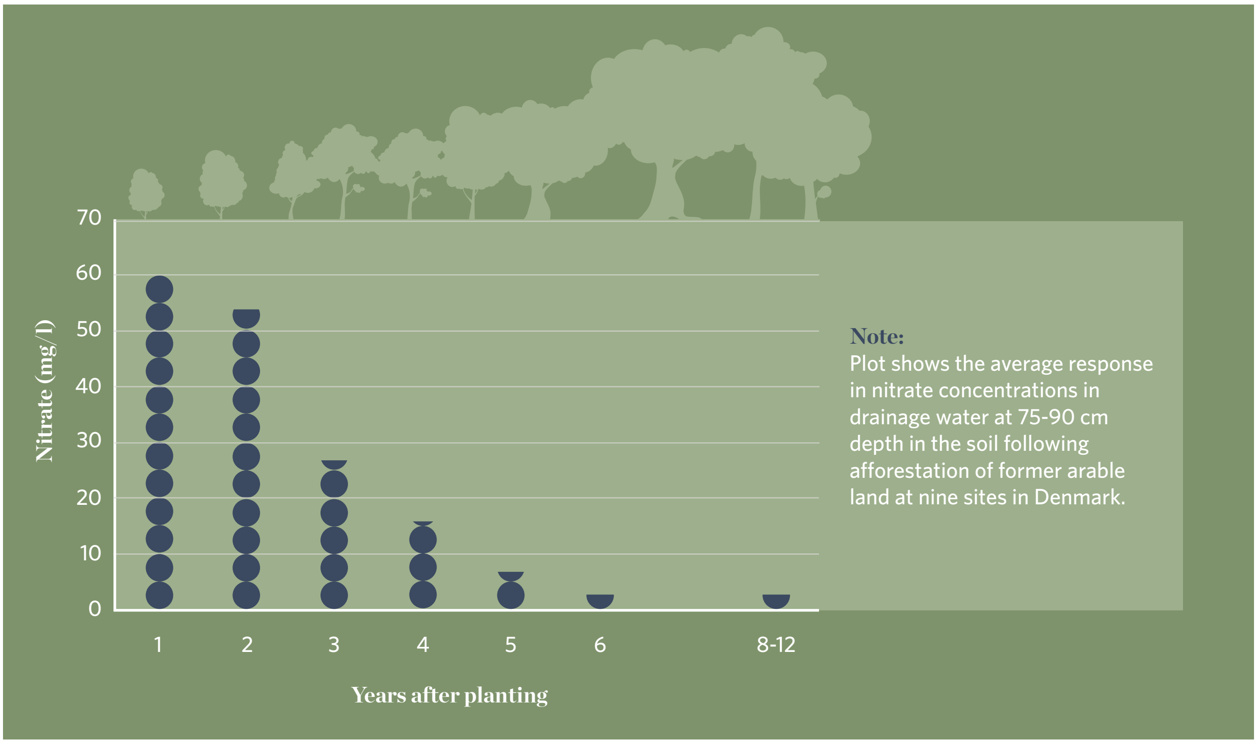
Afforestation is another form of land-use change that supports groundwater; it reduces both nitrates and pesticides. The concentrations of nitrate in groundwater leached from forests is on average lower than that of pasture land, and pest control in forests is usually significantly less intensive than pest control on farmland.

The City of Lyon in France presents an example of land-use change using afforestation to reduce the input of nitrates into groundwater (see Case Study 9 – Eau du Grand Lyon). The municipality sees protecting water at source as paramount to avoid building an expensive filtration plant and to prevent accidental pollution. The objective of the afforestation measures is to conserve the forested natural recharge area, which is also valuable in terms of local biodiversity.

A programme in Baden-Württemberg, detailed below, promotes the change from farmland to permanent grassland.

A wide array of studies shows that significantly less nitrate leaches from afforested land than from arable land. One study estimates that nitrate leaching from afforested land for the study sites in Denmark is at most 15 to 25 percent of that from arable land (Figure 4-4) (Hansen et al., 2007).

Figure 4-4 *Effects of woodland planting on reducing nitrate levels in groundwater*



Source: *Hansen et al., 2004*

Targeted woodland creation has also been found to reduce pesticide concentrations in surface and groundwaters, with effectiveness varying depending on their width and structure (e.g., woodland buffer, shelterbelt or wetland) (Nisbet et al., 2011).

23 The assumption is of normal levels of fertilisation: if pasture land is strongly over-fertilised it can leach high levels of nitrate into groundwater.

Incentive-based schemes, such as results-based payments

Some interesting schemes do not prescribe agricultural practices, but rather work by creating incentives, economic or otherwise. The farmer is free to decide if and how he changes his practices. Results-based schemes give the farmer free rein to decide the means with which he will achieve a certain result. In the German state of North Rhine-Westphalia, for instance, farmers in certain drinking water protection areas are paid compensation on the basis of the mineralised nitrogen left over in the soil in autumn (after the growing season): the lower the value, the higher the payment.

Other schemes do not provide payments but offer access to latest-generation agricultural equipment for free or for a reduced fee. With this approach, for example, the farmer's his sowing could be carried out for him for free by an external person, using a direct-sowing machine (with very limited soil disruption and thus nitrogen mineralisation). The farmer in this case saves the labour required for this work step, and the scheme benefits from the reduced tilling and thus reduced nitrogen mineralisation and leaching into groundwater.

Results of incentive-based schemes are well documented in the German state of Baden-Württemberg, which has an extensive programme addressing groundwater quality in its drinking water protection zones. Starting in 1988, the Regulation on Protected Areas and Compensatory Payments (SchaLVO) programme has been fostering the uptake of a wide set of improved agricultural practices that reduce nitrate leaching into groundwater. Since 2001, the nitrate concentration in the group of drinking water protection zones most at risk has been reduced on average by 14 percent, from 51,7 to 44,6 milligrams per litre of nitrate. The second most at risk group has seen an average reduction of 12 percent in their nitrate levels, from 35,6 to 31,3 milligrams per litre of nitrate, as discussed in Box 4.1. below

Box 4-1 *Voluntary nitrate reductions in Baden-Wurttemberg (Germany)*

ABOUT A QUARTER OF GERMAN GROUNDWATER EXCEEDS THE NITRATE LIMIT OF THE EUROPEAN UNION FOR DRINKING WATER.
A substantial reduction in inputs can be achieved only through measures in agriculture.

In the German state of Baden-Württemberg, policy instruments are a part of the mix of economic and regulatory instruments. The goal is to address two key water management problems: excessive nitrate concentrations in groundwater and unsustainable water abstraction. Around 80 percent of the drinking water in Baden-Württemberg originates from groundwater. Three different policy instruments have been applied: the Regulation on Protected Areas and Compensatory Payments (SchALVO) introduced in 1988 (a regulatory and economic instrument), water abstraction charges and Market Relief and Cultural Landscape Compensation for farmers (MEKA), a voluntary instrument introduced in 1992.

Measures included an increase in the level of on-farm advice, and soil analysis with up to 100,000 controls per year of nitrate residue in soils in autumn, to check farmer performance in terms of fertilisation balance. Other mandatory measures are: increase of the area with permanent grassland, no nitrate fertilisation outside the growing season, a 20 percent reduction of the advised nutrient dosage on crops and reduced soil tillage in autumn.

The MEKA and SchALVO measures have been successful in reducing groundwater nitrate concentration. Results may have been greater if monitoring activities had been expanded and enforcement measures had been imposed. Water abstraction charges allow for the internalisation of environmental and resource costs, but the compensation payments for farmers arguably contradict the "polluter pays" principle, going against Article 9 of the Water Framework Directive.

One positive outcome: transaction costs were reduced by introducing joint applications for compensatory measures (e.g., for MEKA and SchALVO) and by harmonising administrative procedures to already-existing economic or regulatory instruments. (In this case, the water abstraction charge was linked to existing procedures of the effluent tax.)

Source: *Möller-Gulland et al., 2015*

5. Dealing with Floods

Flood events have had a significant and rising impact in Europe in the last decades. From 1980 to 2015, 3,695 distinct flood phenomena were identified in Europe, with the highest number reported in 2010, when 27 countries were affected. Most of these flood phenomena were caused by fluvial flooding. Although flood fatalities have decreased substantially over the years, reported flood events, annually inundated areas and people affected in Europe since 1870 have increased. Key drivers for the observed increase in consequences of flood events in Europe are urbanisation, the growth of socioeconomic activities in flood-prone areas and improvements in reporting of flood events.

NbS-WS can play a leading role in reducing flood risk and the impact of flood events, especially for floods of higher frequency and lower severity. NbS contribute to alleviating flood risk and its impacts in floodplains, as well as in urban environments. NbS interventions can include restoration of natural river characteristics, afforestation and wetlands conservation. NbS generate other benefits in terms of biodiversity preservation, groundwater discharge, erosion control, filtration of pollutants, recreational opportunities and aesthetic value.

5.1. What are key challenges in Europe?

Floods are one of the most common and most dangerous natural hazards affecting societies. They endanger lives, cause heavy economic losses and have severe environmental consequences.[24] Flooding might be caused by several factors via a wide range of flood mechanisms, as explained in Box 5-1. The European Commission's latest assessment, based on a review of Flood Hazard and Risk Maps (FHRMs) prepared by 25 Member States, showed that the most common sources of reported historical flood events in Europe were fluvial (66 percent of events), followed by pluvial (20 percent) and sea water (16 percent) (EC, 2019b).

Box 5-1 *Categories and mechanisms for flooding events*

The European Commission's "Guidance for Reporting under the Floods Directive (2007/60/EC)" identifies five major categories for the source of flooding:

a. **Fluvial:** events caused by rivers, streams, drainage channels, mountain torrents and ephemeral watercourses, such as floods arising from snow melt;

b. **Pluvial:** events caused by rain falling on, or flowing over, the land (including urban storm water and rural overland flow);

c. **Groundwater:** events caused by groundwater rising from below ground;

d. **Sea water (or coastal):** events caused by extreme tidal events, storm surges—that is, water from the sea, estuaries or coastal lakes arising from wave action or coastal tsunamis;

e. **Artificial water-bearing infrastructures:** events caused by failure of such infrastructure, such as water rising from sewerage systems, collapsed dams, etc.

The flooding mechanisms, in other words the way in which a specific source can cause flooding, can vary significantly.

The major flooding mechanisms are natural exceedance of channels capacity, defence exceedance (flowing over a flood defence structure), defence or infrastructural failure and blockage/restriction (for example, of conveyance channels or of the sewerage network). Flood events can vary greatly from one to another. Some evolve rapidly, like flash floods; others develop slowly. Floods differ in the amount of debris they carry, the velocity of the water flow and the depth of the water.

Urban flooding includes all types of flood events, with a combination of sources, mechanisms and evolution characteristics as referenced above.

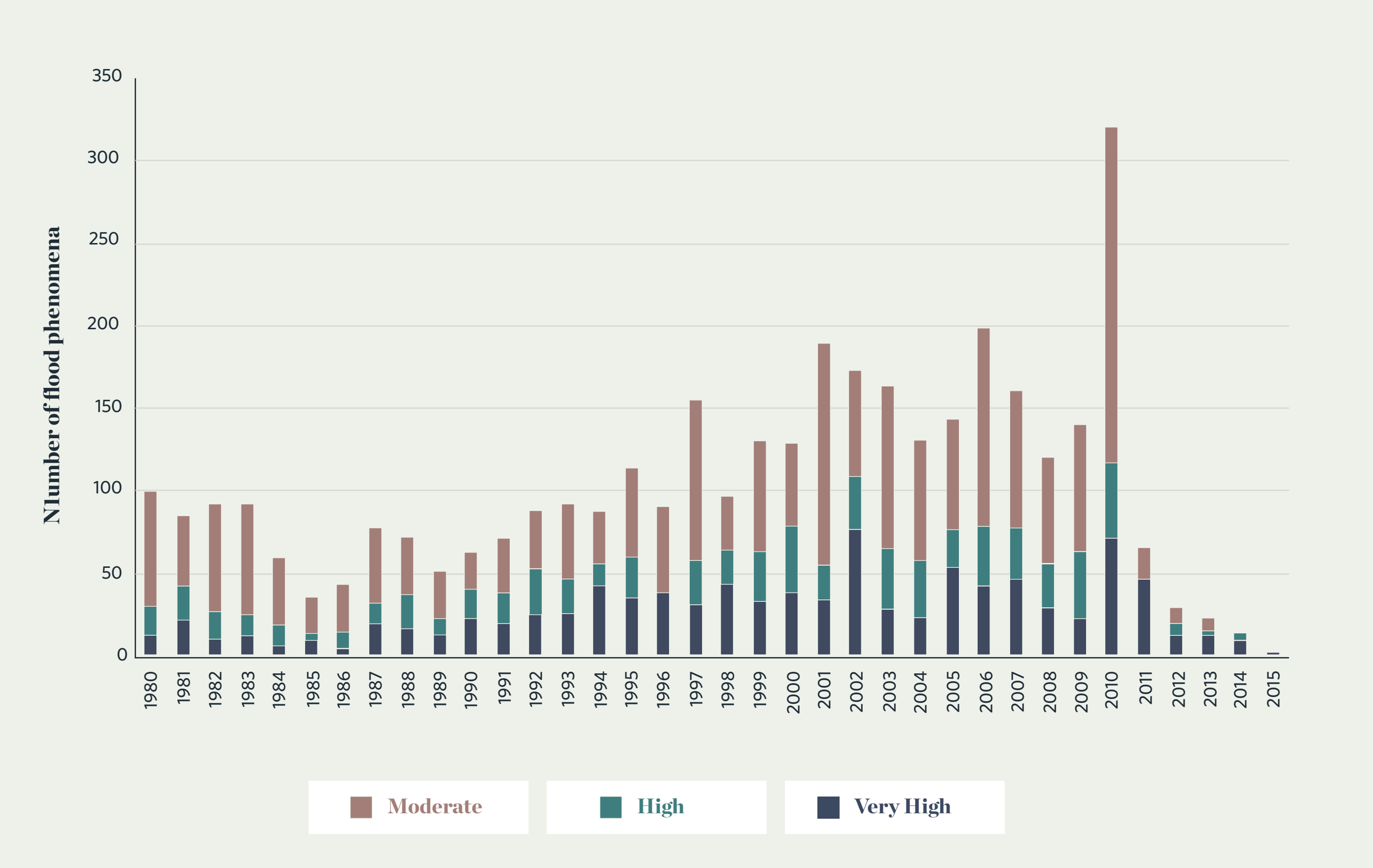
The urban environment is a driver for more flood occurrences and more flood damages: as more people move to the cities, they inevitably turn green areas into impervious surfaces, thereby increasing urban runoff and flooding. In addition, more people, property and financial activities are concentrated in densely populated urban areas, often situated on flood plains and low-lying coastal areas, increasing their exposure to flood hazards. As a result, urban flooding disrupts city services such as energy and water provision, transportation, housing, education and employment, causing wider impacts on the population. While urban flooding is a growing concern, it is not the focus here. This report addresses how to prevent and reduce flooding events in the floodplain.

Source: *EC, 2013a; Hammond et al., 2015*

24 Flooding is defined here as "a general and temporary condition of partial or complete inundation of normally dry land areas". FEMA, the Federal Emergency Management Agency of the United States Department of Homeland Security, found at: https://www.fema.gov/flood-or-flooding

Although European flood events have fluctuated throughout the years, their impact in terms of physical damages and economic losses has risen in the last decades. From 1980 to 2015, 3,695 distinct flood phenomena occurred in Europe, with the highest number reported in 2010 (Figure 5-1), when 321 flood events were registered and occurred in 27 countries during May and June (EEA, 2016c). The percentage of "very high severity" phenomena per year seems to be increasing compared to ones of lower severity. Nevertheless, no conclusions can be made about trends or patterns of flooding in Europe. This is due in part to inconsistent reporting across cases, where not all flood events are captured or categorised consistently.

Figure 5-1 *Number of flood phenomena in Europe 1980 to 2015*

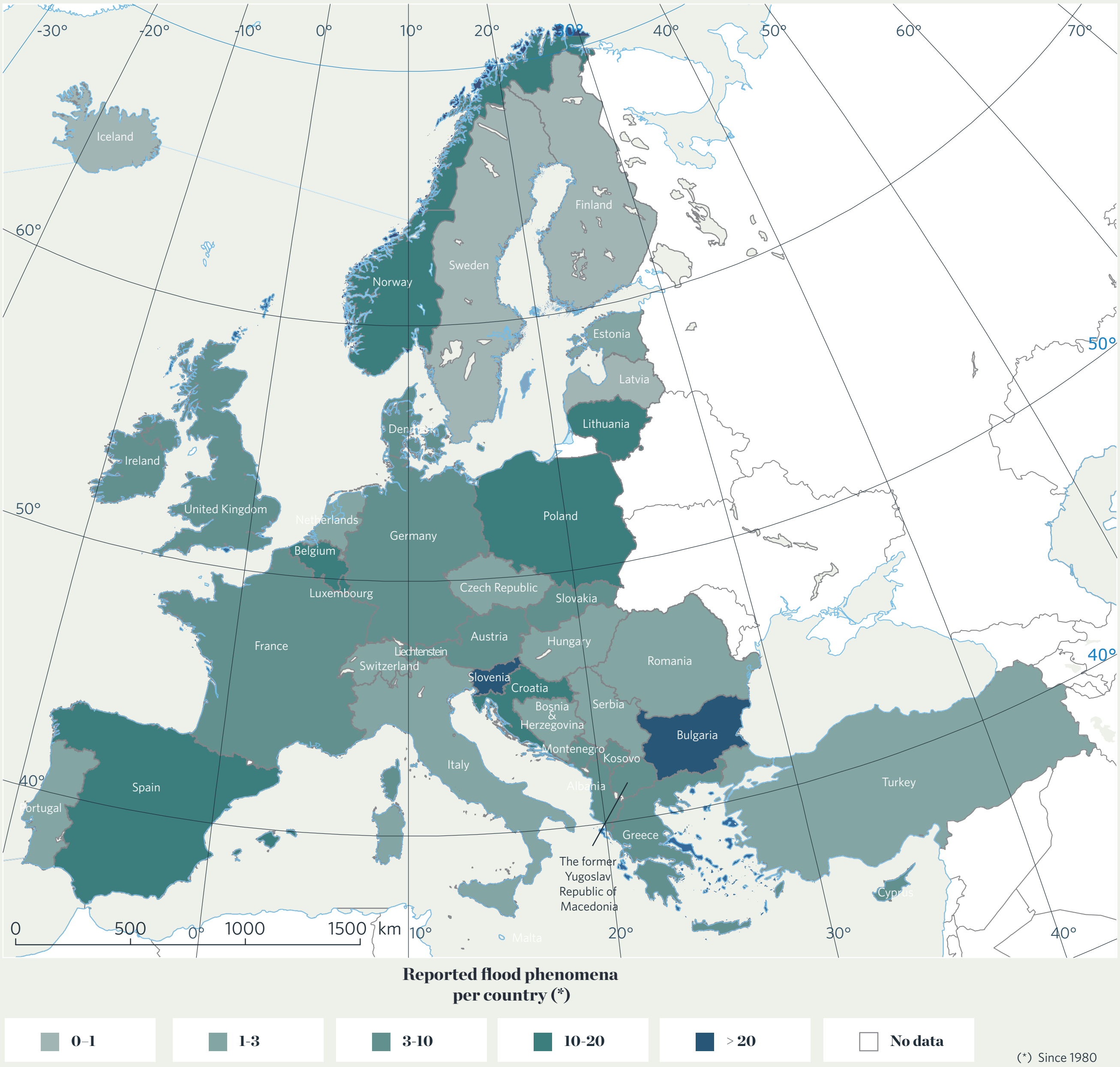


Source: *EEA database, accessed on 15 July 2019*

Note: Flood severity is an assessment of flood phenomena magnitude. It considers the reported values on frequency, reported total damage (in Euros and descriptive classes), number of flood events within one flood phenomena unit and severity classes as reported in the Dartmouth Flood Observatory database (ETC/ICM, 2015). All phenomena with fatalities are in the 'very high' severity class. This data has been derived from the reporting of EU Member States for the EU Floods Directive (2007/60/EC) and combined with information provided by relevant national authorities and global databases on natural hazards.

Figure 5-2 shows the number of reported flood phenomena from 1980 to 2015 across countries, with the number of flood phenomena weighted by country areas to give an indication of which countries are most affected by floods relative to their land mass (EEA, 2016c; ETC/ICM, 2015). For a given unit area, Slovenia, Bulgaria, Luxembourg, Belgium, Spain, Croatia, Lithuania, Norway and Poland have the greatest number of recorded flood phenomena.

Figure 5-2 *Reported flood phenomena per country - number of floods per 10,000 square kilometres per country 1980 to 2015*



Source: *EEA, 2018a.*

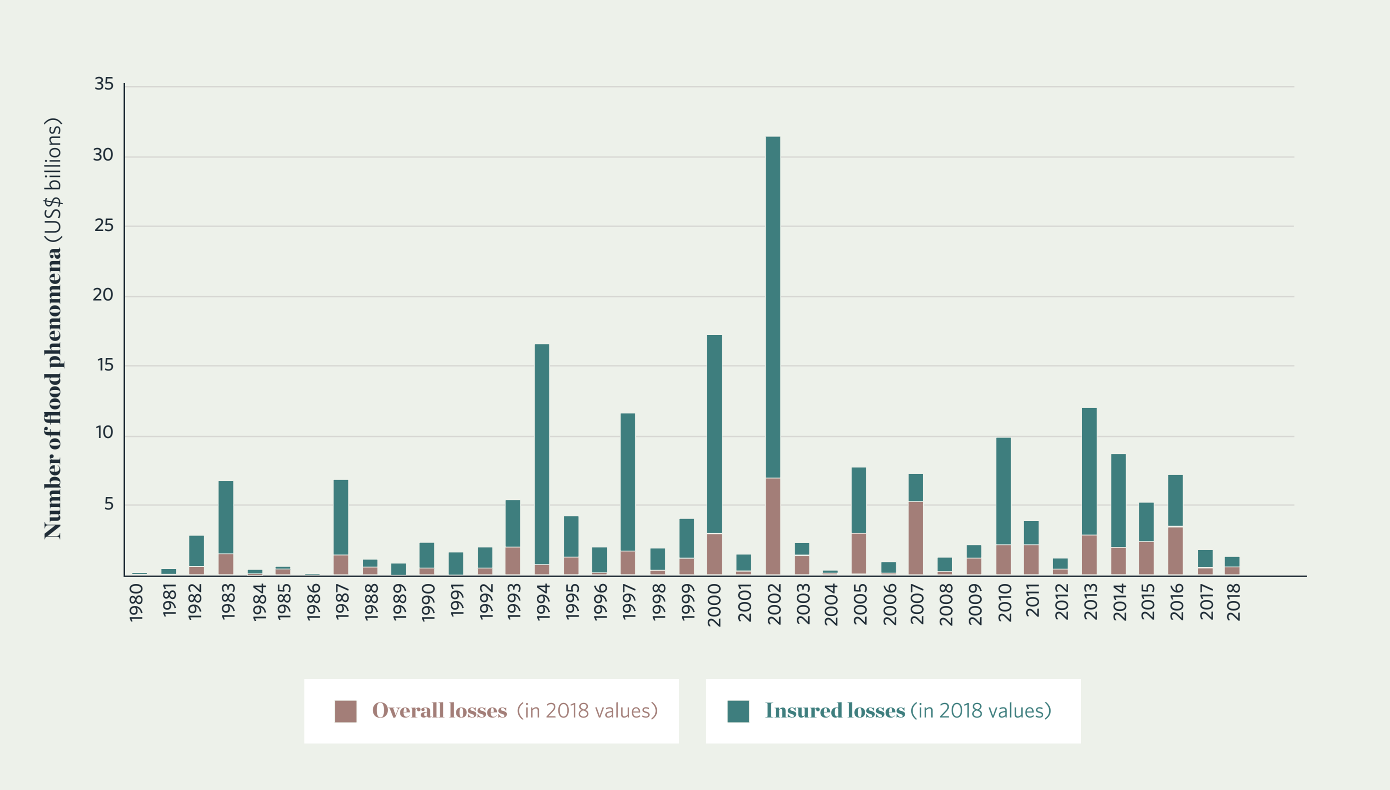
Although the numbers of reported flood events, annually inundated areas and people affected since 1870 have increased, flood fatalities in Europe have fortunately decreased substantially. Key drivers for this increase are urbanisation, more socioeconomic activities in flood-prone areas (which increases exposure of people and assets to floods) and better reporting of flood events and related information (Kundzewicz et al., 2013; Svetlana et al., 2015).

The substantial decrease in the number of fatalities can be attributed to many technological factors that allow more effective evacuation, rescue and relief operations, improved early warning and disaster preparedness, and the fact that flood prevention, emergency management and disaster relief have largely become permanent government services (Paprotny et al., 2018).

Flooding may affect water quality too, although this is usually temporary. The quality of flood water is generally overlooked, even in comprehensive flood risk assessments such as the EU Directive on the assessment and management of flood risks, which focuses only on quantitative aspects, such as flood extent, water depth, etc. (Olsen et al., 2015; Rui et al., 2018). This is due to the fact that deterioration of surface water quality is considered an exception during flooding (Rui et al., 2018). Flood water can contain debris, pollutants and nutrients, however; pollutants such as bacteria and pesticides can be carried long distances. Sedimentation and turbidity can cause growth of algae and phytoplankton blooms that jeopardise water quality.

Recent reports on the frequency and impact of disasters in Europe from 1998 to 2009 suggest that flooding and storms were the costliest natural hazards in Europe during that period. The overall losses recorded in the study added up to about EUR 52 billion for floods, compared to EUR 44 billion for storms and EUR 29 billion for earthquakes (EEA, 2011). Figure 5-3 shows monetary losses linked to floods in Europe between 1980 and 2018 and highlights the notable impact of 2002 floods, which hit Central Europe particularly hard (see Box 5-2 for details).

Figure 5-3 *Overall and insured losses in US$ for floods / flash floods events in Europe 1980 to 2018 based on 751 events*



Source: *© 2018 Münchener Rückversicherungs-Gesellschaft, NatCatSERVICE Munich Re – Retrieved July 2019*

Box 5-2 *Catastrophic flood events of 2002 in central Europe*

Source: *: Munich Reinsurance Company Publications (2004)*

In central Europe, 2002 is etched in people's memories as a year of catastrophic floods.

According to Munich Re (2004), the 2002 floods were one of the worst flood catastrophes in central Europe since the Middle Ages, comparable with the great storm surges of the North Sea and the millennium flood in the infamous flood year of 1342, when—also in August—floods affected virtually all major rivers in Europe between the North Sea and the Mediterranean.

Record-breaking rainfall amounts and intensities were observed at several rain gauges in central Europe during the first half of August of that year (Ulbrich et al., 2003). Severe flooding ensued, affecting most severely Austria, the Czech Republic and Germany (Risk Management Solutions, 2002). Long-lasting intensive rainfall caused severe flooding and triggered sequential flood waves along two major river systems, the Danube and the Elbe. The unprecedented flood heights recorded, with a return period of up to 500 years, caused the death of over 110 people and led to one of the costliest flood phenomena in Europe (Risk Management Solutions, 2002).

According to Munich Re estimates as at 31 December 2002, the floods in August that year alone caused more than EUR 15 billion in damages (including EUR 9.2 billion in Germany, EUR 3 in Austria and EUR 3 in the Czech Republic) (Kundzewicz et al., 2005). The overall loss from all flood events in central Europe that month came to EUR 18.5 billion—and only EUR 3.1 billion of it was insured (Munich Reinsurance Company Publications, 2004). Substantial losses also were felt in Italy, Switzerland, Slovakia, Hungary, Romania and Russia. Other countries with notable losses were in Great Britain, the Netherlands, Spain, Poland, Moldova and Ukraine.

In response to the severe floods in 2002, the European Commission launched concerted action to help reduce the severity of flood events and the damage caused by these floods.[25] This paved the way for the EU Floods Directive for the assessment and management of flood risks (EC, 2007a). The directive established a framework to do this, aiming at reducing the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods. EU Member States' obligations were:

- To conduct preliminary floods risk assessment by December 2011, leading to identifying areas that are at high risk of flooding, known as areas of potential significant flood risk (APSFR);
- To develop flood hazards and risk maps (FHRM) by December 2013, showing how far floods might extend, the depth or level of water, and the impacts they might have on human health, the economy, environment and cultural heritage by conducting an impact assessment;
- To prepare flood risk management plans (FRMP) for each River Basin District (RBD) while ensuring links with the WFD.

The frequency and intensity of extreme weather events are projected to grow with climate change, which will increase flood risk in Europe. Changes in flood risk are expected to be driven by a combination of potential changes in climate (especially precipitation), catchment conditions and accumulation of human activity and economic assets in flood-prone areas (Kundzewicz et al., 2014). Sea level rise and increases in extreme rainfall are projected to further increase coastal and river flood risk in Europe. Without adaptive measures, flood damages, in terms of both people affected and economic losses, are also projected to increase substantially (IPCC, 2014). Another study conducted to assess risks associated with future heat waves, droughts and floods in 571 European cities predicted increases in river flooding, mostly in North Western Europe. These will be particularly worrying in the British Isles and several other European countries, which

25 Flood Action Programme of the European Commission available through: https://ec.europa.eu/environment/water/flood_risk/com.htm, accessed on 27 July 2019.

could see more than a 50 percent increase of their 10-year high river flow (Selma et al., 2018).

In terms of trends in magnitude and frequency of flood peaks across Europe, the picture of flood change in Europe is heterogeneous. No general statements about uniform trends across the entire continent can be made (Mangini et al., 2018). However, regional patterns of notable flood trends do exist. In the Boreal region (which includes most of Sweden and Finland, all of Estonia, Latvia and Lithuania, and much of the Baltic Sea), a clear tendency towards increasing flood frequency and decreasing flood magnitude is detected (Mangini et al., 2018). The central region of Europe seems to exhibit increasing flood severity related to frequency and magnitude (Mangini et al., 2018). In the northern part of the Alps, a general tendency towards increasing flood magnitude is detected, while a clear pattern suggesting the opposite is detected in the southern part of the Alps. The Mediterranean region shows a tendency towards increasing flood magnitudes and decreasing frequencies (Mangini et al., 2018). Nevertheless, there are not many projections of flood magnitude/frequency changes at regional and continental scale, and experts are uncertain about these projections (Kundzewicz et al., 2014).

5.2. What role can NbS play to alleviate flooding challenges?

Until recently, most flood risk management involved conventional engineering measures. Investing in NbS can provide more resilient responses and improve risk management, compared to investing in conventional methods alone. Conventional grey infrastructure for flood protection is increasingly criticised for being unsustainable and expensive because the costs to build and maintain artificial structures are high. A promising alternative is greening flood protection (Janssen et al., 2015).

NbS offer major opportunities to reduce the frequency and/or intensity of floods, especially for events of lower magnitude and severity. NbS that can contribute to dealing with flooding challenges include ponds and basins, reforestation/afforestation, riparian buffers and/or riparian zone restoration, reconnecting rivers to floodplains, flood bypasses and wetlands restoration/conservation. Whereas conventional practices are static, monofunctional and hard-designed, aimed at minimising uncertainty and controlling flood risk, NbS are dynamic, multifunctional and soft measures allowing some uncertainty related to the natural variability and dynamics of ecosystems (de Vriend et al., 2014; Janssen et al., 2015; Mitsch, 2012; Naylor et al., 2012). Though the impact of green infrastructure solutions may not be immediately visible when compared to grey infrastructure, they have longer-term impacts and are more sustainable in economic, social and environmental terms.

Grey and green infrastructure solutions for flooding differ in fundamental ways (EEA, 2017c). Grey infrastructure typically serves as a defence protecting areas from the effects of higher water levels. Green infrastructure solutions (NbS) help prevent lower severity floods and alleviate the impacts of more severe events by absorbing water from run-off. NbS do not interrupt river flows in the way that grey alternatives do, so they are less prone to damage and have lower maintenance costs. Additionally, they have much less impact on river connectivity and aquatic biodiversity. Green infrastructure also offers many benefits besides flood protection that grey infrastructure does not. In terms of cost-efficiency, where a green infrastructure measure is technically feasible, its benefit-cost ratio is greater than that of its grey counterpart for the same degree of flood protection (EEA, 2017c). Nevertheless, cost and benefits depend heavily on the location of the measure (e.g., altitude, land use), and general conclusions on the relative cost-efficiency of individual measures should be avoided because of the limited number of cases analysed (EEA, 2017c).

Compared to conventional grey infrastructure approaches that are predominantly used in flood and storm water management, NbS are low-impact strategies, not only in terms of the level of protection they provide but in the level of risk in case they fail. For example, a reconstructed wetland can store a defined amount of water until the soil and sediment saturation threshold is reached, but it will never be “safe” up

A climate change adaptation plan designed in 2010 included urban environment and blue-green spaces solutions for flood reduction.

to a specific water level as dams and dikes are presumed to be (McCallum & Heming, 2006). If an NbS fail, however, risks are also lower because they tend not to fail in catastrophic ways, as dams would do. Nevertheless, functioning wetlands give a certain amount of safety for people living nearby. What is more, the soil stores the surplus water for balancing drought periods that might follow a flood, especially in summer (Haase, 2016).

A variety of types of NbS can help manage and lower flood risk and its impacts in floodplains as well as in urban environments. NbS contribute to flood risk management through nature retaining, infiltrating, storing and dissipating water flows (Schanze, 2017). Lowering flood risk with NbS is generally achieved by reducing the surface run-off volume through:

- increased infiltration into the soil,
- storage (in either natural or built infrastructure), and
- slow release of water by canopies, water bodies, soil and aquifers.

Ecosystems can prevent floods of higher frequency and lower severity by redirecting or absorbing precipitation, which reduces surface run-off and river discharge. They can also mitigate flood impact by providing the space to hold surplus water, which lowers flood volumes and destructive power (Gunnell et al., 2019; Nedkov & Burkhard, 2012).

Natural components can alter water storage and release at a catchment level in many ways (Gunnell et. al., 2019). Forests and vegetation can reduce run-off by enhanced infiltration through their root network. Leaves, branches, trunks and stems of trees intercept rainwater by temporarily storing it on surfaces and by transpiration. Soil aids flood regulation through infiltration and storage. (Soil types vary in their capacities to store moisture, depending on their particle size distribution, porosity, level of compaction, soil depth, organic content and other factors.) Floodplains, wetlands and water bodies such as lakes and reservoirs aid flood regulation mostly through storage. Floodplain topography can also affect how fast water flows; the 'rougher' or more disrupted the floodplain is, the slower the run-off.

Green and grey infrastructure can be combined for optimal flood protection, as documented by Browder, et. al. (2019) in a report by the World Bank and the World Resources Institute and in the Implementing nature-based flood protection: Principles and implementation guidance report of the World Bank (2017a). River flood management can be supported through restored river floodplains, wetlands, flood bypasses that can diminish the need for high embankments, sluice gates and pump stations. An example of how conventional infrastructure and NbS can be combined can be found in Denmark (see Case Study 20 – Copenhagen). Pluvial flooding and extreme precipitation events are central challenges in the City of Copenhagen: the metropolitan area's utility, HOFOR, managed to overcome legal roadblock and mobilised funding for large-scale interventions, including NbS-WS. A climate change adaptation plan designed in 2010 included urban environment and blue-green spaces solutions for flood reduction.

The rest of this section presents examples of key (NbS) which are used to lower flood risks.

Ponds (detention & retention) and basins

Detention ponds (also known as dry ponds) are a very common NbS for flood mitigation. Designed to detain run-off when water exceeds channel capacity, they drain completely after rainfall. They are dry during the dry weather and wet during the wet weather (Vojinović & Abbott, 2012).

Retention ponds (or wet ponds), on the other hand, retain the water permanently. They capture excess run-off, a portion of which drains out after the rain ends. The water in these ponds is displaced and replaced in part by the stormwater (Vojinovic, 2015). At a project in the UK (rural run-off attenuation in the Belford catchment, Northumberland), detention basins installed to reduce the risk of flooding to a village downstream reduced peak flows an estimated 15 to 30 percent (NWRM, 2015c).

Retention ponds: (a) a pond in Swarzynice, Poland and (b) a stormwater retention pond

a

b

Source: *: (a) by Mohylek—own work, GFDL, Wikimedia Commons website and (b) photo by Zoran Vojinovic*

Afforestation/reforestation

Afforestation is the planting of trees on previously non-forested areas. Because it can contribute to a more natural and sustainable hydrologic cycle, afforestation is a natural water retention measure. It is used to convert artificial impermeable land cover to tree-covered permeable areas, which supports hydrological functioning and delivers important amenities, such as urban forest parks or trees (NWRM, 2015d). Afforestation also is applied in agricultural areas, forests and semi-natural locations.

Afforestation's applicability in Europe depends on a number of factors, including current land use, societal demand and public opinion, and the regulatory environment. European and national policies in many Member States discourage the afforestation of agricultural land. In areas with low precipitation, potential gains from afforestation should be weighed against possible adverse effects of reduced water supply on a local scale. In terms of their design and spatial scale, land use conversions using this method can benefit a wide range of spaces. The smallest realistic conversion is probably the individual field, while the largest could be a whole watershed.

Afforestation is most beneficial in areas of marginal agricultural land, areas with steep slopes and significant erosion or landslide risk and near urban areas. Experimental data suggest that afforestation of more than 15 to 20 percent of the catchment may lead to significant changes in stream flow (NWRM, 2015d).

Afforestation: (a) an afforestation project in Rand Wood, Lincolnshire, England and (b) Kronios Hill after the implementation of measures (temporary timber structures and targeted planting of forests in mountain areas) in the case of Ancient Olympia, Elia, Greece

a

b

Source: *(a) By Alan Murray-Rust, CC BY-SA 2.0, Wikimedia Commons website and (b) Bourletsikas (2014); NWRM (2015b)*

Reforestation can help address floods by slowing, storing and reducing the runoff water in several ways. Alteration of runoff can be attributed to higher rates of evapotranspiration and water holding capacity of forests and the greater infiltration capacity along with increased roughness of soils. Afforestation activities most likely have synergies with appropriate design of roads and stream crossings. Considering that afforestation aims at reducing the urban flood risk through a process of keeping the rain where it falls in upstream areas, it can be argued that it can typically complement flood control dams, built in the upstream areas in order to keep flood /peak discharges.

Wetlands restoration/conservation

Although not usually associated with flood management, wetlands do have important functions in that area as well by protecting adjacent and downstream property from flood damage.

The effectiveness of wetlands for flood abatement varies depending on the size of the area, type and condition of vegetation, slope, location of the wetland in the flood path and the saturation of wetland soils before flooding. A one-acre (approximately 4,000 square metres) wetland can typically store about three-acre feet (about 3,700 cubic metres) of water, or 1 million gallons (about 3,785 cubic metres). Trees and other wetland vegetation help slow the speed of flood waters. This action, combined with water storage, can actually lower flood heights and reduce the water's destructive potential (US EPA, 2006).

(a) Wetland restoration and (b) Wetlands during restoration floodplain planting.

a

b

Source: *(a) Linham & Nicholls (n.d.) and (b) Wikimedia commons website*

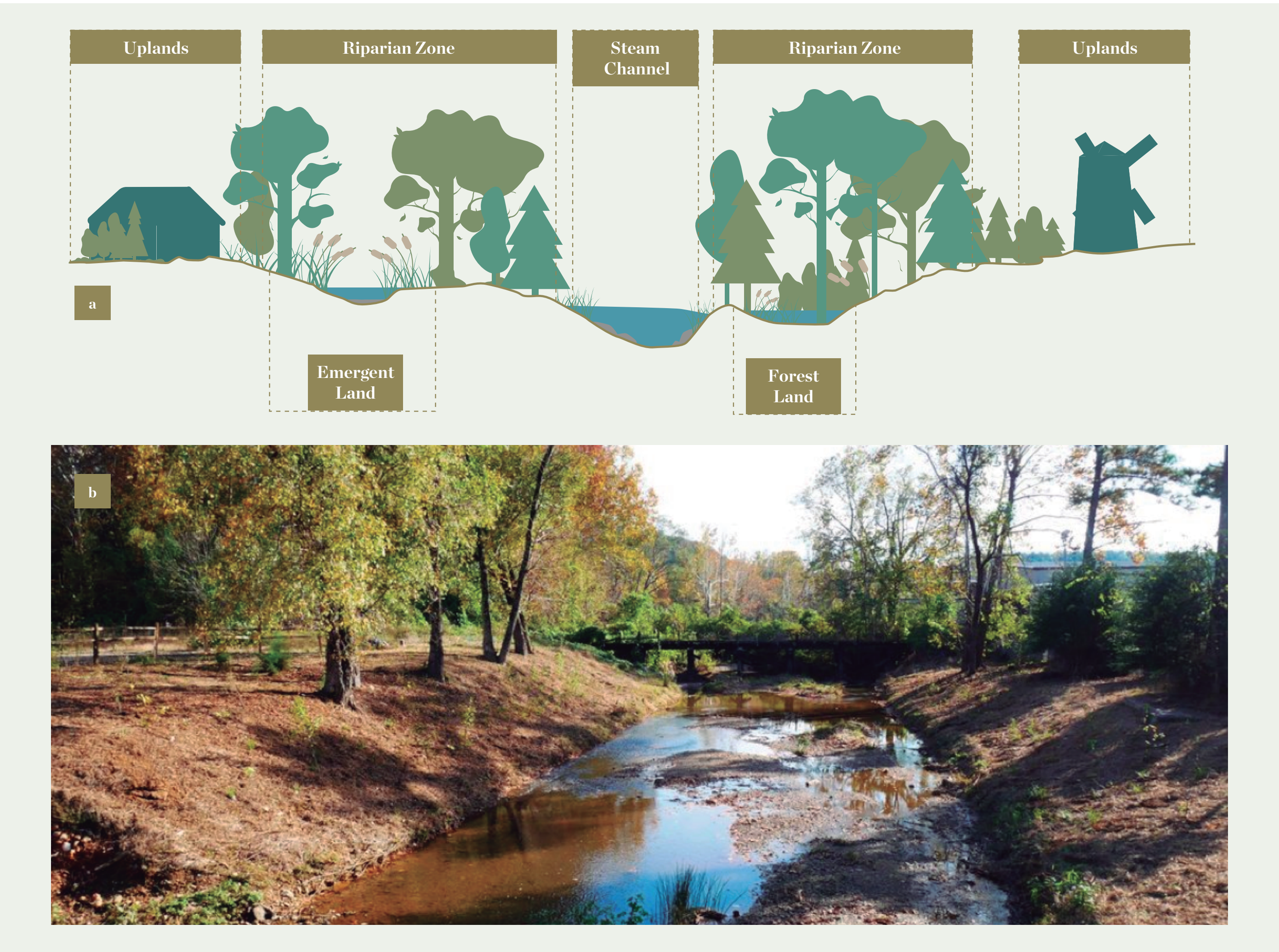
Wetland restoration has been widely used in the US and as nature-based flood defence for coastal Europe. In the Netherlands, wetlands were used to reduce wave attacks on the dikes behind them. Reducing the force of incoming waves meant lower, less heavy and less costly dikes could be used (de Vriend et al., 2014). Another case which supports the part wetlands play in mitigating flood risk is Glasgow in Scotland (see Case Study 17 – Glasgow). The community created new areas of wetland habitat, installed floating islands, restored peatland and removed culverts in a watercourse.

Riparian zone restoration/riparian buffers

Riparian zones provide a wide range of functions and ecosystem services along riverbanks (e.g., chemical filtration, flood control, bank stabilisation, aquatic life and riparian wildlife support) (EEA, 2017a). Riparian restoration in river channels can: reduce damage from flood events, protect the stream channel from scour (the removal of sediment from the stream bed) and offer erosion control, reduce flow velocities, and trap additional amount of sediments in the flood plain (Dufour & Rodríguez-González, 2019; National Research Council, 2002). To this list US EPA and SEPA add increased flood water storage, groundwater recharge, the maintenance of biological diversity and habitat connectivity, and the added aesthetic value of green recreation spaces (SEPA, 2009; US EPA, 2005). Riparian restoration and stream buffers tackle the challenge of excess water by intercepting precipitation, slowing overland flow and promoting infiltration.

Vegetation roughness enables stream buffers to "store water and reduce peak runoff during storm events" (USACE, 1991), while the stored water can be used by plants in photosynthesis and evapotranspiration (Mannik, 2004). This also has benefits for stream temperature (NWRM, 2015f). As a green infrastructure, they could complement grey ones such as dikes along the coastline or rivers channels.

(a) Relationship between wetlands, uplands, riparian areas and the stream channel and (b) Riparian restoration at Shades Creek Watershed



Source: *(a) US EPA (2005) and (b) "Riparian Restoration—Ruffner Mountain", n.d.*

Riparian conservation and restoration works best in areas with high potential for ecological recovery and low constraint from human settlement, land value, economic constraints and demographic pressure.

The Navarra region of Spain selected riparian zone restoration and reconnecting rivers to floodplain as NbS to mitigate flood risk (see Case Study 16 – Navarra). The region's Flood Risk Management Plans have been elaborated around six areas, one of which consists in river restoration projects.

Another NbS of high importance is **reconnecting rivers to floodplains.** The case of Nijmegen in the Netherlands is a good example (see Case Study 15 – Nijmegen). River restoration increases natural storage capacity and reduces flood risk by reducing the volume and speed of water. It does this by reconnecting brooks, streams and rivers to floodplains, former meanders and other natural storage areas and by enhancing the quality and capacity of wetlands. Not only is excess water stored in a timely and natural manner, but the landscape becomes more attractive, biodiversity improves and recreational opportunities increase. In these ways, river restoration directly contributes to climate change strategies aimed at mitigating the effects of increased and erratic peak flows and droughts (RISC KIT, n.d.-b). Loos & Shader (2016) have collected actions for reconnecting rivers to floodplains: the relocation of levees farther from the riverbanks, removal or breach of levees (to allow some water to move to the floodplain), flood bypass, the excavation of floodplains to reach flow levels and changing the rules when the river's flow is regulated to the point it is no longer inundated. In Nijmegen, the floodplain of River Waal was widened, giving it more room to expand under extensive land use pressures posed.

Missouri River. Reconnecting rivers and floodplains.

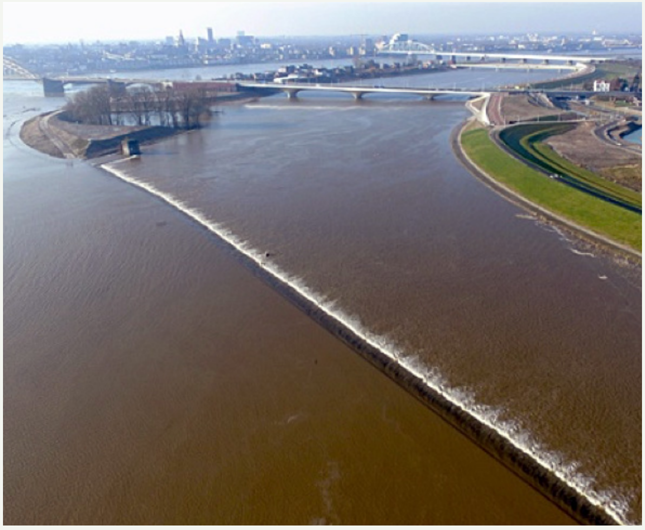
Source: *Galat (2015)*

Flood bypasses

An NbS that can be combined with river's reconnection to floodplain is **flood bypasses**, which divert excess flood waters from a river to reduce peak discharges and protect nearby areas against floods. A bypass channel, also known as a flood-relief channel, is an artificial waterway that protects urban and rural agricultural areas from flooding. It carries excess water from a mainstream or river to the lower parts of the same stream or into another stream and can accept a large amount of excess water). Additional benefit is the reduction of flow velocities compared to the ones encountered in the main riverbed, which might, on the other hand, cause sediment concentration (Naturally Resilient Communities, n.d.). The above mentioned NBS also provides groundwater recharge, fosters wildlife habitat, and serves as agricultural land when not flooded, as documented by Sommer et al. (2001) and Ozment et. al. (2019). The cost of such solution is highly depended on land prices, similarly to floodplain restoration and reconnection, whereas the operations and maintenance costs area typically low (Ozment et. al., 2019). In Nijmegen, an ancillary channel was dug as a secondary meander to protect the surrounding areas from rising waters at a bend of the River Waal (see Case Study 15 – Nijmegen).

(a) The Napa River Basin in California, where flood bypasses have been established along with other strategies, and (b) Flood relief channel along river Rhine at Nijmegen, the Netherlands.

a



b

Source: *(a) Naturally Resilient Communities, n.d. and (b) Dutch Water Sector (2016)*

Green infrastructure, and NbS in general, contribute to multiple purposes at the same time, thus encouraging biodiversity, water quality, recreation and other benefits (EEA, 2017b).

Some examples:

Retention ponds can provide both attenuation and treatment of stormwater. Pollutants are removed through sedimentation, and biological uptake mechanisms can reduce nutrient concentrations (Kellagher et al., 2015; Susdrain, 2019a). A stormwater pond can also be a beneficial wildlife habitat and, if well-kept, enhance the value of nearby housing with high potential ecological, aesthetic and amenity benefits. This in turn ensures community receptivity when adopted in cities (Adeptus, 2015; Susdrain, 2019b).

Afforestation can reduce erosion and sediments run-off. Forests and forest soils can also address pollutants by helping to reduce their sources and intercepting their pathways—ultimately playing an important role in improving water quality. In terms of biodiversity, afforestation may be able to create terrestrial habitat that is ecologically valuable, especially if native or indigenous tree species are used (NWRM, 2015d).

Flood bypasses can restore natural floodplain-forming processes (such as sediment transport and deposition) and improve fish and wildlife habitats (FEMA, 1994). The Yolo bypass, for example, provides tens of thousands of acres of habitat for both fish and birds, including critical rearing habitat for salmon and a suite of endangered fish species. Nijmegen's NbS created a new island which was turned into an urban park with natural vegetation. Such measures can certainly be aligned with a City's services, as seen in the newly built bridges that connect Nijmegen with Lent and the quay constructed (see Case Study 15 – Nijmegen).

6. Dealing with Water Scarcity

Securing a sufficient and steady supply of water for all users (society, nature and the economy) is becoming one of Europe's critical challenges. Climate change, population growth, urbanisation and intensifying economic activity make it a critical concern. By 2030, half of the EU's river basins are expected to experience water scarcity and stress. Droughts, which accounted for EUR 100 billion in economic impacts in the EU between 1976 and 2006, are becoming more widespread, frequent and intense. So are heat waves, which caused the most fatalities amongst all natural disasters in the period 1980-2017. These prolonged periods of low precipitation and intense heat drive over-abstraction of groundwater, especially in agricultural economies. Further, seasonal reductions in river flows often coincide with peaks in demand, stressing the hydrological system. Recent disasters, like the drought that affected Northern and Central Europe in the summer of 2018, have driven home the need for more concrete action to bolster climate preparedness and resilience.

NbS-WS, such as aquifer recharge and wetland restoration, can play a prominent role to increase resilience to water scarcity and stress. Aquifer recharge can boost water availability in periods of scarcity and drought while protecting groundwater resources from salinisation. And restored wetlands, by storing and regulating water flow, can function as important buffers, thereby increasing resilience to extreme weather events like droughts, heat waves and wildfires. Wetlands can act as sponges during wet periods, holding on to water and facilitating natural aquifer recharge. This regulates the water cycle and acts as a damper against extreme temperatures.

6.1. What are key challenges in Europe?

Natural hazards like droughts and heat waves are expected to become more frequent and severe across Europe due to climate change. There are clear signs that climate change is expanding the geographic range and acuteness of extreme weather events. Areas commonly considered as 'water sufficient' now face unprecedented water stress, and this will continue (see Figure 6-3). Once associated mainly with the Mediterranean basin, droughts are now occurring, with devastating effect, in Northern Europe as well, including in countries like Sweden, Finland, the UK, Ireland and Germany. During the summer of 2018, Europe fell into a major drought as a result of heat waves and limited rainfall. Recorded precipitation levels were "below or much below normal" in parts of north-central Europe: for example, Sweden recorded 12 percent of its normal rainfall for the month of July (EDO, 2018). The resulting losses were significant, particularly in the agricultural sector, with widespread damage to crops. In Germany, farmers called for a EUR 1 billion aid package (Hogan, 2018), with EUR 340 million ultimately being set aside through state and federal emergency funds (DW, 2018). Similarly, the Swedish government allocated around 1.2 billion krona (EUR 116 million) as part of its crisis package (Lindeberg, 2018). The UK Met Office published heat wave warnings that summer, with instructions on how to prepare for the extreme weather and stay safe. At the EU level, the European Commission adopted measures and derogations in response to the crisis. The EC allowed cash-strapped farmers to receive higher rates of subsidies in October instead of December (EC, 2018b). Additionally, farmers were offered certain exemptions from greening requirements (see Box 7-4 for more information on CAP subsidies) (EC, 2018c).

In addition to the more intense temperatures and more frequent dry spells, European water managers are dealing with **human-induced pressures on water ecosystems that can trigger and/or exacerbate water scarcity.** These include water abstraction for agricultural, domestic and industrial uses, degradation of water bodies and aquatic ecosystems, flow diversion and regulation (e.g., for irrigation, energy production or flood control purposes), and over-abstraction of groundwater resources.[26] Two or more of these pressures together put severe strain on water-dependent systems.

While closely intertwined, drought and water scarcity need to be examined separately based on their underlying causes and their consequences (Schmidt & Benítez-Sanz, 2013; Hervás-Gámez & Delgado-Ramos, 2019), as discussed in Box 6-1. This enables a more thorough diagnosis of the issues and a better evaluation of measures to address them.

Box 6-1 *Distinguishing between droughts and water scarcity*

Droughts are complex natural phenomena that are prolonged, negative deviations from average precipitation values in a given area.

These temporary drops in precipitation levels result in reduced water availability that can go on for months or years, hindering economic activity, social well-being and ecosystem function. They are difficult to predict and monitor. Drought impacts can be very costly and wide-ranging, including in terms of social, environmental and economic losses.

Water scarcity is a mismatch between water availability and consumption.

In broad terms, the interactions among climatic, geological and socio-economic factors dictate how much water is available in a given region. When a hot, dry summer hits a region with limited inflows, slow aquifer recharge and high human activity, the boundaries of the hydrological system are pushed and an acute water scarcity episode kicks in. The situation is worse when a prolonged drought aggravates the already adverse framework conditions. In addition, lower river flows and groundwater levels reduce water volumes in rivers, lakes and aquifers to dissolve pollutants, thereby reducing water quality. A decrease in water quality may render water inadequate for human consumption, for economic activities or as the underpinning element of environmental systems, thereby increasing scarcity.

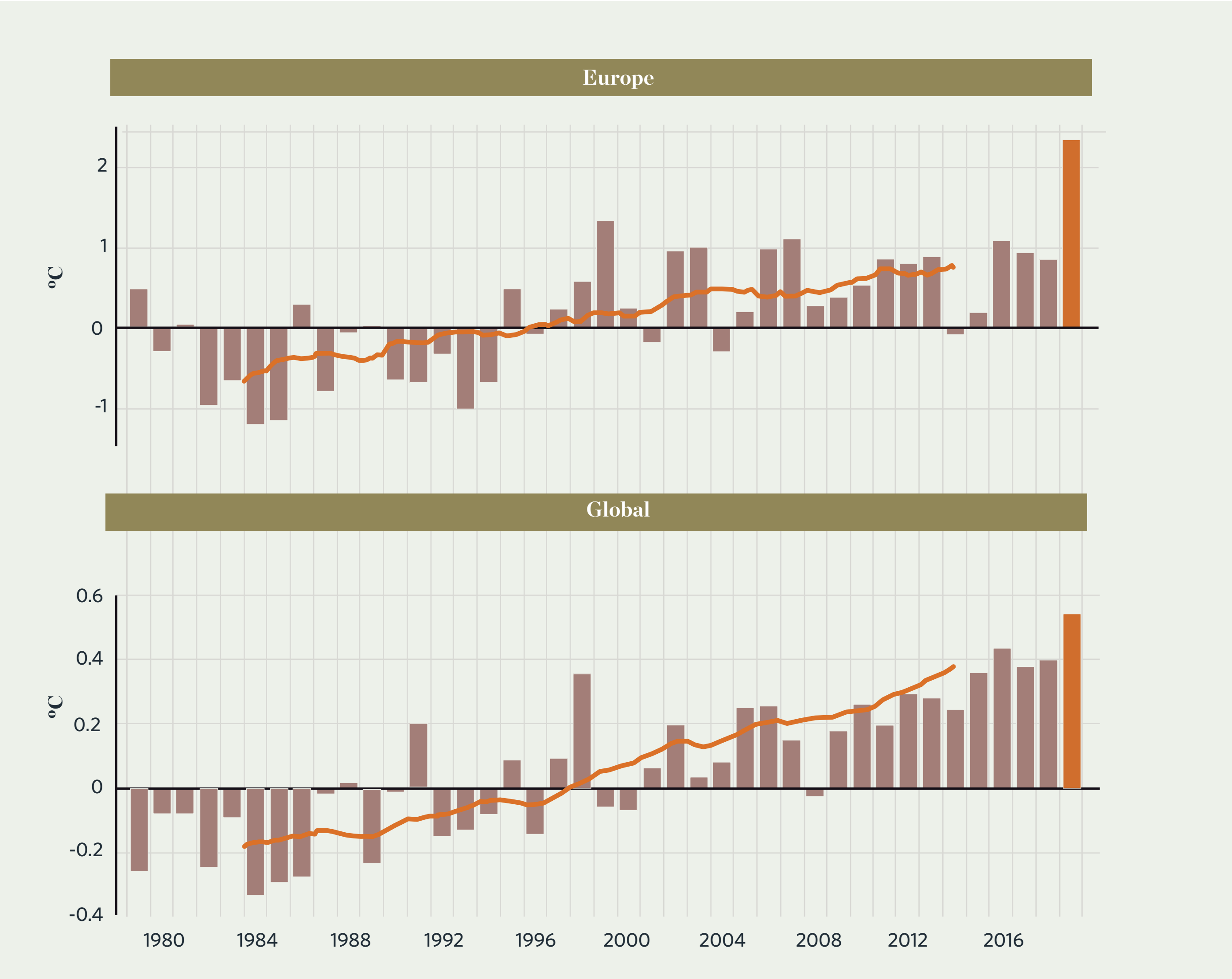
Source: *Schmidt & Benítez-Sanz, 2013; Blauhut et al., 2016; Costigan et al., 2016; Van Loon & Van Lanen, 2015*

26 Pollution and salinisation of reservoirs and aquifers can reduce water availability. These issues are covered more extensively in Sections 3 and 4, which deal with surface water and groundwater quality issues.

In the last two decades, temperatures in Europe have risen, especially during the summer months. The five hottest summers in Europe in the last 500 years happened between 2004 and 2018. In the period 2009-2018, the region faced its warmest decade on record (Leahy, 2019; EEA, 2019). The heat wave and drought from 2003 was especially devastating, causing over 30,000 deaths and combined losses from agriculture and forestry estimated at over EUR 13 billion (UNEP, 2004). Europeans have continued to experience extreme heat waves, with especially intense ones recorded in 2006 and 2018. These extreme events are predicted to become more intense, start earlier and end later.

Figure 6-1 shows temperature increases in the month of June in Europe and globally. While the trend lines are comparable, the increase in temperatures in the month of June has been greater in Europe than globally. June 2019 was the hottest June on record in Europe, with average temperatures at 2 °C above normal (ECMWF, 2019). High summer temperatures lead to high evaporation rates, irregular precipitation patterns and low river flows. These have historically been common in areas of Portugal, Spain, France, Italy, Greece and Cyprus, but in recent years such phenomena have spread to other European regions.

Figure 6-1 *Average June temperatures (°C), shown as differences from long-term average values for 1981 to 2010*

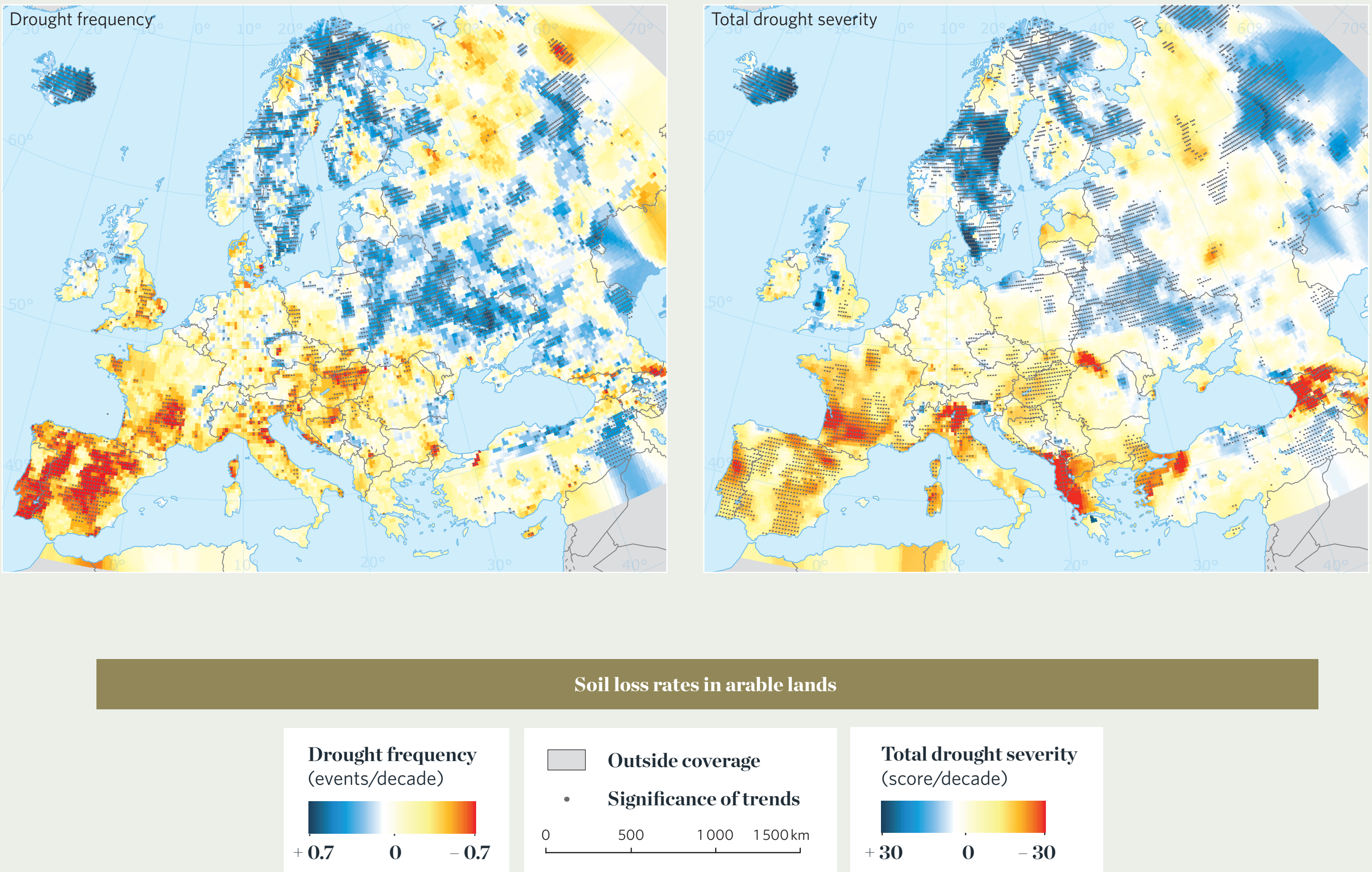


Source: *ECMWF, 2019*

Higher temperatures influence rainfall patterns. For example, annual precipitation figures recorded since the 1960s show declines of up to 90 millimetres per decade in the Iberian Peninsula. Mean summer precipitation has also declined in most of southern Europe by up to 20 millimetres per decade (EEA, 2016a). The declines are expected to continue, with model simulations for the period 2071-2100 showing up to a 40 percent decrease in annual precipitation in southern Europe (Jacob et al., 2014).

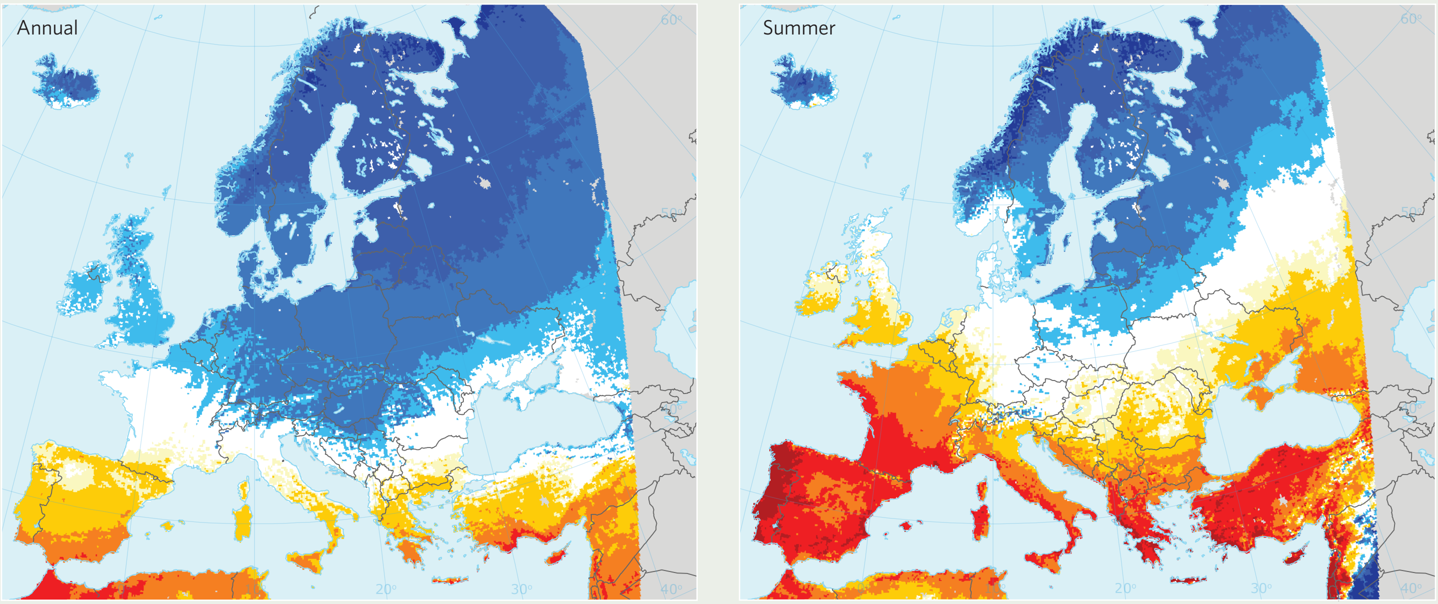
Droughts registered in Europe between 1976 and 2006 affected more than 100 million people and over 37 percent of the continent's land mass (Kossida et al., 2012). The most frequent and severe of these have occurred in southern Europe (see Figure 6-2 and Figure 6-3). In the Mediterranean Basin, precipitation patterns are complex; flow dynamics in Mediterranean rivers and streams change considerably among seasons, limiting availability during specific times of the year. In some areas, as much as 98 percent of the streams and rivers may partially or completely dry up during the summer period (Skoulikidis et al., 2017).

Figure 6-2 *Trends in frequency (left) and severity (right) of meteorological droughts 1950 to 2012*



Source: *EEA, 2016b*

Figure 6-3 *Projected change in annual and summer precipitation in Europe in 2071-2100 compared to the baseline period (1971-2000)*



Projected change in annual (left) and summer (right) precipitation

Projected change in annual (left) and summer (right) precipitation
%
– 40 – 30 – 20 – 10 – 5 5 10 20 30

Outside coverage
0 500 1 000 1 500 km

Source: *Jacob et al., 2014*

Note: This map shows projected changes in annual (left) precipitation (%) in the period 2071,2100 compared with the baseline period 1971-2000 for the forcing scenario RCP8.5. Model simulations are based on the multi-model ensemble average of many different RCM simulations from the EURO-CORDEX initiative.

The financial losses associated with droughts from 1976 to 2006 were estimated at EUR 100 billion (EC, 2007). The main economic impacts were triggered by severe restrictions and temporary interruptions to water supply. This led to high operation and maintenance costs for industrial users and energy producers, income losses and weaker competitiveness in the agricultural sector, and losses in activities dependent on public water, like tourism (EC, 2007). Due to the drought and heat wave in 2003 alone, the hit on agricultural and forestry production for 2002-2003 was estimated at between EUR 4 and 5 billion in Italy, EUR 4 billion in France, and EUR 1.5 billion in Germany. Spain and Austria also were hit hard, with estimated losses of EUR 810 million and EUR 197 million, respectively (COPA COGECA, 2003). The energy sector in France lacked cooling water to run the nuclear plants, and forest fires in Portugal associated with the temperature anomalies caused economic losses of over EUR 1 billion (JRC, 2003). Estimates of the total economic losses for 2003 range from EUR 8.7 billion to EUR 13 billion (EC, 2007; UNEP, 2004). The average impact of droughts reached EUR 6.2 billion per year in 1991-2006, double the yearly average in 1976-1990. These estimations are purely economic; they do not consider social and environmental costs (EC, 2007).

In addition, the freshwater bodies that sustain some of Europe's urban, tourism and agricultural centres are permanently exposed to pressures from human activity. For example, Europe's coastal areas are extensive and largely developed, with many human activities (Jeuken et al., 2017). Coastal centres and small Mediterranean islands with a busy tourist trade have to cope with sharp spikes in public water demand during the peak summer holiday. This places a heavy seasonal burden on the water bodies, ecosystems and water infrastructure—triggering water shortage, overexploitation of coastal aquifers, saltwater intrusion and wetland degradation (Jeuken et al., 2017).

Deltas as well as arid and semi-arid regions hosting agricultural activities also face serious challenges. Some examples are the Westland region in the Netherlands and the

Middle Appenines, the Po River Basin in Italy, the Guadiana in Portugal and Spain, and the Segura River in Spain (EEA, 2018). In those regions, farms irrigate water-intensive crops during the summer growing season, when evaporation rates spike and precipitation is meagre. The result is the overexploitation of groundwater resources, which causes the soil to settle and contaminates the aquifers.

When prolonged periods of low precipitation, high temperatures and sustained water demand happen at the same time, the result is drastically low river flows, affecting socioeconomic and environmental systems. For example, since 1979 a transfer system has transported water from the Tagus, the longest river in the Iberian Peninsula, to the Segura River Basin in southern Spain. The water supply serves 2.5 million domestic users and 150,000 hectares of irrigated land in what is one of the most important agricultural regions in the country (SCRATS, 2016). Law allows transfers totalling 600 cubic hectometres each year. However, low river flows resulted in the complete interruption of the transfer in January 2016 and from June 2017 to March 2018. The foreseen transfer volume in October 2019 amounted to 20 cubic hectometres, the maximum allowed for pre-emergency conditions at the source. Such conditions were expected to continue until at least April 2020 (CEDEX, 2019). The Supreme Court in Spain added to the urgency in March 2019 when it rejected the River Basin Management Plan of the Tagus for failing to include clear provisions on minimum environmental flows—levels deemed necessary to prevent the collapse of the river ecosystem. This was expected to shift the legal thresholds that now define how much water can be transferred each month.

Such critical situations are not exclusive to rivers in the Mediterranean Basin. In 2018, during persistent drought conditions, cargo shipping along the Elbe River was impeded for months. The river connects the Czech Republic to the North Sea via Germany. Similar low-flow conditions in stretches of the Rhine, the second longest river in Central Europe and an essential waterway both economically and historically, resulted in disruptions of barge traffic and six-figure financial losses due to higher transport costs and lower industrial production levels.

Another blend of pressures is a trigger for water scarcity: environmental degradation, intense industrial activity and prolonged periods of low precipitation. Industrial water used for cooling and processing cycles back to the environment at a reduced quality level. If the receiving water body carries abundant resources, it dilutes the industrial effluents and minimises detrimental effects. But if water levels are low, nature cannot do its job. In Finland, a country known for its ample water resources, the issue of drought has started to attract attention as the effects of climate change become evident. Here, the effects on water quality from industries like paper and pulp, mining and aquaculture are expected to worsen. This is due to a conflux of more frequent and severe droughts and a reduced capacity for water retention by fields, forests and wetlands that have been degraded in the past (Ahopelto et al., 2019).

Over the last decades, groundwater volumes abstracted in Europe have been increasing substantially, above sustainable abstraction yields in some circumstances.

Over the last decades, groundwater volumes abstracted in Europe have been increasing substantially, above sustainable abstraction yields in some circumstances.[27] France, Germany and Spain exhibited the highest withdrawal volumes, ranging between 5.3 and 6.5 billion cubic metres per year. While the overall trend between 2005 and 2015 looks favourable for the EU (overall water abstraction fell by around 7 percent between 2002 and 2014), countries like Latvia, Greece, Malta and Denmark increased their extracted groundwater volumes by 53, 49, 32 and 17 percent, respectively (EEA, 2018b; Eurostat, 2017). As reported in the second River Basin Management Plans, Malta is most at risk from over-abstraction, with 79.5 percent of its groundwater bodies in poor quantitative status (EEA, 2018f). Other countries share the problem: Spain (18.7 percent), France (11.2 percent) and Germany (3.5 percent). Long-term climate and hydrological studies that consider population dynamics show a 24 percent drop in the renewable water resources available per capita in Europe from 1960 to 2010 (EEA, 2018b).

Capabilities for measuring, metering and monitoring groundwater abstraction vary widely across Europe. Enforcing sustainable limits is a complex task. In places where oversight from responsible authorities is inadequate, wells and boreholes can proliferate with few or no restrictions. This has been observed in arid and semi-arid regions of the EU, like the Roussillon plain in Southern France, the Guadiana River Basin in Spain, the Puglia region in Italy, the Lower

27 The last decades have seen a marked increase in global groundwater abstraction, with volumes quadrupling in the last 50 years. By 2010, the global estimate had reached 1,000 billion cubic metres per year, or about 26 percent of total freshwater extractions (GEF et al., 2015).

Coralline Limestone aquifers in Malta, and areas of Greece and Cyprus (Dworak et al., 2010; de Stefano & Lopez-Gunn, 2012; Montginoul, 2016). These uncontrolled, intensified abstractions can hinder the ability of aquifers to balance outflows with inflows. The result is a loss of groundwater-dependent ecosystems, soil subsidence, saltwater intrusion and limited water supplies (GEF et al., 2015).

While some Member States have established licensing and permit mechanisms, these have not been fully effective in averting illegal abstraction and over-abstraction in certain regions (Ross, 2016). This has been an especially difficult challenge in areas of southern Europe where groundwater represents the only source of water for economic activities and domestic use. Even when a few clandestine boreholes may be identified and eliminated, the limited pace and capacity of monitoring and control activities has caused the number of unregistered abstraction points to rapidly increase (EASAC, 2010).

EU policies and regulations regarding water scarcity and drought have traditionally been less elaborate than those regarding water quality. Member States have historically taken a reactive approach focused on managing emergencies, rather than an approach focused on risk reduction. The root cause for this lack of integration between water quality and water scarcity policy issues is that, until recently, "most Europeans have been insulated from the social, economic and environmental impacts of severe water shortages" (EEA, 2009).

Extreme weather events that took place over the previous decade, and in particular the heat wave and drought of 2003, have prompted a shift in European drought and water scarcity policy. This has meant a transition from reactive crisis management to clear planning and risk-reduction. Addressing the challenge of water scarcity and droughts in the European Union, the Commission established that Member States should give priority to water saving and efficiency (demand side) measures before identifying and developing new water supply sources (EC, 2007b). Reducing water abstractions—for example, reducing network leakage rates, lowering per-capita consumption or installing drip irrigation systems—can go some way towards addressing growing water scarcity. While water pricing and economic policy instruments have been explored in many Member States, the rollout of new initiatives of this kind is politically complex and sometimes met with resistance. Tackling the main challenges associated with water scarcity will require increasing the resilience and climate preparedness of watersheds in an integrated manner, with the adoption of both demand and supply-side measures that include NbS.

6.2. What role can NbS play to alleviate drought and scarcity?

The European Commission encourages enhancing existing water infrastructure and expanding natural catchments and aquifers before building new waterworks. Most of the discussion on European water scarcity and drought policy took place before the concept of NbS had risen in prominence: as a result, virtually none of the early policy documents mention, let alone encourage, using NbS to address these issues. This changed with the Blueprint to Safeguard Europe's Water Resources, in which the EC highlighted the potential of green infrastructure and Natural Water Retention Measures (NWRMs) to limit the impacts of droughts and water scarcity on the continent (EC, 2012). The highlighted measures included wetland restoration, as well as floodplains and groundwater recharge as multi-functional storage and regulation elements. Upcoming technical and research reports are expected to bring NbS for water scarcity more into the fore, such as outputs from projects like NAIAD and NATURVATION, both funded through Horizon 2020. In addition, the EEA is expected to publish a report on water scarcity and droughts by early 2021.

In Europe, few well-documented cases of NbS have been designed specifically to address the issues of water scarcity and drought. Most of the initiatives to address water quantity challenges have related to policy measures (water licensing, abstraction restrictions, water pricing, benchmarking, awareness campaigns), technical measures (reduced network leakage, water-efficient appliances) and alternative supply sources (desalination, water reuse). Not until recently were NbS considered as additional options that can generate sizeable gains in water volumes. While NbS that address water quality and flood challenges can improve water availability, the NbS that specifically focus on water quantity are presented below, including aquifer recharge and wetland restoration.

Aquifer recharge (AR) has two applications, and both are applied in Europe: natural recharge and artificial aquifer recharge. Both store excess water during seasons of water abundance to ensure availability in periods of scarcity and drought. AR is often carried out to improve groundwater resources and is incorporated into a broader water resource plan.

Natural recharge occurs when precipitation, river bed seepage, flooding and other natural forms of water enter the groundwater system. The City of Barcelona provides a strong example of intervening to support naturally occurring recharge. The local water utility, Aigües de Barcelona, has experimented with constructed infiltration ponds next to the Llobregat River to filter and recharge water back into groundwater stores. It is estimated that, when fully in place, the measure would generate savings of over EUR 4.3 million per year on energy and pretreatment costs (see Case Study 13 – Barcelona). The Medina del Campo Aquifer in Castilla y Leon, Spain, is another example. The agricultural sector there relies greatly on groundwater for irrigation, and the NAIAD H2020 project has identified a series of nature-based solutions and subsidiary management measures to reduce the impacts of recurrent droughts (see Case Study 19 – Duero basin). Excess flows from the Tormes River will be used to reinforce the flows of three other rivers in the area, stimulating a gradual increase in the infiltration and natural recharge of the aquifer. The environmental and socioeconomic benefits of the measures are still to be estimated. This will be done through modelling, economic valuation, participatory validation and the use of multidimensional quantitative indicators.

Artificial aquifer recharge enhances natural groundwater supplies using man-made conveyance systems, such as infiltration galleries or injection wells. Well-documented cases show the effectiveness of this technique, which has been the subject of various large European research projects (Subsol, DESSIN, MARSOL, GO-Fresh) and widely explored in arid- and semi-arid regions beyond Europe. Artificial AR (also known as Managed Aquifer Recharge) has been in operation in countries like the Netherlands since the 1950s (see Case Study 7 – Waternet). In the Netherlands, approximately one-fifth of the drinking water is sourced via large schemes

of artificial AR: these have proven instrumental in balancing water availability and demand in periods of drought and water scarcity (Zuurbier et al., 2018).

Wetland restoration is the renewal of wetlands that have been drained or lost as a result of human activities. Wetlands that have been drained and converted to other uses often retain their soil and hydraulics characteristics, so they can be restored (EPA, 2012). In general, the best way to prevent further loss of ecological and economic value due to degradation of wetlands is by eliminating the pressures that degrade them—for example, designating wetlands as conservation sites. Given their capacity to store and regulate water flow, wetlands can function as important buffers against extreme weather events like droughts, heat waves and wildfires. Wetlands act as sponges during wet periods, holding on to water, thus allowing natural aquifer recharge. They also regulate the water cycle and act as a damper against extreme temperatures (Fennessy & Lei, 2018). An additional benefit is

the prevention of peat fires: These are common under dry, hot weather conditions in drained peatlands and have wreaked large social and economic impacts in places like Belarus and Russia (Anzaldua & Gerdes, 2011). This NbS has been studied and recorded in scientific literature and technical reports, but detailed knowledge on the impact of wetlands on water quantity is relatively limited. The focus of existing studies—and in fact, of the measures themselves—typically examines a wider range of effects than water quantity enhancement and flow regulation (for example, carbon sequestration).

EU water policy with respect to water scarcity and droughts will continue evolving as Europe's water resources come under greater strain. This will represent an opportunity to integrate NbS-WS into emerging solutions.

EU water policy with respect to water scarcity and droughts will continue evolving as Europe's water resources come under greater strain.

7. NbS-WS in Europe: Enabling Factors and Barriers toScale

This section starts by assessing the extent to which European stakeholders have adopted NbS to tackle water security challenges and/or have created enabling conditions for their adoption. Despite a common overall policy framework, European countries have adopted NbS-WS with various levels of enthusiasm and success. Based on a more in-depth review of experiences in five countries (France, Germany, the Netherlands, the United Kingdom and Spain), we found that the first four had on the whole more conducive frameworks and at-scale experience with NbS-WS, which Spain is lacking but intends to develop further. The majority of NbS-WS that European stakeholders have invested in have tackled water pollution challenges. However, to respond to climate adaptation challenges, NbS to address floods and water scarcity are rapidly gaining prominence as well.

We then examine key barriers and enabling factors to accelerate investments in NbS-WS. In many countries, despite an overall policy framework that welcomes NbS adoption, acquired behaviours are often the strongest barrier to scale. In addition, governance, technical, physical or financial factors can play a role in limiting their adoption. For example, although significant funding has been made available for NbS-WS through the Common Agricultural Policy (CAP), funding streams are complex and fragmented, and they do not support widespread improvements in environmental outcomes. We review what has worked well in some countries and what has proved harder to shift in others to provide the basis of our recommendations for incremental change in the last section.

7.1. Pioneering experiences with NbS-WS exist in Europe, but scale is limited

Assessing the extent to which European countries have adopted NbS-WS is complicated by the fact that available information is partial and fragmented. Most NbS-WS initiatives are very localised, and many institutions that invest in nature to tackle water security challenges do not record such investments or assess their impact in a systematic manner. Even calling NbS by the same name is problematic: across Europe, different terminology is used to refer to NbS-WS—like green infrastructure, ecosystem services, nature-based solutions, watershed investments, ecological infrastructure, green-blue investments or Natural Water Retention Measures (NWRM). In the present report, we have identified and documented 19 cases where local governments, water management agencies, water service providers and large corporate water users have taken the lead to invest in NbS-WS, as defined in Section 2. Many more cases exist throughout Europe but not necessarily at the same scale or with the same level of multi-stakeholder engagement.

Over recent years, initiatives to map out NbS experiences have flourished and led to the creation of online databases, many with EU funding. These databases, with the notable exception of that set up by the NWRM project, map a whole range of NbS and are not exclusively focused on NbS-WS. Annex C contains a list of the most relevant databases of NbS cases in European countries, with some examples of NbS-WS. Such databases are far from comprehensive, but they are a good indication of the types of steps being taken. A report by Forest Trends on the state of European markets in watershed investments offers another relevant source of information on the present state of implementation of NbS-WS (Forest Trends, 2017). This publication presents broad trends in the size, scope and direction of watershed investment mechanisms at the European level. National-level data is also provided for a number of countries where watershed investments are prominent, along with information on policy and key trends. Even though we do not have a comprehensive view of where NbS-WS have been adopted in Europe to date, extensive background research undertaken to prepare this report helped us draw preliminary conclusions with regards to the state of play of NbS-WS in Europe.

Despite a common overall water policy framework, European countries have adopted NbS-WS with various levels of enthusiasm and success. Our assessment of the use of NbS-WS has focused primarily on five countries: France, Germany, the Netherlands, the United Kingdom and Spain. As it was not possible to analyse take-up in all 28 EU countries with similar depth, these countries were selected as initial evidence gathering showed that they had adopted NbS-WS at various levels and had different governance and financing frameworks for those solutions. We found that the first four countries had on the whole more conducive frameworks and at scale experience with NbS-WS, which Spain is lacking but intends to develop further. Although all countries operate under the same EU policies, they have not all transposed these policies in their national and in some cases subnational regulatory frameworks to the same extent. In addition, diverse governance structures for their water sectors means that different kinds of stakeholders have taken the lead in investing in NbS-WS or in influencing how decisions are taken in this area, as discussed in more detail in Sections 7.3 and 7.4.

With respect to the types of NbS-WS, these have tended to mirror the gradual shifts in focus of European water policy from one centred on pollution to one that actively addresses a greater set of issues, including floods and water scarcity.

To tackle water quality challenges, particularly with regards to diffuse pollution from agriculture, much of the funding for changes in farming practices has come from subsidies from the Common Agricultural Policy. As discussed in more detail in Section 7.6, those subsidies often constitute the bulk of payments to farmers. The gradual "greening" of the CAP has sought to place greater emphasis on subsidising farmers to adopt practices that help meet environment and climate goals rather than on intensive production. These subsidies have sometimes been affected by delays or inconsistencies in the ways they are disbursed, however. In addition, they are disbursed to farmers on an individual basis, which does not allow adopting a "landscape-scale" approach for prioritisation, implementation or monitoring and evaluation. As a result, impacts have been limited and improvements slow (see Sections 3.1 and 4.1; Box 7-4).

To support the adoption of NbS-WS in a more systematic and targeted manner, some drinking water suppliers or large water users have invested in protecting water resources at source. Several such experiences exist in Europe, although they remain limited. Water service providers have for the most part focused on supporting farmers to adopt improved agricultural practices (or in some cases, to switch to organic farming). Downstream water users do so because it allows them to protect their water sources and keep downstream treatment costs low. The example of New York City (see Section 2) is probably the most well-known internationally. In Europe, several water service providers have been engaged in such activities for years or, in some cases, decades, as nine case studies in Annex A showcase. Stadtwerke München (SWM), the utility serving Munich in Bavaria (Germany), was one of the earliest proponents of these approaches in Europe. In 1991, the water utility launched an initiative to promote organic farming in the valley of the Mangfall River. The initiative, called "Eco-Farmers", was begun in collaboration with farmers. It focused on promoting organic farming in the catchment area of the Mangfall by offering technical and financial aid to farmers, and it has been successfully in operation since its launch. A similar approach was also adopted in the City of Augsburg in the same German state. The initiative was successful in both cities with conducive state laws potentially playing an enabling role, as described in Section 7.2. Since then, other utilities in Europe have followed suit.

Almost all privately owned water companies in England and Wales are currently engaging with farmers at catchment level to protect their water sources, with support from Defra (Department for Environment and Rural Affairs) and Ofwat, the economic regulator, as detailed in the same section. In France some water suppliers, both public and private, have engaged with farmers to protect water resources, protecting land or supporting land-use conversion to less intensive farming (see Case Study 9 – Eau de Paris). However, some policies and local-level regulation have prevented water service providers in France from investing more in NbS-WS to date, despite growing financial support from the French river basin agencies (as described in Section 7.6). Even though successful examples of the adoption of NbS-WS by water service providers in Europe do exist, these examples are still relatively few, scattered and not yet scaled up. As described in Section 7.2, many acquired behaviours at the level of water service providers mean that these activities are still not mainstreamed.

In the area of floods, the Floods Directive (2007) has prompted 26 Member States to include NbS (referred to as NWRM) in some or all of their flood risk management plans (FRMPs) (EC, 2019b). The degree to which MS included them, however, varies significantly. Luxembourg appears as a pioneer in this area, with NWRM making up about 90 percent of individual measures included in the plans. Member States who have had long-standing policies to address flood risk through a combination of grey and green infrastructure built their FRMPs on this basis. For example, four FRMPs in the Netherlands were built on the 2007 Room for the River Programme and the Delta Programme.[28] The Netherlands have been leading the way with producing a consolidated vision for dealing with floods, getting stakeholders to coalesce around such vision and mobilising financial resources commensurate with the plan (see Case Study 14 – Room for the River and Case Study 15 – Nijmegen).

At least 11 MS called for the restoration of natural river characteristics in their FRMPs, such as in Case Study 16 - Navarra in Spain (Annex A). In Bulgaria, for example, there are measures for the re-meandering of rivers. In at least three Member States (Bulgaria, Lithuania and Romania) measures include afforestation. In Croatia, the national FRMP sets out measures for NbS, including the incorporation of water retention and wetland areas in spatial planning; encouraging flood solutions involving wetlands, former floodplains, meadows, pastures and the restoration of alluvial forests; and promoting public awareness on natural water retention. In Romania, the FRMPs include NbS related to forest management in flood risk areas. Other countries, such as Poland, include preparatory studies and related work on NbS.

One water security challenge where NbS-WS are less adopted in Europe is water scarcity and droughts. As described in Section 6, existing knowledge on the impact of NbS on water scarcity is relatively limited in Europe even though such approaches are increasingly in use in the United States and other parts of the world. For example, in Texas, the Edwards Aquifer serves as the primary source of drinking water for nearly 2 million people, including the residents of San Antonio, the second largest city in the state. In addition to a growing population, multi-year droughts have diminished the state's water supplies. As an answer to these challenges, The Nature Conservancy helped establish a water fund in 2000 to protect the aquifer and worked alongside City officials and surrounding communities to ensure it has the greatest impact (see Box 8-2). To date, the efforts have helped local governments invest more than US$500 million in watershed protection and conserve more than 48,560 hectares above the Edwards Aquifer, including 21 percent of the aquifer's recharge zone (Abell, R., et al., 2017). In Spain, we identified two cases that focused explicitly on deploying aquifer recharge, including Barcelona and Medina del Campo. In the latter case (see Case Study 19 – Duero basin), the EU-funded NAIAD project (which stands for NAture Insurance value: Assessment and Demonstration) is exploring the potential role of NbS as a natural insurance mechanism against extreme hydrological events, such as floods and droughts, among other benefits.

Most of the NbS-WS have been tested as pilot projects and at relatively small scale, with some notable exceptions where the establishment of multi-governance platforms facilitated scale-up. One of these exceptions is the Room for the River programme implemented by multiple stakeholders in the Netherlands (see Case Study 14 – Room for the River). The programme ran between 2007 and 2018 and led to the implementation of 34 specific projects across the Netherlands in the catchment of the four main rivers in the country (IJssel, Rhine, Lek and Waal). The project was entirely funded by the Dutch government with a total budget of EUR 2.3 billion. Although the Ministry of Infrastructure and Environment managed the programme, a multi-level governance platform that combined centralised and decentralised approaches enabled the integration of plans across provinces, municipalities, water boards and water management authorities.

The next subsections examine what have been the main barriers to scale and how some countries that have accelerated uptake of NbS-WS have been able to address those barriers. Section 8 goes one step further and formulates recommendations for "transformative scale-up", particularly in areas of governance and financing.

28 Delta Programme, available at: https://www.government.nl/topics/delta-programme/introduction-to-the-delta-programme, accessed on 27 July 2019

7.2. Acquired behaviours often are the strongest barrier to scale

Acquired behaviours have in many cases been the strongest barrier to NbS-WS adoption in Europe (and elsewhere) to date. Reluctance or difficulties to change can affect all key actors with a stake in water sector investments, including national and local governments, water service providers and large water users (such as farmers or corporate users). Resistance to change may be due to a variety of factors.

We found that overall policy frameworks are, for the most part, conducive to investments in NbS-WS (see Section 2.3 and Section 7.3). However, change may be difficult to deliver because of a "path dependency" on past experiences and resistance to change. Stakeholders may not have the incentives or feel responsible for investing in nature for water security, due to complex governance arrangements and the lack of a clear definition of roles and responsibilities in this area (see Section 7.4). Actors may argue that it is not practical to change their existing practices due to physical or technical challenges, as set out in Section 7.5. They may fear the financial impact of adopting what they view as new or untested practices. In many cases, they can access funding to adopt new practices or invest in green infrastructure, but such funding may be inadequate or provided through many fragmented channels that it can result in contradictory or mutually cancelling incentives (see Section 7.6).

Consultation undertaken for the preparation of this report (including workshops in London and Madrid, as set out in Annex E) helped identify key behavioural barriers for different types of actors as well as potential ways to address such barriers, as reflected in Table 7-1 and subsequent sections.

Table 7-1 *Potential barriers to NbS-WS adoption by types of water sector actors and ways to address them*

Water sector actors	Potential barriers	Ways to address barriers
National governments / policy-makers	▪ Limited awareness of what NbS-WS can achieve; this can be observed at the level of all stakeholders below, partly due to lack of proper advice ▪ Perception that NbS-WS are riskier than conventional "grey" solutions and concerns about compliance ▪ Uncertainty about effectiveness and cost-effectiveness of NbS-WS	▪ Establish global, regional or national support structures to disseminate information about NbS, with specific focus on NbS-WS ▪ Define and apply common frameworks for evaluating effectiveness and cost-effectiveness of NBS-WS ▪ Disseminate knowledge about technical solutions across sectors but also on levers for their adoption (policy, governance, financing)
Local governments	▪ Existing procurement rules for water service delivery contracts often place excessive focus on grey infrastructure ▪ Evaluation in procurement processes do not include options to assess NbS ▪ Limited knowledge of how to plan, adopt and monitor NbS ▪ Local policy documents concerning multiple areas that can impact NbS-WS (e.g., urban planning, biodiversity, water) may not be well coordinated and difficult to align due to a silo approach instead of a systemic one	▪ Define contracts based on outcomes rather than on technical specifications or specific outputs ▪ Amend criteria for auditing programmes to allow for NbS-WS ▪ Improve capacity of City decisionmakers to develop plans that incorporate NbS as part of a systemic approach to boost urban resilience ▪ Take part in City networks and alliances that can help disseminate good practices ▪ Develop guidelines that set out how to maximise co-benefits from NbS-WS

Water sector actors	Potential barriers	Ways to address barriers
Water service providers	▪ Operating model is often focused on building grey infrastructure ▪ Focus on regulatory compliance and limited potential for experimentation or risk-taking	▪ Systematically consider combination of green and grey infrastructure in optimised investment plans ▪ Work in partnership with other entities (local governments, water users) to invest in NbS-WS in upstream catchment
Water regulators	▪ Favour short-term achievement of results and regulatory certainty over more sustainable long-term results	▪ Accept greater uncertainty in short-term outcomes in exchange for higher and better distributed benefits over time
Farmers	▪ Reluctant to sell land or water abstraction rights for conservation ▪ Reluctant to modify farming practices for fear of reductions in yield and income ▪ Lack of land to be set aside for conservation	▪ Receive incentive payments or facilitated access to credit to finance transition ▪ Disseminate information about improved agricultural practices and impact on yield ▪ Assign resources to buy or convert land for conservation

Source: *Authors*

Central governments may not be fully aware of the potential that NbS-WS can offer. Beyond offering a conducive policy environment in line with EU policies, governments have a role to stimulate and provide demand for ecosystem services and can set up and fund support structures to encourage adoption of NbS-WS. Section 7.3 provides examples of what some national governments have done or could do in this area to accelerate take-up.

Local governments can act as catalysts and be pioneers for the adoption of NbS-WS. However, many of them are not organised to do so. The provision of water services is largely decentralised in the European Union, as discussed in Section 7.4. Local governments are key investors in water services and are also in charge of specifying contractual terms when they contract out the provision of such services. Local governments can therefore significantly impact the inclusion (or not) of NbS-WS into water sector investment plans and other local development plans. Participants to the London workshop organised in preparation for this report (see Annex F) highlighted that limited awareness of the benefits of NbS-WS at the level of local governments and a lack of willingness on local governments' front to specify results in outcome terms (rather than outputs) limited water service providers' ability to propose innovative solutions in this area. Procurement systems often lead local governments to define results in rigid or prescriptive technical terms (for example, volume of water going through tertiary treatment) rather than in outcome terms (for example, volume of water discharged back into the environment that meets environmental standards).

Many water service providers do not consider investments in nature as central to their investments plans and tend to over-prioritise grey infrastructure investments. Water service providers are typically in charge of providing potable drinking water to citizens and taking away dirty water and treating it before discharging it back into the environment. There is a growing recognition that water service providers also need to act as "good stewards" of water resources, healthy ecosystems and biodiversity. Many acquired behaviours currently prevent the majority of water service providers (and associated contractors and small to medium enterprises throughout the supply chain) from taking on such a role, however. Water service providers may be limited in their ability to fund NbS-WS activities for a number of reasons, such as accounting rules relative to asset capitalisation, issues linked to land ownership, limits on their ability to finance activities outside of their service area, a perception of higher risks associated with these options or difficulties to engage with multiple stakeholders (including with some that may perceive them as competitors over access to water resources).

These limitations often relate to the lack of reliable data on NbS cost effectiveness, maintenance costs and monitoring costs. Methods for keeping track and valuing co-benefits from these solutions (in terms of climate, biodiversity or social cohesion) are also insufficiently developed or not truly operational to drive investment decisions. As a result, few water service providers systematically consider NbS-WS when drawing up their investment plans at present. As one participant to the London workshop put it, they are usually set up to "build stuff" rather than to engage in what they often perceive as complex and uncertain schemes that require them to work with multiple actors, including farmers or environmental NGOs. Their existing procurement rules are designed to obtain works and services rather than ecosystem services from a range of different actors.

Water service providers that have adopted NbS-WS overcame these constraints because they had a problem they could not solve at a reasonable cost with grey infrastructure solutions alone. For example, both Anglian Water and Severn Trent, along with other water companies in England, had to contend with the problem of metaldehyde, as discussed in Section 3.2. They found that engaging with farmers upstream to support them to switch to a more acceptable method of pest control was the only solution to an intractable problem. They deployed different strategies to do so, as described in Case Study 3 – Severn Trent and Case Study 4 - Anglian Water. To achieve results, they had to engage dedicated agri-scientist staff and form partnerships with local actors, including farmers and environmental organisations. This enabled them to meet with farmers on other issues as well, such as excessive fertiliser use. They found that NbS-WS can not only bring benefits in terms of water quality, they can also generate co-benefits for the environment and help them achieve their carbon neutrality goals. For example, by engaging with the Norfolk River Trust to construct an artificial wetland near a conventional waste-water treatment plant, Anglian Water obtained a cheaper waste-water treatment solution overall, cut its energy consumption and generated significant biodiversity and amenity gains in the area. Wessex Water estimated that investing in protecting water at source cost six times less than investing in and operating water treatment infrastructure.

Water sector regulators may be unwilling to accept methods that provide lower certainty of success, at least in the short term. Water regulators have a key role to play in this area: environmental regulators are in charge of setting environmental norms and ensuring that they are met, whereas economic regulators would typically need to approve the investments so that they can be covered by water charges (or other forms of revenues). In the case of New York mentioned in Section 2, the City had to convince the environmental regulator that targeted land protection could deliver similar results as conventional water treatment. It is only after it had done so that it could focus on protecting land in the Catskill Mountains rather than build an expensive water treatment plant. In some cases, however, regulators may be excessively focused on regulatory compliance and may not give providers the space to innovate and adopt NbS-WS instead of or as a complement to more conventional grey solutions. In England and Wales, for example, water companies have found that the Environment Agency sometimes restricted them in their ability to experiment with NbS-WS to achieve WFD objectives for which they are responsible. Regulators can therefore offer support by providing clearer regulatory guidance to facilitate the adoption of NbS-WS by, for example, developing standardised catalogues of NbS-WS typologies, as well as some explanatory guidelines of the different techniques and procedures out of their implementation.

Water regulators have a key role to play in this area: environmental regulators are in charge of setting environmental norms and ensuring that they are met.

As key implementers of NbS-WS, farmers themselves may in many instances be reluctant to adopt new practices with a lower impact on water resources. For example, they may be reluctant to sell (either their land or their water abstraction licences, or both), to change their farming practices or to set aside land for conservation. This might be due to a lack of awareness or well-founded concerns that alternative methods (for example for plant protection) may not be as efficient as the ones they currently use. For example, Anglian Water found that farmers were reluctant to adopt non-polluting slug pellets as a substitute for others based on metaldehyde because alternatives caused the slugs to bury themselves in the ground to die instead of staying at the surface: they therefore could not be certain that the product was fully effective (see Case Study 4 – Anglian Water).

7.3. Policy and regulation need to be sharpened to foster adoption

Water policy in Europe is determined at both national and local levels, based on the overall framework provided by European policies. European MS have to transpose EU directives into national (and, where relevant, subnational) legislation, taking account of their different water governance frameworks (see Section 7.4). As a result, although the indicators for compliance are uniform, there can be significant variation from one MS to another in terms of policy and regulatory frameworks for NbS-WS.

The degree to which water policy and regulation are centralised varies considerably among MS: in countries where water policies are centralised, such as in England and Wales, it has comparatively been easier to foster approaches that can facilitate adoption of NbS-WS. By contrast, in Spain, although a conducive policy environment is in place, water governance has historically been fragmented and coordination among different government levels has not been optimal.

England and Wales, which in many ways has the most centralised approach to water sector regulation in the European context, has brought in rapid changes to its policy and regulatory frameworks in the last five years to accelerate NbS-WS uptake. Policymakers and regulators in England and Wales have made reforms to enable water companies to place much greater emphasis than ever before on NbS-WS in their investment plans, as described in Box 7-1.

Box 7-1 - *Policy and regulatory drivers for NbS-WS adoption in England and Wales*

Over the last 10 years, water sector actors in England and Wales have increasingly focused on investing in NbS-WS to address water security challenges, with numerous water companies investing in green infrastructure (such as peatland restoration or constructed wetlands) or working with farmers to support changes in agricultural practices.

Water companies were privatised in 1989 through a public sale of their assets, concomitant with the establishment of a strong regulatory framework and the creation of Ofwat, the economic regulator for water and sanitation in England and Wales. Water companies in England and Wales have increasingly been investing in NbS-WS; many such initiatives are presented in detail in Annex A. That might be explained by the fact that they are in the unusual situation of owning water sector assets, including the grey infrastructure used for water supply delivery and, in some cases, land. Asset ownership enables them to take investment decisions that take account of the whole water cycle and can be based on a longer-term view of what is beneficial for sustainable service delivery and maintenance of natural assets. Such interest for NbS-WS did not come to them immediately, however.

One of the main policy drivers that has brought about stronger focus on NbS-WS is the Catchment Based Approach (CaBA), a policy developed and promoted by Defra (Department for the Environment, Food and Rural Affairs).

This approach encourages cooperation and partnerships among different actors (water companies, local authorities, government agencies, landowners, river trusts, angling clubs, farmer representative bodies, environmental NGOs, academia and local businesses) and promotes integrated management of river catchments. Catchment partnerships are active in each of the 100-plus WFD catchments across England, including cross-border ones with Wales. A website (www.catchmentbasedapproach.org) was set up at the national level, with support from an EU-funded Interreg project, to provide an online community platform and knowledge hub for all organisations interested in collaborative cross-sector management of the water environment. A national support group and technical groups support ground level initiatives.

Ofwat has also played a key supportive role for investments in NbS-WS.

Every five years, Ofwat sets tariff formulas for water companies that define a price cap for the next five years. They do so based on draft business plans submitted by water companies and their assessment of whether proposed investments contained in those business plans are justified and efficient. Since the last price-review period (2014-2019), water companies have agreed to commit to outcome delivery incentives (ODIs), some of which can be environmental in nature, to reflect their customers' willingness to pay. If the utilities achieve certain targets (including environmental ones), they will be allowed to charge a slightly higher tariff in line with customers' willingness to pay for such environmental improvements. For Severn Trent (see Case Study 3 - Severn Trent), this system provided a strong incentive (both internally and externally) to invest in NbS-WS.

Source: *Authors, based on Ofwat website and interviews with water companies*

By contrast, in Germany, each federal state adopts its own water law, which means that some states have more incentives and support for NbS-WS than others. A long-standing tradition of contractual agreements for nature and environmental protection has allowed innovative cooperative schemes for NbS in Germany. In Augsburg in the state of Bavaria, as early as 1988 the local water service provider Stadtwerke Augsburg (swa) developed and launched a management plan for the municipality based on three pillars: water protection zones, land acquisition and cooperation with farmers (see Case Study 10 – swa Augsburg). Munich, has also resorted to similar measures to protect its groundwater within the same period with its Eco-Farmers initiative from 1991. Critical to the success of the initiative in Munich was the land acquisition and leasing model used by Stadtwerke München, where the City bought land and offered financial support to farmers. A potential catalyst for both cities to have undertaken similar leasing models with farmers could have been the Bavarian state's regulation for restructuring water protection zones, which was issued in 1988. This required increasing the area of water protection zones, which created a conducive framework for Bavarian water utilities to establish contracts with farmers. Bavarian water providers have the freedom to set up compensation schemes directly with farmers, which allows for comprehensive and context-specific contractual agreements with strict water protection measures.

In countries or regions that have a shorter track record of NbS adoption, governments should consider establishing comprehensive support systems and reforms to accelerate scale-up. For example, in Spain, NbS are regulated by the Nature Protection and Biodiversity Law 42/2007. Although there are no legal obstacles to their adoption, NbS are not fully mainstreamed and awareness of their benefits at the level of sector stakeholders is low. To address this, the Ministry of Ecological Transition (MITECO) convened a stakeholder consultation workshop in March 2019 as part of the preparation of the present report (see Annex F for detail). Key recommendations that emerged from this consultation were summarised in a report (MITECO and TNC, 2019) that identified proposed actions (see Table 7-2). Many of these recommendations could be applicable to other countries where NbS-WS adoption is still at early stages.

Table 7-2 *Proposed actions to increase NbS-WS in Spain*

Proposed Actions	Awareness raising	Knowledge	Regulation	Governance	Financing
Raise awareness of the potential of NbS to improve water security	◉				
Include NbS in government priorities and policy framework (e.g., infrastructure strategies, climate adaptation strategies)		◉			◉
Document cases of success and failure of NbS for water security and define clear criteria for their selection and analysis	◉	◉			
Develop an NbS catalogue to share information and improve trust. Include NbS definitions and types that can be adopted with technical norms and potential benefits	◉	◉	◉		◉
Develop a guide to implement NbS with cooperation systems among different administrative levels	◉	◉		◉	
Incentivise their adoption: fiscal exemptions, facilitated approvals, preferable finance, obligatory inclusions in spatial planning processes			◉	◉	◉
Create a network to exchange experiences so as to inspire new initiatives in the urban and rural spaces	◉	◉			◉
Increase basic research and development investment		◉			
Reform university curricula and other advanced learning courses	◉	◉			
Organise trainings on NbS-WS for all public officers who work on multiple policy areas related to water	◉				
Develop the regulation on payment for environmental services so as to allow the development of financial mechanisms (including water funds)			◉	◉	◉
Incorporate financial mechanisms for NbS-WS in existing instruments to recover costs			◉		◉
Decouple project implementation from political processes				◉	◉
Carefully consider participatory approaches to include all key stakeholders and citizens	◉			◉	
Mobilise private finance as per international examples and from the insurance sector					◉
Mobilise European research funds to support access to finance, serve as a guarantee with public and private banks and coordinate with the Common Agricultural Policy (CAP) to mobilise these funds		◉		◉	◉
Launch an innovation prize for inventive financing and governance models	◉	◉		◉	◉

Source: *MITECO and TNC, 2019*

Aside from national or state-level policies, the adoption of conducive local policies is often critical for facilitating the adoption of NbS-WS. As NbS can contribute to multiple purposes (Bouwma et al., 2018), different areas of policy beyond water policies can have an impact on the adoption of NbS-WS and need to be coordinated. These include policies in the area of urban planning (including land use planning), local economic development, energy development, housing (including building codes, urban development plans or property taxes), parks and recreation, transport (due to potential flood damages to the transport network), health, environmental policy and biodiversity protection, food supplies (including urban agriculture) and solid waste management (Philip, 2011). Silos among various local policy areas must be broken to support NbS-WS adoption in line with circular economy principles and systems thinking. For example, in the case of the City of Glasgow (see Case Study 17 – Glasgow), nature-based solutions were integrated into existing local planning policies for regeneration and development—with multiple cross-cutting benefits across multiple policy agendas (flood mitigation, climate adaptation, recreation, heritage, biodiversity, education) and a partnership governance structure was adopted to help implement the Seven Lochs Wetland project. This paved the way for identifying viable financing options for the project as well as other green infrastructure in the project area.

Furthermore, to effectively mainstream water policies, plans and monitoring systems must be well articulated. For example, the River Basin Management Plans (RBMPs), Marine Strategies and Flood Risk Management Plans, the Common Agriculture Policy monitoring plans, among others, should ideally be coordinated given the existence of several areas of potential overlap. However, these processes currently have different implementation cycles and target years.

7.4. Governance: lack of coordination and of a clear voice for nature

Successful implementation of NbS-WS relies on local actors joining forces around a shared vision for a watershed or certain sub-basins. This often spans multiple governance frameworks, including river basin agencies (operating at catchment level), regional and local governments with, in some cases, the participation of national governments. Such fragmented governance frameworks make it more challenging for the water sector to attract investments than in more concentrated infrastructure sectors, such as the power or the telecommunications sector. In addition, when it comes to investments in NbS, additional local actors generally need to be involved in the decision-making process, such as farmers, farmers association or local environmental NGOs. This creates an administrative coordination challenge.

The water sector in Europe is, for the most part, characterised by fragmented governance arrangements, reflecting a long history of water management and complex local government systems. In the vast majority of European countries, municipalities are responsible for providing water and sanitation services. As there are many municipalities, there can be hundreds or thousands of water service providers: examples of this situation are presented in Box 7-2. Historically, those service providers are often under-capitalised, with limited technical and managerial capacities and difficulties to mobilise financial resources for investments.

Box 7-2 *Examples of fragmented governance arrangements for water provision in Europe*

GERMANY

In Germany, 12,000 municipalities are responsible for public water supply and sanitation. Smaller municipalities often belong to municipal associations to provide water and/or sanitation services. Municipalities or municipal associations can delegate these responsibilities to municipal companies, private companies or public-private partnerships. There are about 6,400 public water service providers and about 6,900 sanitation service providers in Germany.

ITALY

In Italy, as of 2012, the management of urban water services was entrusted to 3,161 service providers operating in 8,067 municipalities. However, only a few large service providers serve the majority of the population, following the creation of 91 regional water and sewer utilities, each covering an optimal service area (ATO) and operating under a concession from the regional government.

SPAIN

In Spain, 8,000 municipalities are responsible for providing water and sanitation services, either directly or through a municipal public company (54 percent of market share) or through concessions to a mixed public-private company (13 percent) or a private company (33 percent).

FRANCE

In France, there are 36,600 municipalities and approximately 15,000 water service providers, thanks to successive grouping processes. France is about to embark on a radical reorganisation of its water service delivery systems with the implementation of the Loi NOTRe, which seeks to strengthen competencies of the regions and of the groupings of municipalities.

Source: *Wikipedia; (French Government website, 2017)*

Some countries have taken steps to consolidate their water sector to provide the basis for more efficient water management. The World Bank reported in 2017 that a number of European countries, such as Portugal, Italy and Romania, have undertaken reforms to aggregate or group these water services to strengthen their capacities and bolster their ability to access financing for investments (World Bank, 2017b). For example, consolidation of water service providers in the United Kingdom (England and Scotland) and in the Netherlands, with a mix of public and privately owned and managed companies, has taken place over several decades.

In both cases, although it is difficult to assign clear correlation, these countries have also seen strong incorporation of NbS-WS into the development of their water service providers' management plans (see Case Study 2 – South West Water; Case Study 3 – Severn Trent; Case Study 4 – Anglian Water; Case Study 5 – United Utilities; Case Study 6 – Wessex Water and Case Study 7 – Waternet). Multiple factors can help explain why multiple water companies in England and Wales have been willing and able to invest in NbS-WS, which include conducive policy and regulatory frameworks (as described in Box 7-1 above) and the fact that service providers were aggregated along river basin lines in the late 1970s.

Fragmented governance systems, in which multiple relatively small entities are in charge of delivering services, can be an impediment for accessing finance for water investments, as detailed in Section 7.6. For example, the European Investment Bank, which is a major lender to the water sector throughout Europe, indicated that fragmented governance in the Spanish water sector has been a key obstacle for lending to the sector in recent years (MITECO & TNC, 2019). Mobilising investments for NbS with fragmented governance systems can be even more complex. For example, cities or water service providers may be limited by law in their ability to invest outside of city boundaries.

Local governments play a major role in determining whether or not NbS are considered as an investment option to boost water security. Local governments either provide water services themselves or choose to delegate responsibilities for service provision to private or mixed-ownership operators. When services are delegated services, local governments often remain in charge of planning and key investment choices. In those cases, they would retain the power to decide whether to include NbS-WS into the mix of investment options. However, they often lack adequate knowledge about what NbS can achieve in terms of water security benefits or perceive such projects as more complicated or expensive to undertake.

Some pioneer local governments have embraced NbS as they can see the multiple benefits that they can generate, not only for water security but also for the local economy and the environment. The City of Glasgow is an example of how NbS-WS can be integrated in existing local planning processes and deliver cross-sectoral co-benefits at the local level. The City implemented a plan for better managing natural wetlands and for creating new wetland habitat linked to planned development that can help mitigate flood risk and tackle diffuse pollution in the area. Among the key factors to the success of this initiative were the multiple cross-cutting benefits across different policy agendas: flood mitigation, climate adaptation, recreation, heritage, biodiversity and education (see Case Study 17 – Glasgow).

Privately owned water service companies that operate via delegated management contracts are often limited in their ability to propose innovative NbS as a way to deliver services in a more cost-effective and sustainable manner and generate co-benefits. For example, Eau du Grand Lyon, a Veolia subsidiary, has been able to maintain a forested area in the City centre to protect critical water resources partly because it has been present for many years through successive contracts (see Case Study 8 – Eau du Grand Lyon). Its experience when trying to replicate this kind of solution in other locations (including in Aguas Calientes, Mexico, in partnership with The Nature Conservancy) is that it is easier to preserve existing ecosystems than it is to restore degraded ones. As presented during the workshop in London, they found that due to their position as a contracted operator (rather than as network owners), scaling up NbS requires a long-term vision to be agreed and co-constructed by the company and its client (the municipality, in this case). Long-term benefits need to be taken into account instead of short-term targets that are often easier to reach with grey infrastructure and can be prioritised by politicians and regulators alike.

The WFD mandated that each Member State identify River Basin Districts and establish administrative arrangements to manage water at that scale, including through River Basin Management Plans (see Box 2-1). Some countries had river basin management structures already in place (such as France, which created six Agences de l'Eau to manage water on a river basin scale in the 1960s). In other MS, this meant setting up new institutions or redefining the role and functions of existing governance institutions. Transition from established administrative boundaries to jurisdictions based on geographical boundaries has been a challenge in many countries.

Since the adoption of the WFD, 124 river basin districts have been established throughout the European Union (Demirbilek & Benson, 2019). Many of these RBDs are transboundaries. In France, for example, there are 12 river basin districts out of which 4 are overseas territories. Germany has 10 river basin districts: 6 are international and shared with Denmark, Poland, Czech Republic, Austria, Switzerland, France, Luxembourg, Belgium and the Netherlands. All four RBD in the Netherlands are international. Spain has 25 river basin districts, out of which 6 are international sharing water courses with Portugal and France. The UK has 16 river basin districts: 11 in England and Wales, 3 in Scotland and 4 in Northern Ireland (EC, 2019d).

The creation of river basin management authorities is broadly in line with the OECD Principles on Water Governance.

The creation of river basin management authorities is broadly in line with the OECD Principles on Water Governance (OECD, 2015).[29] These 12 principles encourage a clear definition of roles and responsibilities among institutions playing a role in the water sector, fostering management at appropriate scale and ensuring policy coherence, "especially between policies for water and the environment, health, energy, agriculture, industry, spatial planning and land use", a key aspect for providing a conducive policy environment for NbS-WS adoption as described in Section 7.3. However, an assessment of the extent to which OECD governance principles have been adopted in EU countries found that countries have implemented the EU WFD differently: some have been slower than others in creating effective river basin management agencies (OECD, 2018).

Even where administrative arrangements are in place to plan water resources at river basin scale, stakeholders may see those planning processes as overly administrative and not deployed at a scale that can generate adequate levels of investment in NbS, which typically bring multiple benefits for multiple actors.

7.5. Technical barriers can limit the scale-up potential of NbS-WS

There might be physical barriers to the scaling up of NbS. Land may not be available to build green infrastructure, such as constructed wetlands to "polish" waste water, at a scale that is commensurate with addressing needs of large urban centres. Improved agricultural practices also lead to more extensive farming practices, which tends to require more land for comparable production volumes (although this is not necessarily true over time, when soil degradation is taken into account). Limited land may be available for protection or it may be too expensive, particularly when pressure is high to assign land to food production or urban expansion.

The lack of robust quantitative studies on benefits of NbS-WS creates a barrier to its acceptance by decision-makers. A key issue that has sometimes limited consideration of NbS-WS as part of water investment programmes is the lack of data on effectiveness and cost-effectiveness of these solutions, so they can be compared reliably to grey infrastructure solutions. Numerous case studies are available, but none of the databases included in Annex C systematically track the effectiveness and, most importantly, the cost-effectiveness of these investments so as to enable robust comparisons with grey infrastructure. There are few frameworks to acknowledge and assess the value of co-benefits of NbS-WS and to guide cross-sectoral project and policy design and implementation. One example is the EU Biodiversity Strategy, were the potential of Payments for Ecosystem Services (PES) is promoted, which implies that such payments can be made in the European Union. However, existing M&E systems are not simple, systematised and interlined. Outcomes are perceived to be riskier since they are dependent on a number of physical (and behavioural) factors. In addition, there is no accepted framework for monitoring and evaluating co-benefits from NbS-WS. Inadequate consideration of NbS-WS at the time of infrastructure planning and project development may be caused by a severe lack of practical and technical guidance for their adoption, including consideration and assessment of co-benefits within and across the stages of implementation and decision-making (Ürge-Vorsatz et al., 2014).

29 Developed by the OECD Water Governance Initiative, these principles were adopted by the OECD Regional Development Committee in 2015 as well as by more than 60 organisations through the Daegu Multi-stakeholder Declaration in April 2015 at the 7th World Water Forum.

7.6. Financing: too little, too fragmented, not sufficiently outcome-based

Like any other investments in the water sector, NbS-WS can be supported by multiple funding and financing sources. Box 7-3 shows the types of funding and financing that may be accessible for a water service provider. Other types of water stakeholders (such as farmers, municipalities or corporate water users) would have access to a similar mix. This section examines how NbS-WS are currently financed throughout Europe and provides a basis for the recommendations formulated in Section 8.

Box 7-3 *Funding and financing sources for the water sector*

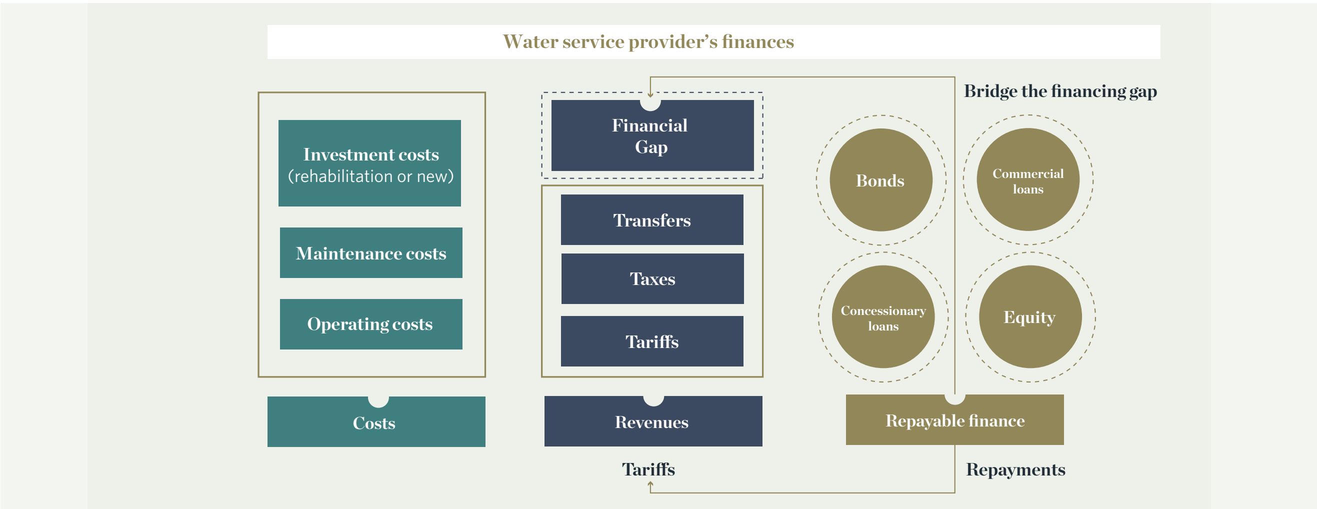
FUNDING SOURCES

Funding sources include all forms of revenues, including from tariffs, taxes (domestic grants and subsidies) and transfers (from philanthropic organisations or international grants) that enable a water service provider to cover its costs. These are commonly referred to as the 3Ts.

FINANCING

Financing refers to repayable financing that is provided up front to enable a water service provider to invest and bridge the financing gap between its costs and revenues. Financing may come from private sources (equity, commercial loans, bonds) or public sources (concessionary loans).

Figure 7-3 *Financing: too little, too fragmented, not suciently outcome-based*



Source: *Adapted from OECD, 2010*

From 2014 to 2020, an average of EUR 5.5 billion per year was committed to the restoration and conservation of watersheds and to sustainable management activities in the European Union (Forest Trends, 2017). The Forest Trends report identified three mechanisms for funding and financing NbS-WS: public subsidies for watershed protection, user-driven watershed investment, and water quality trading and offsets:

- Public subsidies reward land managers for enhancing or protecting ecosystem services. They are funded by governments—sometimes with multilateral or donor support—and typically operate at a large scale.
- User-driven watershed investments channel payments from water users, such as companies or water service providers acting on behalf of customers, to landholders or other parties (the sellers) in exchange for conserving, restoring or creating green infrastructure. Buyers may contract directly with sellers in a process known as bilateral agreements for watershed protection or pay into a collective water fund that pools contributions for greater impact. User-driven programmes can be voluntary or a mechanism to meet regulatory compliance.

- Water quality trading and offsets are mechanisms that allow water users to manage their impacts on watersheds by compensating others for offsite activities that improve water quality or supply. Compensatory activities are packaged as a credit or some other unit traded in an established "market," defined by watershed boundaries. Trading and offsets are often compliance-driven.

Public funding for NbS-WS dominates in Europe

An estimated 99 per cent of all funding for watershed investment in Europe comes from public funding sources (Forest Trends, 2017). These subsidies come from multiple channels, mostly from the European Union (in the form of CAP subsidies or dedicated grant funds) and from national, regional or local governments. Regarding CAP payments, national governments are expected to provide co-funding for Pillar 2 payments (as explained in Box 7-4). According to Forest Trends (2017), out of EUR 5.5 billion annual funding for rural development, EUR 3.5 billion of rural development funds comes from the European Union budget as co-financing and is matched by EUR 2 billion of contributions from MS budgets. The share of EU co-financing varies significantly from one MS to another, ranging from 26 percent of total payments in Luxembourg to 95 percent in Romania, with an average across the EU of 65 percent. Landowners also need to provide typically 20 percent in match funding for public subsidies under Pillar II of the CAP, whereas subsidies cover 80 percent of total implementation costs.

Public funds, although significant, can be challenging to mobilise and tend to be poorly coordinated, thereby limiting the potential to support large-scale investments in NbS-WS across Europe. As a result, these payments have not resulted in significant improvements in environmental outcomes due to difficulties encountered over the years with "greening" the CAP, as described in Box 7-4.

Box 7-4 *"Greening the CAP": further to go to help reach water and environmental objectives?*

The Common Agriculture Policy (CAP) is one of the most important funding sources across the EU.

It was introduced in 1962. Its current aims are to support farmers and improve agricultural productivity to ensure a stable supply of affordable food, promote a reasonable living for farmers, help environment and climate objectives, maintain rural areas and landscapes across the EU, and maintain a vibrant rural economy. Half of EU's land mass is farmland, even though farming currently accounts for less than 2 percent of EU's GDP. The CAP is based on instruments that can be summarised as follows:

- **Farmer subsidies –** direct payments for income stability, remuneration for environmentally friendly practices not paid by the markets;
- **Market measures –** interventions when difficult market situations occur;
- **Rural development measures –** national and regional programmes to support rural areas.

The CAP has been criticised over the years for problems associated with farming intensification, overproduction, subsidy dependency, diffuse pollution, soil degradation and loss of wildlife.

To address these issues, the CAP was reformed multiple times to improve its environmental performance. Some of the most important reforms included the promotion of 'environmentally compatible' farming practices and the introduction of the cross-compliance concept in 2003, which requires farmers to comply with a set of standards for public, plant, and animal health and welfare and decoupled direct payments from production to give clearer market signals to farmers. Green payments were introduced in 2013: they are a new type of direct payments to reward farmers for the public goods they provide when they adopt measures that contribute to soil, water quality and groundwater, amongst others. Green payments can be provided to farmers that implement improved agricultural practices, such as crop diversification, conversion of arable land to permanent grasslands and setting aside around 5 percent of arable land as ecological focus areas (including riparian buffers). The purpose of these payments is to improve the CAP's environmental performance.

Some of these payments can support NbS with the potential to contribute to water security.

The European Commission's Multiannual Financial Framework (MFF) 2014-2020 had a total budget of EUR 959.51 billion: 38 percent (EUR 362.79 billion) was allocated to the CAP, which disburses funds through two pillars:

- **Pillar 1 - the European Agricultural Guarantee Fund (EAGF)** primarily finances direct payments to farmers and measures that regulate or support agricultural markets. It accounts for 77 percent (EUR 277.84 billion) of the CAP budget and is entirely financed by the EU. It funds direct payments (subject to cross-compliance) and green payments. The green payments account for EUR 12 billion a year, which corresponds to 30 percent of all direct payments under the CAP, or 8 percent of the entire EU budget.
- **Pillar 2 - European Agricultural Fund for Rural Development (EAFRD)** finances the EU contribution to rural development and actions going beyond compulsory legislation. It corresponds to 23 percent (EUR 84.94 billion) of the CAP budget and is jointly funded by the EU and Member States themselves. It funds voluntary measures taken by farmers and land owners to adopt Agri-Environment and Climate Measures (AECM), which can include steps to contribute to achieving WFD objectives. In addition, it can fund regional programmes (via rural development payments) that support competitiveness of the forestry and agricultural sectors and protect the environment. At least 30 percent of rural development funds must be allocated to investment in the environment and climate, which includes compliance with WFD objectives.

The European Commission launched a public consultation in 2017 to inform a fitness check of the CAP on how to modernise, simplify and improve it. A complementary independent analysis identified a series of challenges with respect to CAP's track record in achieving environmental objectives, as shown in the table below.

CAP challenges Supporting evidence
Local and regional level successes but limited results at the EU level: Limited budget; low uptake; large number of exceptions
Efficiency is very low: Climate measures were included in the Agri-Environment measures (AEM) but the overall budget was not increase
Internal coherence between CAP measures and payments is low: Conflicting objectives between production and conservation
Multiple types of payments targeting similar objectives result in confusion, dilution of results and limited coherence
Limited incentives for farmers to work together to formulate joined-up approaches and demands
External coherence between CAP and other EU policies is low: Although environmental objectives of the CAP complement those of the WFD and environmental standards are included via the cross- compliance mechanisms, the CAP is not sufficiently aligned with other policies in areas of biodiversity protection and climate
Relevance is mixed: Outcome indicators are weak or missing
Monitoring is insufficient
Limited use of latest environmental criteria, tools and knowledge
EU added value is mixed: Measures targeted as part of green payments are not fully applicable in all MSs
Although some good results are found at national/local level, these do not necessarily add up at EU level

Source: *(Peer et al, 2017)*

Overall, the CAP has not been very effective at addressing environmental issues, due to limited levels of environmental ambitions, the lack of clear environmental outcomes for green payments, limited monitoring and evaluation and budget allocations that do not reflect the environmental policy requirements .

The environmental payments covered in Pillar 1 and 2 have not achieved their intended results to reduce environmental impacts. Regarding green payments, an evaluation by the European Court of Auditors showed that MS have in fact decreased their spending for environmental measures over time. As a result, only 5 percent of all EU farmland were managed with improved agricultural practices as of 2017. Furthermore, green payments and rural development payments only partially support water objectives. There is insufficient regulation enforcement (e.g., on irrigation) at the MS and local levels. Monitoring and evaluation is suboptimal, with data on agricultural practices and water impacts not submitted in a timely, reliable and consistent way.

Based on the results of the fitness check assessment, the EC published legislative proposals in June 2018 for the future of the CAP based on nine objectives, which include higher ambition on environment and climate action.

Looking forward, the European Commission proposes a flexible, simplified and performance-based CAP. The new European Parliament will examine these proposals.

Source: *ECORYS, 2017; Peer et al, 2017; Waylen et at 2019; ECA, 2017; AEC, 2014*

Other substantial public funding for NbS-WS comes from EU dedicated grant programmes. Given the high level of emphasis placed on NbS in EU policies (as shown in Section 2.3), multiple EU-funded grant programmes such as Horizon 2020, LIFE and Interreg have initiated calls on multiple aspects of NbS, particularly NbS-WS, as described in Box 7.5. Such EU programmes allocate multimillion-dollar budgets to investment in NbS-WS every year. However, these flows are by no means regular and are allocated through calls for proposals that require forming complex multi-partner consortia across European countries.

Box 7-5 *Key EU-funded grant programmes relative to NbS-WS: Horizon 2020, LIFE and Interreg*

HORIZON 2020, THE EU FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION RUNNING FROM 2014 TO 2020, IS THE MAIN RESEARCH FUNDING INSTRUMENT AT THE EU LEVEL FOR NBS.

The programme has three pillars: Excellent Science, Industrial Leadership and Societal Challenge. NbS are included in the societal challenge "Climate action, environment, resource efficiency and raw materials" and were defined by an expert group established in 2014, Nature-Based Solutions and Re-Naturing Cities. The final report, "Towards an EU research and innovation policy agenda for nature-based solutions and re-naturing cities", was published in March 2015 and defined the research agenda on this topic. For the period 2014-2020, the "Climate action, environment, resource efficiency and raw materials" portion received EUR 3 billion in funding out of a total budget of EUR 77 billion available for H2020. In 2017, for example, the European Commission selected 22 projects which received around EUR 219 million under this societal challenge. Of these, seven projects focused on nature-based solutions—with a budget of around EUR 49 million. The budget allocated to nature-based solutions in 2019 amounts to about EUR 17 million out of a total budget of about EUR 375.6 million available for this challenge.

THE LIFE PROGRAMME IS THE EU FUNDING INSTRUMENT FOR ENVIRONMENT AND CLIMATE ACTION.

It was created in 1992 to contribute to the development of EU environmental and climate policy and legislation by co-financing demonstration and pilot projects (as opposed to research). The LIFE programme is managed by the European Commission, DG Environment and DG Climate Action. The implementation of programme components is delegated to the Executive Agency for Small and Medium-sized Enterprises (EASME). The current funding period 2014-2020 has a budget of EUR 3.4 billion. LIFE has the following subprogrammes: environment (Nature and Biodiversity; Environment and Resource Efficiency; Environmental Governance and Information) and climate action (Climate Change Mitigation; Climate Change Adaptation; Climate Governance and Information). NbS-WS figure under the Environment and Resource Efficiency subprogramme. The projects in this category mobilised EUR 163.5 million, of which the EU will provide EUR 82.4 million. It was not possible to identify the share allocated to NbS-WS.

INTERREG TRANSNATIONAL COOPERATION, KNOWN AS INTERREG B, IS A VALUABLE EU INSTRUMENT FOR SUPPORTING COOPERATION ACROSS BORDERS THROUGH PROJECT FUNDING.

Projects need to involve regions from several countries of the EU to promote better cooperation and regional development through a joint approach to tackle common issues. Interreg puts the EU Cohesion Policy into practice and is funded by the European Regional Development Fund (ERDF). Over the period 2014-2020, its budget totalled EUR 10.1 billion invested in several cooperation programmes responsible for managing project funding. The 2014-2020 is the fifth period of Interreg (Interreg V) and is based on 11 investment priorities (thematic objectives). One of these, Environment and Resource Efficiency, includes funding for NbS-WS projects in its overall budget of EUR 82.5 million.

Source: *EC, 2015b; EC, 2013b*

Public funding also comes directly from national or local level budgets. France and the Netherlands are amongst European countries which allocate substantial public funding to water resource management and have recently increased the share of investments earmarked for NbS-WS. The Netherlands is well-known for having built its national identity and survival on its ability to manage water. It is a low-lying country prone to regular flooding, and they have had to expand its land mass by reclaiming land over water. In 2006, the government launched the Room for the River programme, a multi-level partnership which invests in a mix of grey and green infrastructure to reduce flood risks (for example, by enlarging floodplains to allow rivers to follow their natural course: see Case Study 14 – Room for the River). This series of projects, conducted between 2007 and 2018, were funded by the Dutch government, which dedicated EUR 2.3 billion for initial investments; more funding will be needed to cover operation and maintenance costs). In France, a growing share of public funds dedicated to the water sector through the river basin agencies is allocated to NbS-WS (Box 7-6).

Box 7-6- *River basin agencies funding in France: towards a greater share for NbS-WS*

IN FRANCE, SIX RIVER BASIN AGENCIES (AGENCES DE L'EAU) WERE CREATED IN 1964 TO ENABLE INTEGRATED WATER RESOURCE MANAGEMENT AT RIVER BASIN SCALE.

One of their key functions is to collect water abstraction and discharge charges from water users in a given river basin and allocate those funds as grants to water users in the same basin, to ensure that "water pays for water". The majority of these funds initially financed what is referred to in France as the "small water cycle" (including piped water and sewer network expansion and rehabilitation, and investments in waste-water treatment plants). In 2016 river basin agencies received an additional mandate through the biodiversity law, which requires that they also fund projects with a climate and biodiversity focus. Every six years, the agencies publish multi-year programmes that specify fee levels as well as methods for distributing public subsidies to local actors (local governments, water companies, associations). Financial support for a given project cannot usually exceed 80 percent of the total project cost. These programmes are approved by the water basin committees, which are multi-stakeholder governance platforms representing local water users and actors.

AT PRESENT, THE RIVER BASIN AGENCIES' MAIN OBJECTIVE WHEN DISBURSING FUNDS IS TO SUPPORT INVESTMENTS THAT ENABLE WATER BODIES TO REACH GOOD STATUS IN LINE WITH WFD OBJECTIVES.

A review conducted by the river basin agencies found that the annual budgets dedicated by river basin agencies to protecting freshwater and wetland ecosystems had risen over the years; it reached approximately EUR 250 million per year during the 10th programme (2013-2018). Further increases are planned in the 11th programme (2019-2024); the river basin agencies are expected to contribute to putting in place the French Biodiversity Plan 2020, with a total of EUR 5.1 billion for investments in climate change adaptation, preservation and restoration of freshwater ecosystems, and water pollution reductions (This approach is in line with the conclusions from the second session of a large public consultation organised at the request of President Emmanuel Macron from November 2018 to July 2019 (Assises de l'Eau). The meeting set out new approaches for the water sector to tackle water and climate adaptation challenges. The first part of the debate centred on mobilising investments to reduce leakage and improve network management, and the second part emphasised the need to invest in NbS-WS for climate change adaptation. The main objectives at national level are source water protection, saving water and improving allocation, as well as preserving rivers and wetlands.

The Seine-Normandy river basin agency, which works in the area around the Seine river basin in north west France, is one of the most advanced in integrating those priorities into the design of their funding programmes. For their 11th programme, Water and Climate, the agency plans to disburse close to EUR 3.84 billion over six years. This includes EUR 519 million for source water protection, EUR 305 million to support agricultural transitions and EUR 340 million for restoring ecosystems. To encourage innovation, the agency has created a specific type of "contract water-climate" to deliver subsidies. Through these contracts, applicants can obtain public funding for their investment project if they conduct a landscape scale analysis of water, climate and biodiversity challenges and propose a consolidated, multi-actor plan to address them. These include at least three relevant activities for climate change adaptation and at least one action to sensitise local actors to the links among water, biodiversity and climate.

Source: *Ministère de la Transition Ecologique et Solidaire, 2019; Eau Seine Normandie, 2018*

Private funding through user-driven investments in NbS-WS is steadily growing

On the private funding side, some water users which are heavily dependent on water resources for their business, as well as water service providers have funded programmes that incorporate NbS-WS over the last decades. These programmes are payments for ecosystem (or environmental) services (PES). For example, the payers may be supporting landowners and farmers to farm land based on certain conditions to reduce contamination of water resources. Large mineral water companies that are dependent on excellent water quality for their products, such as Danone and Nestlé, were amongst the first private corporations to support farmers with cash or in-kind payments if they adopted eco-friendly farming practices (see Case Study 11 – Vittel; Case Study 12 – Volvic).

A Forest Trends analysis of user-driven watershed investments in 2015 found that even though these investments are much smaller than public sources, the frequency of their use is steadily growing in Europe. The number of these programmes almost doubled between 2005 and 2015, according to Ecosystem Marketplace 2016, a survey of programme administrators on watershed investments (2014 and 2015). In 2015, they located 40 such programmes in Europe, with a reported EUR 39.4 million in watershed payments supporting investments on 604,400 hectares. The majority of the NbS-WS financed this were agricultural or pastoral sustainable management (62 percent), grassland conservation (50 percent) and forest restoration or enhancement (50 percent). Other types of interventions included forest conservation and wetland restoration or enhancement (Forest Trends, 2017).

A number of water service providers have been funding NbS-WS via user payments. This is most evident when they have a direct financial interest in paying for environmental services because doing so reduces their treatment costs

or delays (and in some cases eliminates) the need to invest in expensive treatment technology or additional infrastructure. As described throughout this report, a number of water companies in England and Wales are supporting NbS-WS and paying for those measures out of tariff revenues. Ofwat, the economic regulator, has specifically authorised them to use their revenues for such purposes (Box 7-1). By 2020, water companies in England will have spent more than £28 billion since privatisation on work to meet regulatory requirements for the environment. Historically, the majority of environmental spending has been on waste-water treatment, but in the last few years the water sector has escalated its use of catchment management, preventing pollution at source.

Figures from the Green Alliance Policy Insight (2018) show that in the Ofwat 2009 periodic review (PR09), which set water companies' spending for 2010-2015, only £60 million out of the £4.6 billion allocated to improve drinking water and environmental quality was spent on catchment management schemes and incentives (roughly 1.3 percent). By the 2014 periodic review, covering spending for 2015-2018, budgets for catchment management had more than tripled to £200 million. The periodic review PR19 initial assessment of plans for spending in 2020-2025 show that water companies propose spending more than £5.3 billion on improving the environment in the next planning period (2020-2025). Of this total, £4.5 billion is related to waste-water obligations, particularly removing phosphorus (£2.2 billion). For example, Anglian Water plans to invest £630 million to make the region resilient to the risks of drought and flood, nearly an eightfold increase in the scale of investment compared to the last planning period. Furthermore, £40 million have been allocated to protect drinking water quality through catchment management (Anglian Water, 2019). Although growing in importance, funding assigned from water companies is small by comparison to CAP subsidies paid to farmers in the UK; that amounted to about £3.1 billion in 2015, equal to 70 to 80 percent of the payments the UK received from the EU (Green Alliance, 2018).

In other countries, where the policy framework is less clear or conducive, water companies or municipal water service providers have also entered into PES schemes but have been on a weaker footing to set up these programmes sustainably. As a result, some face substantial hurdles in financing such programmes. For example, Eau de Paris, a water service provider owned by the municipality of Paris that provides water services to Greater Paris, had to seek special conditions from the EU in order to make payments to farmers above a certain monetary threshold. This shows more could be done to establish a clear status for PES in France and other European countries to clarify when and how these can be made, as they are sometimes perceived to run counter to the more standard approach embodied in the "polluter pays" principle (FNE et al., 2016). The conclusions from the Assises de l'Eau in France (see Box 7-6) point to a willingness to test those approaches at greater scale, to offer specific incentives for farmers to improve farming practices. In addition, SDAGE (Schéma Directeur d'Aménagement et de Gestion des Eaux)—local governance platforms which address specific water issues and cover about half of France—provide conducive structures for the adoption of such approaches (Ministère de la Transition Ecologique et Solidaire, 2019).

Repayable financing is limited and has mostly come through green bonds

Although public funding highlighted above is significant, it is still insufficient and too fragmented for tackling water security challenges at the necessary scale (especially in terms of quality, scarcity and flooding). To our knowledge, no comprehensive assessment of total funding needs has been made. However, the fact that challenges are not being overcome fast enough (as described in Sections 3 and 4) or are mounting (as discussed in Sections 5 and 6) is enough evidence that greater investments are needed to address them—and at a faster pace than at current rates.

Mobilising repayable financing to invest earlier in NbS-WS could help address current funding limitations, as long as clear revenue streams are identified to repay overtime. Removing constraints around funds availability would help bring forward investments—in turn front-loading conservation efforts and preventing further deterioration of water resources. This could be critical for preventing potentially irreversible damages to ecosystems and for avoiding the construction of grey infrastructure that may later become unnecessary or stranded. In addition, some interventions require substantial up-front investment because they provide benefits only when done at scale. For example, if land needs to be purchased and set aside for conservation, financing would typically need to happen up front.

Repayable financing for NbS-WS has been relatively limited in Europe to date, except as components of larger

financing packages in the form of either loans or bonds. Possible reasons for this include the fact that revenue streams for investments in NbS-WS have not been clearly identified or measured, and that projects that need such financing are relatively small and location-specific.

Public financing has been extremely limited, except when water companies have been the borrowers. The European Investment Bank (EIB), the European Union's bank and the world's largest multilateral lender, is also the largest provider of public financing for water investments across the continent. Lending by the EIB to the water sector is relatively limited, however: whereas total lending to Member States totalled EUR 316 billion between 2014 and 2018, lending to water, sewerage and solid waste amounted to EUR 14 billion over that period, or less than 5 percent (EIB, 2019). In December 2017, the EIB adopted a new strategy for its water lending that stressed its intention to invest in water security, including in NbS-WS (EIB, 2017). In practice, however, demand for loans that incorporate NbS-WS has been limited, and the EIB's ability to prepare projects with such features has also been limited. To address these constraints, the EIB set up a Natural Capital Financing Facility (NCFF) to channel financial resources into natural solutions across the European Union, using loan capital, guarantees as well as technical assistance grants.[30] However, the NCFF has had difficulties building a pipeline of projects, including in the water sector, as most projects that were received were poorly prepared with no clear revenue streams. The current approach is to incorporate NCFF financing windows (including grants for technical assistance) into the design of standard loans, as part of green-grey lending instruments. This approach was successfully applied in the design of a EUR 55 million EIB loan to the City of Athens which supports the implementation of its 2017-2020 investment plan. A EUR 5 million window funded by NCFF will support the implementation of the Municipality of Athens Resilience Strategy for 2030, with investments in improving green and water -related infrastructure.

One of the key issues limiting the potential for EIB to lend to the water sector is the sector's high degree of fragmentation and poor governance. In Italy, the EIB was able to lend more to the water sector through the creation of so-called hydrobonds, to address the small-scale nature of Italian water authorities (Rees, 2018). Those bonds, issued by an association of water supply providers that had formed a Special Purpose Vehicle (SPV), were structured and bought by the EIB and other financial institutions. This allowed nine small water suppliers in the Veneto region (followed by an additional four) to raise EUR 500 million for capital expenditure. Such structuring was possible thanks to a change in the water sector regulatory framework in Italy, which allowed giving investors more security and more stable financial returns.

Private financing for NbS-WS has been mobilised mostly through green bonds issued by credit-worthy entities, such as national and local governments, public banks or corporates including water service providers. The rapid development of the green bond market over the last 10 years has allowed channelling private funds into NbS-WS on a scale never achieved before—although this has been limited to a small number of actors so far and is difficult to track. The key characteristic of green bonds is that their proceeds are ring-fenced for spending on a limited number of project types with green characteristics. Since the EIB launched the first green bond in 2007 to finance its climate-related projects, more than US$750 billion has been raised through these instruments. Issuance in 2019 alone was expected to reach US$250 billion, according to the Climate Bonds Initiative's State of the Market report (2018). According to a recent survey of private investors' interest in natural capital, green bonds are a vehicle of choice for many investors looking for sustainable finance opportunities (TNC & EF, 2019). Green bonds are followed by other related types of bonds, such as sustainability bonds, resilience bonds, blue bonds or water bonds (see Box 7-7).

Only a small proportion of proceeds from such bonds is dedicated to NbS-WS, however, although it can sometimes be difficult to assess how water entities use green bond proceeds. The adoption of the Green Bond Principles on water in May 2018, which specifically define nature-based solutions in the water sector, can help signal to investors which green bonds are more beneficial to nature than others.[31] Leading green bond issuers in the water sector have included Anglian Water in the UK, which has raised £580 million from investors via green bonds since 2017, and NWB, the Netherlands Water Bank, which has issued EUR 3.6 billion in green bonds (which they call "water bonds"). However, only a very small proportion of the proceeds is used for investments in NbS (see Box 7-7).

30 The Commission and the EIB published a guide on how to invest in NbS in Europe, which also includes how to access support from the European Investment Bank's dedicated NCFF (EC & EIB, 2019).

31 Type of NbS mentioned include: groundwater recharge systems, restoration of riparian wetlands for flood storage, creation of safe delta flood zones, altering river flows, use of pumps to transfer water to/from natural aquifers, afforestation/reforestation, construction of artificial wetlands and creation of wetland retention ponds.

Box 7-7 *NWB, the Netherlands Water Bank: largest green bond borrower in Europe?*

- **NWB (formerly known as Nederlandse Waterschapsbank) is commonly referred to as the Dutch Water Bank.** It was founded in 1954 by 142 water boards in the Netherlands, following the disastrous North Sea flood of 1953 which caused the death of more than 2,000 people. In response, investments were needed to restore and protect the Netherlands from future floods. This included investment in the so-called Delta Works, which included dams and storm surge barriers in the southwest of the country, with an estimated price tag of around 20 percent of national GDP at the time. Although the Delta Works were not funded through the NWB, it is estimated that more than 50 percent of the country would be under water without the infrastructure and knowledge generated by NWB financing.

- **The NWB is majority owned by the Dutch water authorities, with minority shares owned by the Dutch state and provinces.** Its mission has gradually expanded over time to provide public financing not only for the water boards but also for public housing (since 1984) and later, for health care and education projects. Today, NWB provides funding for over one third of the public investment agenda in the Netherlands and is the second largest lender to the Dutch public sector. In 1996 the bank received its first AAA rating, the highest possible, which it has consistently maintained with a stable credit outlook, thanks to a history of zero default, and healthy leverage ratios.

- **Financing climate mitigation and adaptation (under which water falls) remains one of its nine priorities** (alongside social housing, health care, export promotion and promoting a circular economy). Water has decreased over time and now accounts for only 11 percent of its portfolio. The bank still meets 92 percent of Dutch Water Boards' financing needs, having lent them EUR 675 million in 2017.

- **NWB has been a pioneer in the use of so-called water bonds, which they started issuing in 2014.** Proceeds from such bond issuances are a key pillar of their overall funding strategy: they are then on-lent to water authorities to mitigate climate change through waterway management and energy recovery from waste water, to adapt to climate change through flood protection, and to promote water-related biodiversity projects such as dredging water beds, water treatment and waste-water transport.

- **NWB had issued seven water bonds until 2018, raising EUR 3.6 billion in USD, SEK and, of course, Euros.** In 2018 alone, NWB's green bond issuance totalled EUR 644 million, and 25 percent of its total funding was raised through green and social bonds. NWB's water bonds have been approved through a second opinion by Cicero and received the highest rating (dark green) from this green investment rating agency. They also have received high ratings by ESG data providers. Most of the proceeds from NWB's water bonds support the activities of the water boards that would also occur under a regular bond, namely flood protection (28 percent from 2014 to 2017), waste-water transport (20 percent) and water system management (20 percent).

Source: NWB website

Green bonds have some clear limitations, however, when it comes to mobilising private sector investments into NbS-WS. They are mostly accessible to large-scale, creditworthy issuers unless there are mechanisms in place to package multiple small or medium-scale investment projects into a fund that can itself borrow funding via green bonds. They can be more or less green, depending on the types of projects that are financed (which is where the adoption of Green Bond Principles with a focus on nature-based solutions can definitely help). They can also be more demanding to prepare for issuers than other types of financing instruments as scrutiny and transparency around use of proceeds is usually greater. As a result, some company treasurers are sometimes reluctant to go down the route of issuing green bonds, as they do not necessarily see a price advantage in doing so. More forward-looking companies, such as Anglian Water, have correctly identified that issuing green bonds allows them to tap into a deeper and growing pool of investors in search of sustainable finance opportunities, as described in Box 7-8. Ultimately, green bonds can be useful only if there are clear revenue streams associated with their repayment. That is where blended finance approaches are needed, to establish financing structures that allow mobilising upfront private financing whilst tapping into diversified revenue streams for their repayment. These can include water charges (both abstraction charges and tariffs for water services), subsidy schemes (such as the CAP payments) and other public funding streams, which need to be combined in a predictable manner.

Box 7-8 *Anglian Water: exclusive focus on raising financing through green bonds going forward*

- **Anglian Water led the way in the UK water industry when it adopted a Green Bond Framework in line with the Green Bond principles.** In August 2017, the company was the first UK utility company to issue a green bond, with a £250 million issue. Within two years, they had raised a further £580 million from investors through green bonds. Proceeds are used to finance green projects with environmental benefits.

- **Going forward, Anglian Water is planning to cover all of its financing requirements (estimated at £3 billion over the next five years) through green financing instruments,** as all of its future capital expenditure is deemed to be compliant with the Green Bond principles. The company has segmented their investment plan into 12 categories, according to their green and social characteristics. They are in the process of developing metrics for each category of investment so they can report not only on financial performance indicators, but also on the extent to which these investments allow them to contribute to the Sustainable Development Goals. Whereas some of their investments generate more water savings (such as installing smart metres), others enable them to reduce water pollution. Since 2010, Anglian Water has been reporting on the carbon impact of their investments, with the objective to cut carbon emissions by 60 percent by 2020 from a 2010 baseline and to become carbon neutral by 2050.

- **Investments in green infrastructure, such as constructed wetlands, are considered the "greenest,** (see Case Study 4 – Anglian Water with the example of a constructed wetland at the Ingoldisthorpe water recycling site). This investment demonstrated benefits associated with this type of green infrastructure, and Anglian Water plans to invest in more than 50 constructed wetlands in the next five-year price review period (2020-2025).

- **Anglian Water has identified that a growing pool of investors (particularly based in Europe) are interested in balancing returns in multiple areas and want to know more specifically what their funds contribute to.** Such investment categorisation enables Anglian Water to tap into diverse investor pools, with different priorities in terms of financial, social or environmental returns. They noted that green financing instruments allow them to attract a deeper pool of investors and achieve more active trading in secondary markets, all of which can help to keep future financing costs low.

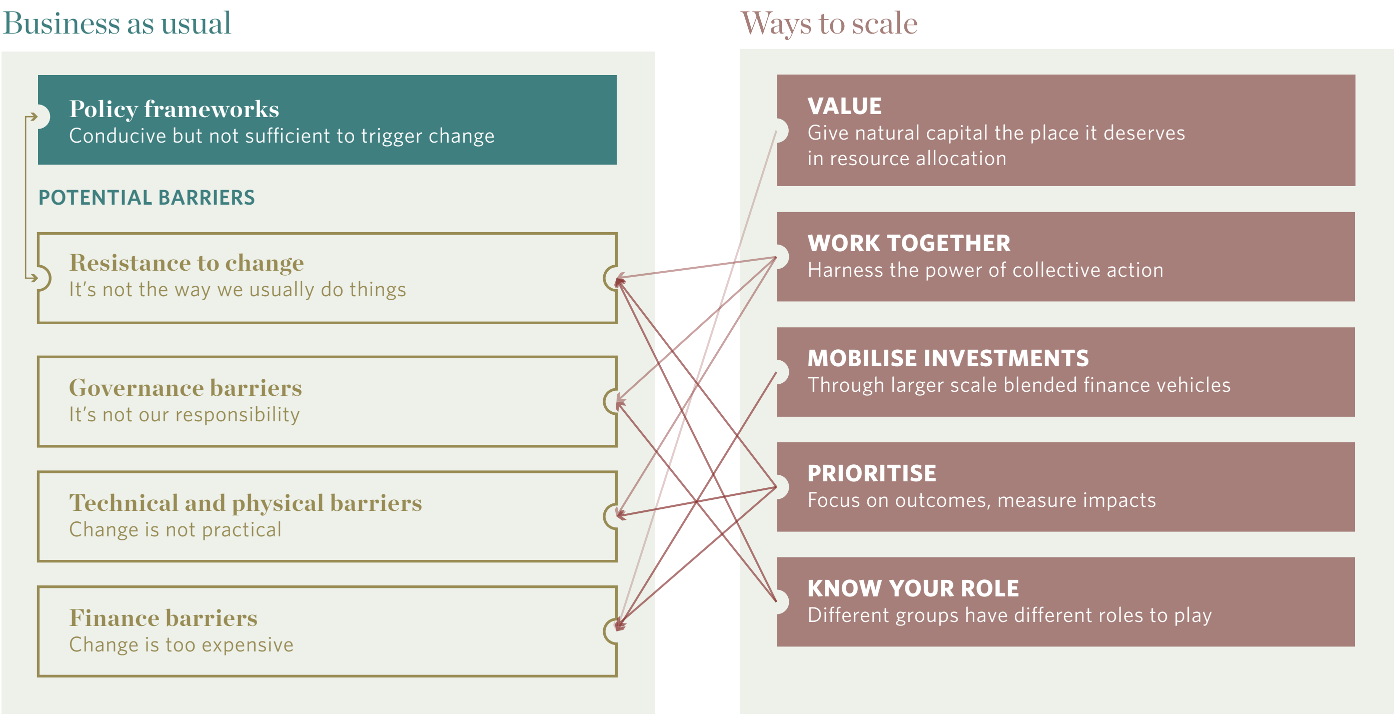
Source: *Anglian Water, 2019; interview with Jane Pilcher, Anglian Group Treasurer*

8. Transformative Ways to Scale

This section recommends ways to accelerate and scale NbS-WS. Where Section 7 highlighted existing approaches deployed by some European countries or Europe-based companies to address challenges, approaches presented here can be disruptive and scale-up NbS-WS further and faster. Each of the levers presented in this section could address several of the identified barriers at once as shown on Figure 8.1. If deployed in a well-coordinated manner, they have the potential to accelerate NbS-WS deployment so as to make a significant difference to alleviate current and looming water security challenges in Europe.

The analysis undertaken for this report has shown that momentum is building to accelerate investments in NbS-WS in Europe. The policy framework is overall conducive, there is growing awareness and political will at least in some MS. Substantial financial resources are already dedicated to those investments and this share is growing. What is lacking, however, is a coherent articulation of what NbS-WS can achieve, how much they cost and how they could be implemented and financed at scale. Figure 8-1 provides potential ways to scale NbS-WS that are discussed in more detail in the following sub-sections.

Figure 8-1 *Potential ways to disrupt business as usual and deploy NbS-WS at scale*



Source: *Authors*

8.1. VALUE: give natural capital the place it truly deserves in resource allocation

WHY?

Natural capital should be fully taken into account in investment decisions so that NbS-WS can be considered on a comparable basis with grey infrastructure options. This demonstrates that one NbS can generate multiple benefits in diverse areas, such as water security, biodiversity, climate, jobs and social cohesion, and amenity value.

RECOMMENDATION

Water sector actors (including national and local governments, water companies and large water users) should measure the impact of their investment decisions on natural capital and give priority to NbS-WS when they can increase natural capital values. Opportunities for such investments should be clearly articulated and prioritised so as to generate interest from public and private actors looking for sustainable investment opportunities.

WHY IT CAN BE TRANSFORMATIVE

This is a radical shift in how we measure and track value, so that clean water resources, biodiversity or reduced catastrophic risk from wildfires or floods are fully accounted for in investment and asset allocation decisions.

Preserving natural capital for future generations is essential for water security. Natural capital can be defined as the world's stocks of natural assets such as soil, air, water and all living things. Humans derive a wide range of services from this natural capital, often called ecosystem services, that make human life possible. Natural capital related to freshwater consists of healthy streams and rivers as well safely managed groundwater bodies (or aquifers). The latter may be "over-abstracted" (beyond a safe renewable yield) or become saturated with salt or nutrients, which means that groundwater bodies may become either too expensive or impossible to use. This amounts to an irremediable loss of natural capital for current and future generations. For this reason, it is essential to value natural capital, either for its own intrinsic value or via proxies, and measure the future streams of benefits that such capital can provide if maintained in usable and good condition.

One way to acknowledge and measure contributions made to conserving and enhancing natural assets is to adopt a natural capital accounting approach. At present, the majority of water sector actors do not treat nature as mainstream investments and are not able to fully compare NbS-WS with grey infrastructure. This is partly due to the fact that natural capital is still inadequately valued or taken into consideration in investment decisions, including by water sector actors (see Box 8-1).

Box 8-1 *What are natural capital accounting approaches?*

Natural capital accounting approaches operationalise the idea that natural capital should be considered in decision-making alongside other forms of capital, including built, social, human and financial capital. Taking account of natural capital can support decisions that maintain and enhance nature rather than degrade it.

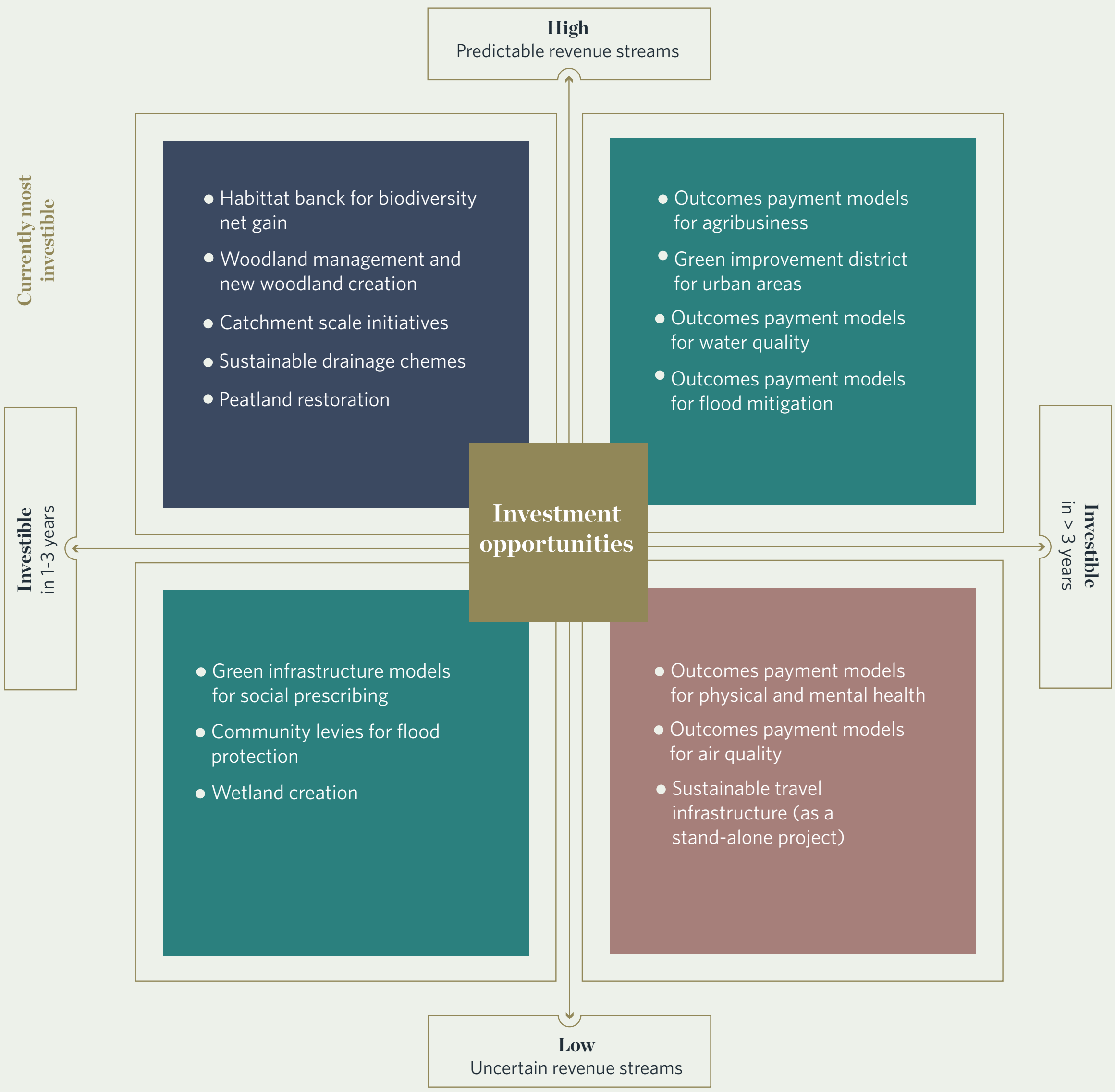
This approach differs from other more mainstream approaches that seek to bring environmental considerations into decision-making. Whereas ecosystem service approaches focus exclusively on benefit flows from biotic resources, natural capital approaches measure both stocks of natural capital (including biotic and abiotic natural resources) and flows of environmental benefits. They examine both dependencies of an economic activity on natural capital and its impact on such capital, rather than focus exclusively on impacts. At the global level, natural capital approaches have been supported and operationalised in recent years by the Natural Capital Coalition, a coalition managed by ICAEW (the Institute of Chartered Accountants in England and Wales): more than 300 organisations in the coalition work to develop and encourage a supporting environment for the adoption of natural capital approaches by corporates and investors. In 2016, the coalition developed and adopted the Natural Capital Protocol as "a decision-making framework that enables organisations to identify, measure and value their direct and indirect impacts and dependencies on natural capital".

Source: *Natural Capital Coalition, 2019*

The UK is one of the leading countries in Europe where natural capital approaches are adopted, including in the water sector. Following the publication of the landmark Natural Environment White Paper, The Natural Choice, the government established the Natural Capital Committee in 2012 as an independent advisory committee, initially for three years, to advise the government on the sustainable use of natural capital. As part of its terms of reference, the committee publishes annual reports on the state of the natural environment. The committee has also developed tools and approaches, such as a guidance on developing natural capital accounts for corporate (Eftec, RSPB & PwC, 2015). Their recommendations paved the way for the UK government's adoption of a 25 Year Environment Plan in 2018. Despite noting progress, the committee's sixth report (Natural Capital Committee, 2019) highlighted a marked degradation in the state of natural capital and called for major shifts in business practices to ensure that this landmark plan would not remain an empty shell. Progress is being made, with the adoption of an agricultural bill to replace the EU Common Agricultural Policy after Brexit. The bill includes the adoption of "public payments for public goods" that would provide subsidy flows to actions taken by farmers that can maintain and enhance natural capital, as well as the planned adoption of an environmental bill.

Water companies in England and Wales as well as local governments have started adopting these approaches to support decision-making. The Greater Manchester Combined Authority (GMCA), with support from eftec, Environmental Finance and Countryscape and in partnership with multiple local actors, released a natural capital investment plan. It identified what investments can be made to enhance natural capital in the Greater Manchester region and the associated business models to apply these investments (with a view to attract blended finance) and prioritise them (eftec, Environmental Finance & Countryscape, 2019). The plan classified potential investments according to the timeframe for investments and the predictability of revenue streams. It found that a number of NbS-WS, such as peatland restoration or outcomes payment models for agribusiness, scored highly in levels and predictability of revenue streams, as shown on Figure 8-2.

Figure 8-2 *Investability assessment of a pipeline of potential natural capital project types in Greater Manchester*



Low priority focus | Medium priority focus | Priority focus

Note:
The near term investment opportunities are those that provide the greatest opportunity to stack multiple revenue streams and funding mechanisms.

Source: *Eftec, 2019*

Several water companies in the UK (such as United Utilities, Anglian Water and Yorkshire Water) have also adopted ways to track multiple types of capital in their investment decisions. For example, Anglian Water has adopted a natural capital accounting approach to better track and report on their contribution to restoring natural capital, including their contribution to conserving water resources, biodiversity and soil. Natural capital is one of the "six capital" that Anglian Water has tracked since 2015, alongside social, human, manufactured, financial and intellectual capital in its annual report (Anglian Water, 2018). This approach is also applied to support decision-making for individual investment schemes, such as the constructed wetland at Ingoldisthorpe (see Case Study 4 – Anglian Water).

Although such approaches remain somewhat marginal to date in Europe, their broader adoption could radically shift how the value of clean and reliable freshwater—as well as preserving freshwater ecosystems—is taken into account in investment decisions. Their adoption would help water sector actors better understand the natural capital they are reliant upon and reflect their NbS-WS related investments on their balance sheets.

Adopting a national framework encouraging or even mandating the adoption of such approaches could provide the necessary leadership for water sector actors to follow suit.

8.2. WORK TOGETHER: harness the power of collective action

WHY?	RECOMMENDATION	WHY IT CAN BE TRANSFORMATIVE
Investing in NbS-WS generates multiple benefits for multiple parties. They are often not implemented as no one actor can derive sufficient benefit to justify making the investment.	Beneficiaries should work together at basin or sub-basin level to establish governance and financing structures that enable joint planning, investment, management and maintenance of NbS-WS. Models for such governance platforms exist throughout the world and in Europe and could be systematically encouraged at national and regional level, by proposing models for such groupings and rewarding governance and financing innovation.	Multi-partner governance platforms are a prerequisite to attract funding and financing from varied sources in a coordinated manner and to achieve impact at scale.

As discussed in Section 7.4, multiple levels of governance for water sector management in Europe have led to overlapping responsibilities and lack of clarity. Many European cities were built on their ability to access resources from surrounding rural areas, including water and food. Whereas food supply chains have become increasingly diversified and global, the management of water resources remains a largely local issue which provides a direct link between cities and their hinterland. Given the ongoing climate crisis and rapid urbanisation, cities' footprint on their local water resources and their interdependence with surrounding rural areas is set to increase (Garrick et al., 2019). Rather than entering into a competitive relationship, cities, large users and surrounding rural areas (where water is sourced), can work collaboratively to steward water resources for mutual benefits. This in turn has the potential to strengthen social cohesion, improve the environment and smooth the transition towards a more sustainable economy. Potential partners include local governments, water service providers, large water users (industry, energy producers, irrigation groups), small farmers (preferably through associations) and local environmental groups.

Governance and financing mechanisms, such as water funds, can be developed to address such governance failures and mobilise multiple types of funding streams. The Nature Conservancy, and multiple partners are promoting the establishment of Water Funds (defined in Box 8-2) where they can aid targeted and sustained investments in NbS-WS.

Box 8-2 *Water Funds: multi-stakeholder governance and financing mechanisms to mobilise investments in NbS-WS*

Water funds are financial and governance mechanisms that coordinate public, private and civil society actors in order to contribute to water security through nature-based solutions and sustainable management of the basin. Water Funds are transparent, adapted to the local context, inclusive and innovative, and they promote long-term systemic change. Establishing them is based on scientific evidence to identify whether and how NbS-WS can contribute to water security in their area of intervention.

A water fund provides the following benefits:

- Develop a shared vision that translates into actions to achieve water security;
- Bring together different actors who, through collective action, promote the political will necessary to achieve meaningful and positive impacts;
- Influence local water governance and decision-making processes;
- Drive the launch of natural infrastructure projects and other innovations in the basins;
- Mobilise diverse funding and financing sources (both public and private) via a large variety of financing and governance models.

The first water fund was established in Quito in 2000 in response to growing water demands and concern over watershed degradation. The municipality of Quito, the water company of Quito and The Nature Conservancy helped create the Fund for the Protection of Water (FONAG). The goal was to mobilise critical watershed actors to exercise their civic responsibility on behalf of nature, especially related to water resources. The multi-stakeholder board—composed of public, private and NGO watershed actors—provides a mechanism for joint investment in watershed protection, including supporting the communities that live there. FONAG conducts source water protection through a variety of mechanisms. First, it works to protect and restore high Andean grasslands (páramos) and Andean forest in critical source areas of water for Quito, including those owned by local communities, private landowners and the Quito water company. FONAG also focuses on strengthening watershed alliances, environmental education and communication to bring additional watershed actors. Working with several academic institutions, FONAG has also established a rigorous hydrologic monitoring program to communicate and improve outcomes of investments. FONAG has an endowment of more than US$10 million and an annual budget of more than US$1.5 million. The largest source of funding (nearly 90 percent) comes from Quito's water company, which by a municipal ordinance is required to contribute 2 percent of the water company's annual budget. Since its inception, FONAG has worked to protect and/or restore more than 40,000 hectares of páramos and Andean forests through a variety of strategies, including working with more than 400 local families.

Another 35 water funds have since been established with support from The Nature Conservancy, including throughout South and North America as well as in Nairobi (Kenya) and Cape Town (South Africa).

Source: *Abell R. et al., 2017*

Multi-partner governance platforms exist in various forms in Europe. They are usually set up at a more local scale than River Basin Districts and engage stakeholders around local investment projects. Examples of such platforms include the SAGE (Schéma d'Aménagement et de Gestion des Eaux) in France, which are local water governance platforms comprising of multiple actors that are created when a specific water challenge has been identified. As of May 2019, under 200 SAGEs were in place and the French government was planning to generalise this approach across the country. Part of the plan is to better include climate and biodiversity considerations in the measures planned and implemented by such platforms.

In England and Wales, a number of regional collaborative alliances have formed over the last 10 years to help address shortcomings of water resource management planning conducted in silos by individual water companies. Five alliances are working to coordinate water resource planning at regional level with multiple local actors. Though the alliances began as water users' initiatives, Defra and water sector regulators mandate their creation throughout England and require that they produce regional water resource management plans. The most advanced ones are Water Resources in the South East (WRSE) and Water Resources East (WRE), presented in Box 8-3.

Box 8-3 *Water Resources East in Eastern England*

Water Resources East (WRE) is a water management governance platform in Eastern England that brings together more than 70 partners around the development of a shared plan for managing water resources in the region, including NbS-WS that generate multiple benefits and mobilise financial resources for these solutions. Anglian Water initiated WRE in 2014 to develop collaboration among water users in different sectors, to improve the environment while responding to the pressures of population growth and climate change. WRE projects are based on the idea that "there is not a lack of water, but a lack of sustainable and resilient water management". WRE became an independent, not-for-profit company in June 2019. WRE is planning to include as many stakeholders as possible in these planning efforts so as to identify solutions to address an expected supply-demand gap of 750 megalitres a day. Potential answers are likely to include standard grey solutions (including building more storage) but will examine ways for such storage to be multi-purpose as well as communicating with floodplains to contribute to restoring ecosystems.

Source: *WRE 2019*

Member States should actively encourage the creation of local governance water management platforms. As demonstrated by TNC's experience with water funds and existing experiences throughout Europe, such governance platforms can take many forms, from coordination platforms that ensure planning and implementation by multiple actors are well aligned, to full-fledged self-standing institutions (such as FONAG in Ecuador), with their own budget and staff, supported by multiple revenue streams. Such governance platforms are particularly necessary when the launch of NbS-WS needs to be well-coordinated to achieve impact at landscape scale. Permanent institutions can be more effective at ensuring green infrastructure (such as forests or constructed wetlands) is adequately maintained. Otherwise, if it does not sit on any other institution's balance sheet, it might fall through the cracks. To the extent possible, these should be flexible, partnership-based institutions that include relevant local actors and help them to see the critical importance of investing in nature for local water security.

8.3. MOBILISE investments through blended finance packages

WHY?

Public funding constitutes the lion's share of investments in NbS-WS in Europe to date. Although significant, these funding streams do not allow addressing water security challenges at the scale of a given region or for specific types of investments that can have big impact if set up at scale (such as peatland restoration or carbon sequestration). Besides, strong competition regarding the use of public funds for water investments means that NbS-WS are not prioritised. Private investors are actively looking for opportunities to grow their sustainable finance portfolios but lack adequate financial products to channel their investments.

RECOMMENDATION

Philanthropic or private funding can help prepare consolidated projects that can be structured in a way to attract private financing. Intermediary partners (such as environmental NGOs, consultancies or investment banks with environmental objectives) are needed to help package water-sector investment needs in a way that can attract financing as long as reliable and predictable funding streams exist to repay upfront investment.

WHY IT CAN BE TRANSFORMATIVE

Mobilising repayable financing would allow investments earlier in the game and prevent further deterioration of water resources and biodiversity. Attracting private financing would provide access to substantial, liquid and deep financing markets, necessary for scale.

Water investments are local, technical and highly context-specific. This makes the task of scaling up investments challenging, particularly for NbS-WS, which vary hugely because they are designed and implemented according to local environmental conditions. Fragmentation is a significant issue for NbS-WS projects, which are frequently small, very localised and relatively inexpensive compared to other larger grey infrastructure projects. In addition, given that issues such as poor water quality take a very long time to address, long-term investments are required to enable sustained improved agricultural practices and to reverse previous degradation.

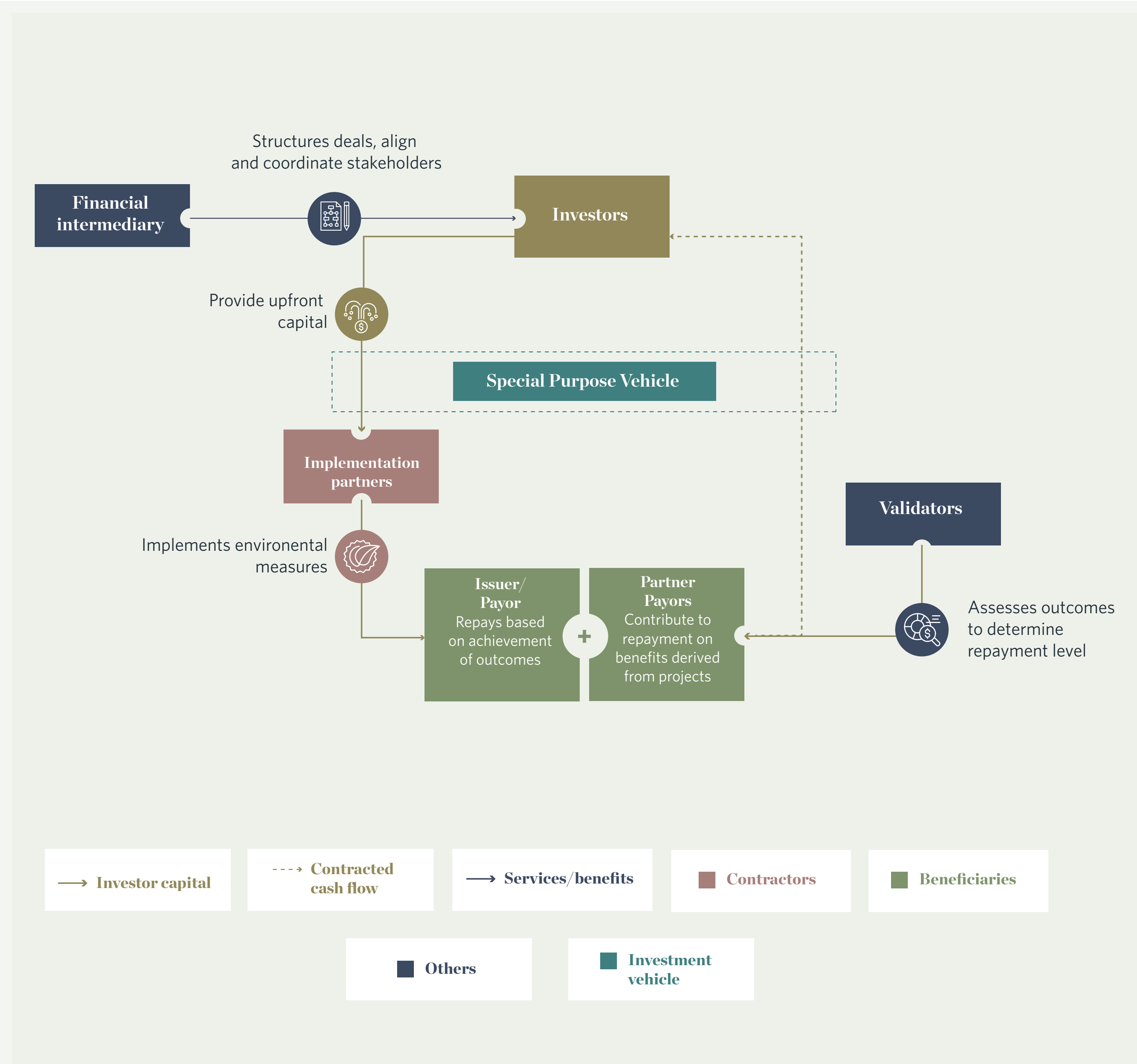
Long-term investments are required to enable sustained improved agricultural practices and to reverse previous degradation.

To marshal funding at a scale that can make a substantial difference, it is critical to establish structures that can absorb diverse funding and financing streams in a well-coordinated manner, even while keeping a sharp eye on results. The multi-governance platforms mentioned above can lead the way in attracting blended finance. This is defined as "the strategic use of development finance and philanthropic funds to mobilise private capital flows to emerging and frontier markets, resulting in positive results for both investors and communities" (OECD, 2019). Although the term "blended finance" was coined in the context of emerging countries, such blending of multiple funding and financing streams is equally necessary in developed markets. This is because funders and financiers have different appetites for risk, payback periods, ability to design bankable projects and attract other funders and expectations in terms of combining economic, social and environmental returns (see Figure 8-3).

A number of blended finance mechanisms have emerged in recent years to speed up private sector finance for specific water challenges. Private financing is typically provided up front to finance investments. Clear revenue streams need to be identified to repay those initial investments (plus a return) when target environmental outcomes have been achieved. Potential revenue streams can include dedicated tariff revenues from water (or waste-water) service providers, payments for environmental services, public subsidies, carbon offsets and revenues from associated economic activities (tourism, organic farming or sustainable forest management). Different categories of private financiers would expect different returns: some social impact investors can accept to simply get their initial investments back, but mainstream investors who are considering "green finance" mainly as a way to diversify their portfolios (or to boost its resilience) would typically expect a return on par with other investments in grey infrastructure.

Examples of these structures have so far emerged mostly in the United States, where innovative approaches to conservation finance have been developed over time and a significant municipal bond market has developed thanks to favourable tax legislation (OECD, 2010). Such outcome-based blended finance structures have been applied to a variety of water security challenges, ranging from managing urban drainage (see Box 8-4 on Environmental Impact Bonds), reducing the risk of catastrophic wildfires (Box 8-5, Forest Resilience Bonds) and delivering surface water quality improvements (Box 8-6, the Delaware Water Revolving Fund). Examples of these structures are discussed below, as well as their applicability to Europe water security challenges.

Figure 8-3 *Example of outcome-based blended finance structure*



Source: *Adapted from EDF, 2018*

Environmental impact bonds are pay-for-success financing structures, similar to social impact bonds that have been applied to a variety of social issues, ranging from reducing the risk of ex-prisoners' reoffending to chronic homelessness (OECD, 2016). With EIBs, private financiers pre-finance investments in environmental improvements and public funders commit to reimbursing them (plus a margin) when specified environmental outcomes have been achieved. Among the potential applications for these financial vehicles are green infrastructure, smart sewers and stormwater infrastructure, and coastal wetlands restoration. The first of its kind was issued by DC Water in Washington, D.C. (see Box 8-4), followed by similar structures in Atlanta and Baltimore.

Box 8-4 *Environmental Impact Bond in Washington, D.C. for urban drainage*

Washington, D.C.'s municipal water supplier, the District of Columbia Water and Sewage Authority (DC Water) issued the first Environmental Impact Bond in 2017 to finance 20 acres of green infrastructure projects for stormwater management such as permeable pavement, green roofs and landscaped retention facilities.

A third of the City is serviced by a combined sewer system. In 2005, the US Environmental Protection Agency (EPA) and DC Water entered into a consent decree with a 20-year long-term control plan (LTCP) with an estimated US$2.6 billion in planned investments to reduce combined sewer overflows (CSO). In 2015, DC Water renegotiated the terms to incorporate large-scale green infrastructure to replace one of three deep tunnels that were part of the original LTCP. Green infrastructure had never been deployed at this scale. DC Water turned to Quantified Ventures to model and advance this transaction. The company brought in impact investors to share the risk by investing in an Environmental Impact Bond, a US$25 million tax-exempt bond sold in a private placement to Goldman Sachs Urban Investment Group and Calvert Impact Capital. The bond was issued as a municipal bond, with a three-tiered structure aimed at sharing risk of project failure with investors based on three possible outcomes:

- As-expected performance of green infrastructure projects: No performance payment is made between issuer and investors;
- Over-performance: Issuer makes a performance payment to investors, in addition to regular interest payments, in the case of over-performance where higher than expected performance is achieved;
- Under-performance: Investors make performance payment to the issuer in the case of under-performance, allowing the issuer to recoup and redeploy some of the investment into other projects.

Quantified Ventures went on to evaluate possible similar transactions in other cities across the United States. Atlanta won a grant from the Rockefeller Foundation to help design a US$14 million bond, which was released in February 2019 and sold on the open market rather than private placement. The bond for Baltimore was still under preparation at the time of writing.

Source: *Herrera, 2017 July 14; Roy M. J. et al., 2018 May 1; Water, Finance and Management, 2018 June 18; U.S. EPA Water Infrastructure and Resiliency Finance Center, 2017*

Environmental Impact Bonds have several advantages over alternative funding mechanisms focused on public funding. They support a stronger focus on environmental outcomes, both for the borrower and for investors. They allow transferring performance risk to investors, thereby conserving public funds and improving their efficiency. They help attract investors who want to align their financial returns with positive environmental impact. Having a stronger focus on outcomes means building a stronger evidence base, which in turn can inform future planning. The first iterations have taken a relatively long time to prepare and generated high transaction costs, however. It will be essential to extract lessons of the early experiences to bring down those costs and accelerate preparation over time.

Similar structures have been developed to finance investments in reducing the risk of catastrophic forest fires. Forest fire risk affects a great number of stakeholders and sectors and its prevention requires their collaboration. A forest resilience bond was first launched in California in 2018 to provide a structure for investing in forest maintenance and reducing the risk of catastrophic fires (described in Box 8-5).

Box 8-5 *Forest Resilience Bonds (FRB): investing to reduce the risk of catastrophic wildfires*

Forest resilience bonds (FRB) were conceived to fund sound forest management practices to reduce fire risk and increase climate resilience. Associated benefits include protecting water resources, avoiding carbon emissions and creating rural jobs. FRBs are structured in a way similar to EIBs: investors provide upfront capital to pay for restoration projects that protect forest health, while public and private beneficiaries agree to make payments based on the water, fire and other benefits created by restoration activities. Water companies pay into this mechanism because they can benefit from a reduction in sediment loads resulting from forest fires. The FRB contracts with the beneficiaries to share in the costs of forest restoration while providing modest returns to investors. This financial mechanism was conceived by Blue Forest Conservation (BFC), a start-up launched by business school graduates of the University of California, Berkeley with support from the World Resources Institute.

A first application of this structure was the FRB Yuba Project I LLC in the North Yuba River watershed. The aim of this project is to protect 15,000 acres of forest in the Tahoe National Forest in California. The project site is located 50 miles from the town of Paradise, where the deadliest wildfire in the history of California took place in 2018. A group of private investors—comprised of CSAA Insurance Group, investment firm Calvert Impact Capital, the Rockefeller Foundation, and the Gordon and Betty Moore Foundation—provided an initial investment of US$4.6 million. Both foundations accepted a below-market interest rate of 1 percent, whereas other financiers expect to earn a 4.5 percent interest rate.

The beneficiary group, which will repay investors and provide the user payments, includes the Yuba Water Agency (a water utility) and the California Climate Change Investment programme (US$2.6 million in grant funding via a programme called CalFire). The primary implementing partner is the National Forest Foundation, which organises contracts with the U.S. Forest Service (USFS) and the state. The FRB structure allowed speeding up implementation from an estimated 10 years to four. The FRB Yuba Project I LLC is managed by a new non-profit set up by BFC. Restoration is carried out through prescribed burning, ecologically based tree thinning, meadow restoration and invasive species management, all specifically designed to reduce the risk of severe fire, improve watershed health and protect water resources.

Source: *Alberta Water Portal website, BFC, 2017; Jung, H.Y. et al., 2009; Nunes, J. P. et al., 2018; Santos, R. M. B. et al., 2015; Smith, H. G., 2011; Writer, J. H., 2014; U.S. Forest Service website*

The FRB mechanism brings together investors providing upfront capital, beneficiaries from forest restoration activities and the groups that develop, implement and monitor these activities. This mechanism has the potential to join disparate stakeholders in a way that provides economic value to all parties while accelerating forest restoration. The use of private capital accelerates restoration work, thereby lowering the risk of future fires, protecting nature and generating significant savings for beneficiaries. This structure also paves the way for larger projects and costs sharing—thus greater efficiency. Knowing that funds are available for this type of investments can also spur and motivate new projects.

Each stakeholder has a strong motivation to participate. For utilities, the FRB can be an opportunity to have some control over the state of the land they depend on. In general, utilities rely on designated watersheds for their water needs but often do not own the land that makes up the watershed. For the national government, this mechanism provides an opportunity to achieve environmental and infrastructure policy goals while simultaneously helping rural communities by creating job opportunities. FRBs can also represent an opportunity for private landowners who suffer from losses caused by wildfire and lack the resources for land restoration. Additional possible beneficiaries include insurance companies, which often suffer significant losses when wildfire destroys insured property, and private water-dependent companies (BFC, 2017).

The FRB structures would be highly applicable to water security challenges in Europe. As noted in Section 2.4.2, several countries in Europe are at risk of catastrophic fire damage, with Spain, Portugal, Greece, Italy and some areas in the Balkans presenting the highest risk. A recent report published by Blue Forest Conservation provides guidance to develop FRB structures that could be of use in Europe (BFC, 2017). These guidelines also describe the process and steps to take to evaluate the feasibility and then develop conservation finance structures similar to the FRB.

A more recent example of such structures was developed by The Nature Conservancy in collaboration with i2 Capital in Delaware to support surface water quality improvements.

Box 8-6 *The Revolving Water Fund: outcome-based payments for surface water quality improvements*

In collaboration with i2 Capital in Delaware, The Nature Conservancy developed the revolving water fund (RWF) model to facilitate investment of private capital into watershed-scale conservation efforts. This mechanism is inspired from more standard water funds (as presented in Box 8-2), a finance and governance mechanism for downstream beneficiaries to invest in upstream conservation practices designed to secure freshwater resources. The innovation of the RWF consists in quantifying the benefits obtained from restoration activities in the watershed and selling them to municipalities in the same watershed that seek to cost-effectively comply with water-quality standards.

The Brandywine-Christina Healthy Water Fund is the first application of the RWF model. It was developed by TNC in Delaware and the University of Delaware's Water Resources Center with a grant from the William Penn Foundation as part of the Delaware River Watershed Initiative. In 2017, i2 Capital also received a Conservation Innovation Grant from the USDA's Natural Resources Conservation Service to support scaled implementation of the revolving water fund model. The pilot aims to restore the Brandywine-Christina watershed in Delaware and Pennsylvania to "fishable, swimmable, potable" status by 2030.

The Brandywine-Christina watershed spans some 583 square miles across Delaware and Pennsylvania and comprises four sub-watersheds. Most of the watershed lies in Pennsylvania, but most of the people live in the Delaware portion of the watershed, which provides drinking water to about 60 percent of Delaware's residents. The conservation efforts in the watershed are often not well coordinated and most funding is limited to traditional grants and private philanthropic contributions. Substantial action has been hampered by political boundaries, as the watershed stretches into four states and falls under different regulations. For these reasons, water quality remains degraded: large stretches of rivers and streams are subject to fishing and swimming restrictions, and water must be heavily treated before distribution. Of growing concern are also storm water run-off (suburban/urban and agricultural) for water quality and increasingly severe storms which are triggering damaging floods and erosion.

In the City of Newark pilot, capital from the fund pays for on-farm restoration activities upstream in the same watershed. If the City can demonstrate to regulators that these restoration activities have reduced their nutrient and sediment loads, the City will pay back the revolving water fund. This payment will cycle back into the fund, cover the costs of the project team, fund further restoration activities and eventually pay back private investors who may later invest more if the project is successful. Paramount to the success of this scheme are the long-term relationships established with regulators, municipal partners and water providers, which enabled the development of performance metrics acceptable to all stakeholders. Furthermore, the fund structure includes an advisory board with expertise in conservation, freshwater science, regulatory compliance, agricultural practices and drinking water provision, necessary to ensure that conservation projects are well designed and implemented.

Source: *Revolving Water Fund website, The Nature Conservancy, 2015; The Nature Conservancy and University of Delaware Water Resource Center, 2017; The Nature Conservancy website: Water Fund Toolbox*

Heavy reliance on public funding has possibly dampened innovation in this area in the European Union to date, where funding for NbS-WS has come mostly from public sources. However, analysis for this report shows that the need for investment that addresses Europe's water security challenges is great and that mobilising investments in NbS-WS could reduce overall investment costs and meet other objectives. There is evidence that Europe provides a supportive environment for greater innovation in this area. In addition, there is solid demand from private investors looking for sustainable financing opportunities, particularly in the related areas of freshwater and sustainable agriculture, and a dearth of financing vehicles that enable channelling such investments (TNC & EF, 2019). Water tariffs or even public subsidies could provide a basis for secure revenue streams for these structures.

Potential to replicate these types of structures exists throughout the EU. Structures that can attract a mix of funding and financing at scale could be set up at national, regional or local levels. Such structures could be focused on specific NbS-WS (such as peatland restoration or denitrification) or on addressing a mix of water security challenges in specific locations. However, key challenges would need to be overcome. Identifying willing borrowers who are prepared to take the risk of tying financing to their environmental performance might be difficult, especially when actors are used to receiving public funds that are not dependent on results. This can also be challenging in areas where environmental improvements can be relatively slow to materialise and are affected by natural factors (such as heavy rains). Another disadvantage might be where financiers have little incentive to fund innovative projects. Finally, as payment to investors is based on delivering outcomes, contracting arrangements require precise outcome measurement. This creates issues such as the selection and measurement of outcomes, the attribution of what leads to and who causes changes in selected indicators, and the risk of pursuing easy targets instead of substantial results (Roy et al., 2018).

8.4. PRIORITISE: identify where greatest results can be achieved

WHY?	RECOMMENDATION	WHY IT CAN BE TRANSFORMATIVE
Diverse funders currently examine fragmented investment project opportunities with limited coordination. Mobilising a mix of private and public funding and financing requires estimating investment needs, identifying where certain types of NbS-WS can work at landscape scale and building pipelines of NbS-WS projects. Private financing for opportunities where repayment opportunities are greatest would allow freeing up public grants where those are more limited, or where innovation is needed.	Building shared pipelines of investable projects should be actively encouraged and supported through philanthropic or public funding, and potentially through organising innovation prizes. This calls for identifying water security hotspots across the European continent or at country or regional level, making it easier to prioritise resources and ensure that the right mix of funding and financing flows where it is needed. This will also require a stronger focus on results (even in investments that are not outcome-based) so that effectiveness and cost-effectiveness are measured on a more reliable basis and can be compared with grey infrastructure solutions.	Building joint project pipelines across multiple locations would allow overcoming fragmentation on the supply side for the finance equation. At present, potential funders have limited visibility on where the needs and potential for NbS-WS are, which hinders their ability to innovate and to offer adequate financial products.

A stronger focus on results is needed at multiple levels. The fact that most NbS-WS remain small-scale and have usually been publicly funded means that defining and measuring the cost-effectiveness of these solutions versus grey alternatives has received insufficient attention. NbS are sometimes assumed to have a positive impact on water security and other environmental indicators and are therefore worth funding. However, efforts to measure exactly how much impact they have and at what cost and to understand how these solutions perform when compared to grey infrastructure solutions have been more limited to date. The European continent provides an excellent space to generate more data on effectiveness and cost-effectiveness of NbS-WS and to organise it in a way that can inform investment decisions. Existing EU-funded research projects have not produced sufficient economic and financial data, and available information tends to be dispersed among project sites. Databases which contain data on NbS-WS (as presented in Annex C) should be better integrated with other standard economic and financial data. Measuring results should be multi-dimensional to capture the fact that NBS generate multiple benefits in areas such as freshwater biodiversity, flood and drought risk management, and amenity values. Strong methods to estimate co-benefits (in terms of biodiversity and climate in particular) would need to be developed.

Continent-wide studies that identify water security hotspots would help to focus efforts, particularly of funders and financiers that are more mobile in terms of resource allocation. A companion report under preparation by TNC and Ecologic will identify where potential for surface water protection is greatest in Europe, based on a study initially developed by TNC (Abell et. al, 2017). Such continent-wide or national studies are only a first step, however; more detailed analysis at the local level is needed to confirm the potential for NbS-WS to achieve measurable results with a reasonable degree of certainty. Such assessments should use reliable tools that can predict returns from changes in land-use or farming practices. Information should be packaged as business cases for those investments to offer better transparency in the market.

One potential way to accelerate the development of shared project pipelines would be to offer a prize for innovation. A common saying in the water sector is that "it's not a lack of money; it's a lack of good projects". Identifying good projects and making sure they are prepared to a standard that can attract an adequate mix of funding and financing is a time-consuming and expensive process: it is particularly wasteful if multiple agencies are simultaneously looking for well-structured projects. Innovation prizes that spur water sector actors to work together, possibly through blended finance models, to bring investment in natural capital for water security are one way to overcome such a barrier. In this case, innovation would be based on the ability to define (and put in place) sustainable approaches to invest and maintain the natural capital that provides services related to water security. Any entity or group may apply—including municipalities, regional governments, river basin organisations, water companies (public or private), corporations (water users), irrigators, banks or investment funds, NGOs, universities and any combination of them. Innovation prizes could be structured in two stages: ideation (participating organisations submit innovative ideas to address governance and financing challenges to invest in NbS-WS) and delivery (organisations are assessed based on a full business case and linked financing strategy).

8.5. KNOW YOUR ROLE: different groups have a specific role to play

Adopting NbS-WS calls for coordinating and collaborating across sectors to reinforce understanding and policy consensus. Scaling-up NbS-WS then requires a system that combines technical, business, finance, governance, regulatory and social innovation. In this final section, we present two primary recommendations for each actor to do its part. Other recommendations are included in the report, particularly in Table 7-1 and Table 7-2.

Table 8-1 *Key recommendations for scaling up NbS-WS by types of actors*

Actors	Key recommendations for each type
National governments / policy-makers	▪ Maintain high level of ambition in terms of water security outcomes: do not extend WFD deadlines but bring forward investments in water security ▪ Fund the development and application of strong monitoring frameworks for NbS-WS, with a focus on data on their effectiveness and cost-effectiveness ▪ Clarify the legal framework for payments for environmental services so that a variety of actors (water service suppliers, large water users) have a clear framework to make such payments where these can reduce their total costs over time (investment costs, operations and maintenance costs)
National governments	▪ Identify water security hotspots and potential for NbS-WS to address them ▪ Help build project pipelines by organising national-level innovation prizes

Actors	Key recommendations for each type
Local governments	▪ Reach out to stakeholders in the basin or sub-basin to strengthen collective action for water security ▪ Review policies across all sectors where local government can play a strong role to incentivise NbS-WS adoption ▪ Include NbS and their co-benefits for multiple sectors whenever reviewing options and planning investments for enhancing urban water security ▪ Define water service contracts based on outcomes rather than specifying technologies or outputs ▪ Promote NbS-WS in relevant interactions with the city's hinterland/relevant urban-rural interactions
Water service providers	▪ Systematically consider NbS-WS as options in investment planning and programming to minimise overall costs ▪ Collaborate with other actors on regional water resource planning and implementation ▪ Systematically monitor effectiveness and cost-effectiveness of NbS-WS they implement to build evidence base
Water users (corporations)	▪ Join multi-sectoral governance platforms for water management ▪ Contribute funding for NbS and other investments that contribute to overall water security ▪ Consider NbS as an attractive way to deliver on multiple objectives, including water stewardship, biodiversity and carbon neutrality targets
Farmers	▪ Adopt improved farming practices to reduce pressures on water resources ▪ Embrace NbS-WS as a way to get a just retribution for land stewardship services they can provide, with benefits in terms of income and recognition ▪ Seek facilitated access to credit to help with the transition
Public financiers	▪ Provide grants for innovative projects and seek to reduce the risks of private financing ▪ Move towards a loan-based model for NbS-WS with clear revenue streams
Private financiers	▪ Engage with water actors, public funders and intermediaries to better articulate what sustainable finance opportunities they are looking for ▪ Seek returns on multiple fronts: financial, environmental and social
Intermediaries (NGOs, consultancies, academic institutions)	▪ Bridge information and knowledge gap between water sector actors and providers of funding and financing ▪ Perform a brokering role, by helping identify and match project pipelines and funding and financing sources ▪ Innovate and develop outcome-based blended finance vehicles

Source: *Authors, 2019*

Annex A

	Geographical area	Programme/Lead agency	NBS-WS
1	United Kingdom	IUCN peatland programme	Targeted land restoration
2	South West England	South West Water	Improved agricultural practices (reduced fertilizer use); targeted land restoration
3	Midlands, England	Severn Trent	Improved agricultural practices; Targeted land restoration (peatland)
4	Eastern England	Anglian water	Improved agricultural practices (alternative pest control), construction of artificial wetlands
5	North West England	United Utilities	Land restoration, Forestry Best Management Practices (BMP), Improved agricultural practices, Targeted land protection
6	South West England	Wessex water	Improved agricultural practices (reduced fertilizer use, cover crops); targeted land protection
7	Amsterdam, Netherlands	Waternet	Aquifer recharge; targeted land restoration
8	Greater Lyon, France	Eaux du Grand Lyon (Veolia)	Artificial recharge ponds; Targeted land protection (forest)
9	Paris and surroundings, France	Eau de Paris	Targeted land protection; Improved agricultural practices (reduced fertilizer, alternative plant protection); Land-use change from farmland to pasture land
10	Augsburg, Germany	Stadtwerke Augsburg Wasser GmbH	Improved agricultural practices; Land-use change
11	Vosges, France	Vittel	Improved agricultural practices (reduce fertilizer use, land use change); Forestry Best Management Practices (BMP)
12	Puy-De-Dôme, France	Volvic	Targeted land conservation; Forestry Best Management Practices (BMP)
13	Barcelona, Spain	Barcelona City Council; Catalonian Water Agency; Besòs-Tordera Consortium	Construction of artificial wetlands; targeted land restoration
14	The Netherlands	Room for The River programme	Reconnecting rivers to floodplains
15	City of Nijmegen, The Netherlands	Room for the River programme	Reconnecting rivers to floodplains
16	Navarra, Spain	Government of Navarra	Riparian zone restoration
17	Glasgow and Clyde Valley, Scotland	Glasgow and Clyde Valley Green Network Partnership	Construction of artificial wetlands; Targeted land restoration (peatland)
18	Copenhagen, Denmark	City of Copenhagen; Greater Copenhagen Utilities (HOFOR)	(Urban) land-use change; Retention ponds, basins and squares
19	Castilla y Leon, Spain	Duero Hydrographic Confederation	Natural aquifer recharge

1. IUCN UK

Peatland restoration for water, climate, and biodiversity benefits

Geographic Location	Nature based solution	Lead agency
United Kingdom	Peatland restoration	IUCN UK Peatland Programme

Description

The IUCN UK Peatland Programme was set up in 2009 to promote peatland restoration in the UK through partnerships, science, policy and practice. This programme has several functions: informing policy and legislation at both regional and national levels; advocating for peatlands and their value to decision makers and the public; identifying financing opportunities for restoration on the ground; and developing restoration and management good practices. The programme is hosted by the Scottish Wildlife Trust and is overseen by a collective partnership that includes government institutions, conservation NGOs and academia (Defra, Moors for the Future Partnership, National Trust for Scotland, Natural England, North Pennines AONB Partnership, RSPB, Scottish Wildlife Trust, Scottish National Heritage, University of East London and Yorkshire Wildlife Trust).

Challenges

Peatland is extremely important for carbon storage and water management. Globally, peatland contains more than twice the carbon stored in all forests in the world and is important for water regulation. The UK is rich in peatland: it is home to over 2million hectares of peatland (2.6 million hectares of deep peat), and 13 percent of the world's blanket bogs. Blanket bog is a type of peatland where peat blankets the land surface due to poor surface drainage in wet, cool climates, which is encountered particularly in the Northern hemisphere. To deliver its important functions, peat must be wet. However, for centuries peat and its vegetation have been cultivated, drained and degraded. Dry peat easily erodes and washes away, represents a fire hazard and emits a significant amount of greenhouse gas. At least 80 percent of peat bogs in the UK are currently degraded. Such degradation reduces peat bogs' ability to purify water and can lead to water discolouration, which is very hard to address through existing water treatment techniques. Given that 70 percent of UK drinking water comes from upland catchments dominated by peat bog, the restoration and conservation of these ecosystems is paramount.

Financing

While the UK has committed to the conservation and restoration of peatlands and the methods and solutions used have been tested and proven effective, a key constraint is securing adequate finance on a long-term basis. Programme targets are ambitious and require significant upfront funding, from diverse sources, in order to be achieved. In 2016, IUCN estimated that the restoration of the peatland habitat in the UK (not including maintenance) would require mobilising GBP 500 million over the following 10 years. Current public funding is limited and competitive; private finance will be key to reaching the programme's goals. Using voluntary carbon markets could be a viable means to source private funding.

The IUCN Peatland Programme has developed a Peatland Code to enable this approach: it is a voluntary standard for UK peatland projects wishing to market the climate benefit of restoration. It sets out best practice requirements, including a standard method of quantification which will ensure buyers that the climate benefits arising from peatland restoration projects are real, quantifiable, additional and permanent. Some limited investments have already been made through that route— for example, at Heathrow Airport, looking to offset its carbon footprint. However, this approach calls for bilateral agreements and can be challenging to scale up. An alternative, as proposed by EFTEC and the IUCN Peatland Programme, would consist of establishing financing vehicles that could mobilise financing streams from multiple beneficiaries, which reap not only carbon benefits but also water quality or biodiversity gains.

Moors for the Future, the North Pennines AONB Partnership and Yorkshire Peat Partnership are working together to restore the heavily degraded peats

50,000 ha have been restored

Actions and impacts

The IUCN UK Peatland Programme launched a UK Peatland Strategy in April 2018 after almost 10 years of partnership work, through steering committees, workshops, and direct consultation. The programme's current target is to have 2 million hectares of peatland (the majority of peatland in the country) either in good condition, under restoration management or sustainably managed by 2040. Half that will be managed by 2020. This will be achieved through many interventions, including: communicating the value of peatlands to a wider audience; conserving and enhancing the best peatlands; restoring damaged peatlands to functioning ecosystems; adapting management of drained, productive agricultural peatlands; and sustainably managing peatland through sympathetic land use. Over 200 peatland restoration projects have already been implemented across the UK and have shown some positive results.

One example of these projects is Flows to the Future in the Flow Country, Scotland; it is one of the UK's most important regional sites, with 10 percent of the UK's blanket bog and almost 5 percent of the world's blanket bog resource. Damage caused by land use changes (for example, plantation forestry and drainage for grazing improvement) has spurred the RSPB, a programme partner, to buy part of the land and lead restoration activities through the creation of a nature reserve. Another example is within the Pennines, a range of mountains and hills in England that are home to around half of England's blanket bog. Here, programme partners Moors for the Future, the North Pennines AONB Partnership, and Yorkshire Peat Partnership are working together to restore the heavily degraded peats. around 50,000 hectares have been restored, which is only a small percentage of the total area needing restoration work. Moors for the Future is a partnership that includes the Environment Agency, Natural England, National Trust, RSPB, several water companies (Severn Trent Water, United Utilities, Yorkshire Water), Pennine Prospects, and representatives of the moorland owner and farming community. It received initial funding from the Heritage Lottery Fund.

A third project—Pumlumon, in Wales—is led by Montgomeryshire Wildlife Trust. It covers 40,000 hectares, including heavily drained blanket bog. The goal is to restore and build a landscape that is sustainable for people and wildlife: So far, 270 hectares of drainage ditches have been blocked.

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2. South West Water

Engaging upstream to reduce eutrophication

Geographic Location	Nature based solution	Lead agency
South West England	Improved agricultural practices (reduced fertiliser use), targeted land restoration	South West Water and partners

Description

South West Water provides drinking water and waste water services throughout Cornwall and Devon and in areas of Dorset and Somerset. It is responsible for the supply of the region's drinking water, the treatment and disposal of sewage, and the protection of inland and bathing waters. Since 2003, the water provider has invested heavily in catchment-based solutions. Since then, and particularly in its2020-25 business plan, South West has increased its focus on catchment-based solutions to improve raw water quality by reducing pollution and sediment loads from land use runoff and soil degradation. Its catchment-based interventions have multiple purposes, helping slow the flow of water from upland areas and, in turn, reducing flood risk and increasing water availability.

Challenges

In 2003, South West Water had to face the challenges brought by eutrophication at Upper Tamar Lakes. Back then, the reservoir had started experiencing an annual nutrient-driven algal bloom, which caused problems for water supply and ecology downstream. To address this problem, the company turned its attention to nature-based solutions and later launched its catchment management scheme, Upstream Thinking, in 2007.

Their catchment-based interventions have multiple purposes, helping slow the flow of water from upland areas and, in turn, reducing flood risk and increasing water availability.

Actions and impacts

Through Upstream Thinking, South West Water applies natural landscape solutions to water quality challenges. The aim of the project is to prevent pesticides, nutrients and other pollutants from getting into rivers. Doing this, less pressure is put on water treatment plants, allowing the process to be faster, cheaper and more efficient. Improved water quality in the catchment also has a positive impact on biodiversity in the area. The main delivery partner organisations work closely with a wide range of stakeholders, including the Environment Agency, Natural England, the Farming and Wildlife Advisory Group, the National Farmers Union and the local Catchment Partnerships. The current programme consists of a partnership between South West Water, the Devon Wildlife Trust, the Cornwall Wildlife Trust, the Westcountry Rivers Trust and the Exmoor National Park Authority. The programme targets 750 farms in the area and 1,300 hectares of moorland and other semi-natural land[32].

The programme works with farmers and landowners to minimise impact on watercourses. Farm advisers visit farms and carry out an assessment resulting in a whole-farm plan, which includes capital investment proposals targeted at water quality improvements, which can be up to 50 percent funded by the Upstream Thinking programme. The plans can include improvements to slurry storage, fencing to keep livestock out of rivers, alternative water sources for livestock, and better pesticide management.

One component of the programme is delivered by the Exmoor Mires Partnership. It allowed investigating and restoring over 2,000 hectares of land on Exmoor in the period 2010-15 by blocking drainage ditches. Blocking drainage ditches allows the moorland to hold more water and release it more slowly, reducing potential flooding elsewhere. In the first implementation period, a third less water left the restoration areas during heavy rainfall. This early success meant that the Environment Agency fully endorsed the project; work on blocking drainage ditches on Exmoor continues, with a target of restoring a further 500 hectares of peatland by 2020.

Financing

Upstream Thinking is delivered by South West Water, a part of Pennon Group, a private utility company. The programme is funded by South West Water from customer charges as agreed with Ofwat, the water regulator for England and Wales. The investment from SWW has been over £20m in the last 10 years.

Funds are transferred to delivery partners who administer the farm advisory and grant programme. The funding is also used to attract further available catchment funding (e.g. Interreg, Defra schemes). This match funding acquisition has increased the total catchment spending by a ratio of 1:2, raising the actual investment to three times its initial size.

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3. Severn Trent

Engaging with farmers to address key surface water quality pressures

Geographic Location	Nature based solution	Lead agency
Midlands, England	Improved agricultural practices, construction of artificial wetlands, targeted land restoration	Severn Trent (English water company) and partners

Severn Trent has identified that some of the water pollution issues they faced could only be addressed through catchment based approaches rather than through hard engineering solutions

Description

Severn Trent is a privately owned and publicly listed water company which serves over 4.3 million customers in the West Midlands (including the cities of Birmingham, Coventry, Warwick, and Shrewsbury). It provides water and waste water services in an area that covers the catchments of two of the largest rivers in England, the Severn and the Trent. The company has invested substantially in protecting water resources and improving water quality at catchment level to reduce its treatment costs, deliver on its responsibilities to improve water quality under the Water Framework Directive (WFD), and benefit the environment.

Challenges

Severn Trent has a strong environmental track record (with close to 100 percent compliance on environmental discharge standards). There are still 500 water bodies failing to achieve "good status" as per the WFD, however, although the company is a main contributor in only 40 percent of these cases. Challenges relate mostly to water quality from diffuse agricultural pollution and degraded ecosystems, such as peatlands, in the catchment area. Severn Trent has identified that some of the water pollution issues it faces could be addressed only through catchment-based approaches rather than through hard engineering solutions.

Actions and impacts

Severn Trent has deployed a range of actions to protect water resources and restore functioning ecosystems to achieve environmental standards at least cost. It has eight agri-scientists on staff and others who are seconded in river and wildlife trusts, major implementation partners for them.

1 Peatland restoration

Heavily degraded peatlands are present throughout the UK, as a result of decades of draining and overexploitation by land owners. Degraded peat leads to erosion (thereby impacting water colour and increasing the risk of flooding) and releases carbon into the atmosphere. More than 1 million of Severn Trent customers are served from water sources in the Peak District, where the peat bogs have been severely degraded over many years. Peatland degradation means that the water runs off quicker into reservoirs and results in water coloration, which is very hard (and expensive) to treat. Over the last 10 years, Severn Trent has been involved in the Moors for the Future partnership with many other organisations, such as the Peak National Park, the National Trust, the Environment Agency (the environmental regulator), United Utilities (water company) and local organisations. The project focuses on restoring peatland through revegetation, blocking gullies and tree planting. Even though Severn Trent's interest stemmed from improving water quality, these efforts also generate biodiversity and carbon sequestration benefits. This work helps with avoided investment costs at the treatment site and avoided operating costs (chemical use) equivalent, which means that there is a strong financial case for it. Early evidence has confirmed the business case for this type of activities, and the company has decided to increase its investments in this area.

2 Improved agricultural practices

Several water companies, including Severn Trent, have been engaging with farmers to address water pollution from metaldehyde, a highly polluting metallic compound included in pellets to kill slugs. This is extremely costly to treat once it has entered surface water. Severn Trent had 11 catchments where this was a significant issue. It has engaged with over 2,000 farms and make payments of up to £8 per hectare to help farmers switch from metaldehyde to ferric phosphate, which is much less harmful for the environment. Farms can receive grants of up to £5,000 per farm to address any water quality issue that requires infrastructure investments and land management changes. After two and half years of implementation, metaldehyde contamination has dropped rapidly, and 10 out 12 treatment works became compliant by 2017. Severn Trent also makes small grants to farmers via the Cash for Catchments program to support small, community-led projects that can restore ecosystems, preserve biodiversity or help with natural flood management, river restoration, or control of invasive species.

*Engagement with **2000 farms** to help farmers switch from metaldehyde to ferric phosphate, which is much less harmful for the environment*

Financing

Severn Trent could make such investments thanks to regulatory support (Ofwat, the economic regulator for England and Wales, is a strong supporter of the Catchment Based Approach introduced by Defra, the Department for the Environment, Forestry and Rural Affairs). Severn Trent has invested its own resources (from water tariffs) in those schemes and has sought to mobilise matching funding from other sources, including European grant programmes (e.g., LIFE), public subsidies (from the UK Environment Agency), and farmers themselves. For example, it is investing £1 million in the Moors for the Future programme over the 2015-2020 period and is benefiting from matched funding from EU LIFE (grants of £3 for each £1 invested by the company). Going forward, following extensive customer consultation which confirmed a willingness to pay for environmental improvements, the national water industry regulator, Ofwat, has agreed to include an outcome-based payment into their tariff setting formula linked to their environmental performance. It is projecting to increase such investments under the next business plan period (AMP7, 2020-2025). One key issue it will face: public funding for its implementation partners (such as the Rivers Trust) is going down and will be affected by impending cuts in EU funding. It will need to identify alternative sources of co-financing.

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4. Anglian Water

Investing in green infrastructure for surface water quality

Geographic Location	Nature based solution	Lead agency
Eastern England	Pesticides reduction in surface water (metaldehyde) intended for drinking water, wetland construction for waste water treatment	Anglian Water

Description

Anglian Water is a water utility that covers the largest geographical area in England and Wales (east of England and Hartlepool), covering 20 percent of the land area of the two regions (27,476 square km). The service area is located in a comparatively low-lying region and receives, on average, a third less rainfall than the rest of England. The company, privately owned and managed, supplies 4.3 million people with drinking water and collects and treats wastewater from over 6 million people across the area. Due to the agricultural nature of the area, each year Anglian Water spends substantial amounts of money removing pesticides from drinking water to ensure compliance with the standards set out in the EU Drinking Water Directive (DWD). This has potential implications for customers' bills as well as energy and chemical use.

Challenges

Anglian Water faces a number of environmental challenges in a high-growth, water-stressed region. One of the challenges met by Anglian water in its catchments is metaldehyde, a highly soluble, organic compound commonly used as a pesticide against slugs and snails. Another challenge for Anglian water was its Ingoldesthorpe Water Recycling Centre, a wastewater treatment plant managed by the company which is located on an important site for biodiversity. The high level of ammonia and phosphorus at the site exceed the European Drinking Water Directive (DWD) standards.

Financing

The Slug it Out campaign scheme costs are largely influenced by market prices for the cost difference between the pesticide products. The scheme was funded by Anglian Water through its opex programme (and therefore through tariffs). The pilot trial was delivered for a total cost of £3.5i. It would require significant scaling up to cover the 8,500 farmers who manage land across high-risk portions of the water company's service area. By comparison, installing treatment for the whole region affected by metaldehyde would cost as much as £595 million, which would significantly impact customer bills.

Anglian Water financed the entire **Ingoldesthorpe Water Recycling Centre** project and invested £500,000 in constructing the artificial wetland. The success of this pilot led the company to further promote NbS, both internally and externally to industry regulators. The company proposed the development of several wetlands for waste water treatment in its business plan for 2020-2025. For this period, the company proposed a further £800 million worth of investment in enhancing and protecting the environment, which is more than double that of the previous five years' plan. If approved by the economic regulator, Ofwat, as many as 59 treatment wetlands could be built in the coming years. A key challenge will be to redesign Anglian Water's procurement systems, which are designed to contract large engineering firms rather than smaller, local level organisations such as river trusts.

Actions and impacts

1 "Slug it Out" campaign

Anglian Water launched the Slug it Out campaign in 2015 with the aim of reducing metaldehyde levels in the region's waters before they reach the treatment works. It is an example of a catchment management approach as opposed to an 'end of pipe' solution. Slug it Out" provides incentives to farmers to change their practices, paying them the cost difference between metaldehyde and alternative chemical slug controls containing ferric phosphate as the active ingredient. Ferric phosphate pellets are typically more expensive than metaldehyde, but ferric phosphate is not soluble and can therefore be removed through conventional water treatment. Farmers needed to be sure ferric phosphate products would be effective A key influencer in this debate is the way in which the two types of pesticides operate. While metaldehyde kills slugs by desiccation (so that they remain visible on ground surface), ferric phosphate makes slugs sensitive to light: they hide and die underground. As a result, they are less visible to farmers, who may wonder if the product has been effective. In fact, both products are effective against the target species and work at the same speed. The campaign allowed farmers to experience the alternative ferric phosphate products on their own land so they could see its effectiveness for themselves.

Another key success factor was that Anglian Water employed a team of agricultural experts to engage with farmers rather than use existing staff. These experts advised the company on farming practices and brokered relationships with farmers, whose business they understand. The campaign runs across several Anglian river catchments and involved 216 farmers working 22,500 hectares. From 2015 to 2018, the trial led to a 94 percent drop in levels of metaldehyde detected in reservoir waters. In 2019, the majority of raw water reservoirs within the trial area were compliant with DWD standards.

2 Constructed wetland at Ingoldisthorpe Water Recycling Centre

In a drive to achieve the standards of 1 micron/litre for ammonia and 4.5 micron/litre for phosphorus, Anglian Water engaged with the Norfolk Rivers Trust, a local charity focused on catchment-based approaches. River Trusts are independent community-led charitable organisations delivering water management advice and practical work for the conservation and/or restoration of land, rivers, and wetlands at a catchment scale.

With financing from Anglian Water, the Norfolk Rivers Trust built a wetland treatment site between the autumn of 2017 and the spring of 2018 at the Ingoldisthorpe Water Recycling Centre. The wetland filters water after it has passed through the existing treatment plant to ensure it meets high quality standards, thereby replacing the need for conventional, energy-intensive infrastructure. This green infrastructure works as a natural treatment plant for millions of litres of water a day and helps reduce ammonia and phosphorus in the catchment: partially treated water passes through the wetland to be further filtered and cleaned before it returns to the River Ingol. This type of natural infrastructure has the potential to generate cost savings, reduce carbon emissions and increase wildlife in the area. Early results show that water quality has improved beyond expectation and that wildlife thrives in the newly created natural environment.

94% drop in levels of metaldehyde

The campaign runs across several Anglian river catchments and involved 216 farmers covering 22,500 hectares.

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5. United Utilities

Targeted land protection and catchment-based approaches

Geographic Location	Nature based solution	Lead agency
North West England	Targeted land protection and restoration	United Utilities

17,000 ha
designated as Sites of Special Scientific Interest (SSSI)

Description

United Utilities is the United Kingdom's largest water company. It was founded in 1995 when North West Water and NORWEB merged and serves nearly 7 million customers. The group manages the regulated water and waste water network in North West England, including Cumbria, Cheshire, Greater Manchester, and Merseyside. United Utilities owns 184 reservoirs and manages 56,000 hectares of land, primarily around Lake Vyrnwy, the River Dee, and the Haweswater reservoir. The company opted for a catchment approach in these areas in 2005 when it established the Sustainable Catchment Management Programme (SCaMP).

Challenges

The land owned by United Utilities surrounding the reservoirs is also used for agricultural purposes by tenant farmers for food production. It is an important spot for biodiversity, with around 17,000 hectares designated as Sites of Special Scientific Interest (SSSI). Industrial pollution and agricultural activities have damaged many habitats around the catchment areas, and large areas of SSSI were designated by Natural England as being in unfavorable and declining condition. Furthermore, years of drainage of the uplands has caused peat bogs that are 5,000 years old to dry out and erode, releasing colour and sediment into watercourses and millions of tonnes of carbon dioxide into the atmosphere. Removing colour requires additional chemicals, power, and waste handling that meets increasingly demanding drinking water quality standards; this resulted in significant increases in annual operational costs for the company.

Actions and impacts

United Utilities developed SCaMP with the Royal Society for the Protection of Birds (RSPB). It aims to help protect and improve water quality; reduce the rate of increase in raw water colour; reduce or delay the need for future capital investment in additional water treatment; deliver government targets for SSSIs; ensure a sustainable future for the agricultural tenants; enhance and protect the natural environment; and help build resilience to climate change. SCaMP 1 (2005 to 2010) included projects across 27,000 hectares of the company's water catchment areas in the Peak District and the Forest of Bowland. Working with farm tenants and in conjunction with partners, such as the RSPB, Natural England, and the Forestry Commission, the utility invested in moorland restoration, woodland management, farm infrastructure improvements, and watercourse protection. After the first five years, water industry regulators Ofwat, DWI, the Environment Agency, and Natural England supported further investment for catchment management between 2010 and 2015 across 30,000 hectares in Cumbria and South Lancashire (SCaMP 2).

Activities included: restoring blanket bogs by blocking drainage ditches and gullies, restoring areas of eroded and exposed peat, restoring hay meadows, establishing new woodlands, stabilising land through scrub planting, restoring heather moorland, improving farm facilities with better livestock housing, providing new waste management facilities to reduce runoff pollution of watercourses, and fencing to keep livestock away from areas such as rivers and streams and from special habitats.

Another approach of SCaMP is the establishment of drinking water safeguard zones (SZ). These zones are drinking water catchments where water quality in rivers, reservoirs, or groundwater is deteriorating and is becoming harder to treat due to human activities on the land. SZ can be used to target measures, advice, and incentive schemes for landowners and managers to help improve water quality. Within the North West, the Environment Agency has designated 20 surface water and nine groundwater catchments as safeguard zones.

The utility's latest approach for tackling water quality issues in lakes, rivers, and coastal waters is Catchment Wise. Building on SCaMP, this initiative aims to drive a similar change around wastewater issues—sharing expertise about how land is used and managed across the region and tackling pollution at the source to improve the quality of water. Catchment Wise is an initiative in partnership with other organisations across the region.

Within the North West, the Environment Agency has designated ***20 surface water and 9 groundwater catchments*** *as Safeguard Zones.*

Financing

During the SCaMP 1 phase, United Utilities invested £10.6 million, followed by £11.6 million in SCaMP 2. Undertaking the SCaMP improvements allowed farmers to access additional agri-environment income for 10 years, while Natural England and the Forestry Commission provided grants for a total of £2.7 million towards project costs. The funding is focused on the highest-priority areas and in places where the benefits can be maximised. In addition to its work on SCaMP, United Utilities also commissioned a number of catchment investigations in recent years and continues to develop plans for a programme of catchment management in its business plan. The Catchment Wise Interventions Fund approved funding for 15 projects aimed at delivering water quality improvements to help achieve "Good Status" and "Sufficient" under the Bathing Waters classification.

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6. Wessex Water

Reducing nutrients through innovative trading platform

Geographic Location	Nature based solution	Lead agency
South West England	Improved agricultural practices, construction of artificial wetlands, natural aquifer recharge	Wessex Water

Description

Wessex Water is a water company supplying drinking water to 1.3 million people in the South West of England. About 80 percent of the supplied water comes from groundwater sources in Wiltshire and Dorset. The remaining 20 percent comes from surface reservoirs filled by rainfall and runoff from the surrounding catchment. To respond to elevated nitrate concentration in its reservoirs, the company adopted a source water protection approach in 2005 that consisted of promoting changes in agricultural practice in the catchment area, implementing a natural aquifer recharge system, and planning constructed wetlands. The company also supported the development of a trading platform, EnTrade, which enables farmers to bid to receive support for adopting improved agricultural practices that can reduce nutrients. This platform, which later spun off as an independent entity, is exploring applications for various interventions to improve water quality.

Challenges

Before implementation of a catchment approach, more than 20 percent of Wessex Water's water supply sources were affected by elevated nitrate concentrations. The company had built four treatment plants to remove nitrates, and 11 sites had carbon filters to remove pesticides. The company estimated that building more treatment plants would not benefit the environment and that the cost burden would fall on its customers. In 2005, it adopted a catchment-based approach, with a focus on engaging farmers to protect water sources from excessive nutrients.

Supply of drinking water to **1.3 million people**

About 80% of the water supplied comes from groundwater sources in Wiltshire and Dorset.

Actions and impacts

Wessex Water assembled a team of scientists and catchment advisers trained to offer agronomic advice to farmers within the catchment areas of public water supply boreholes and reservoirs. The catchment approach targets 21 catchments at risk across the region: 15 groundwater sources at risk from nitrate, one groundwater source threatened by pesticides, and five reservoirs at risk from a combination of pesticides and nutrients. Wessex Water catchment advisers make direct and personal contact with all the landowners and farmers within their catchments and discuss the issues and raise awareness. The response is usually positive, as owners and farmers are generally concerned with the impact of their practices and are keen to reduce pollution. While pollution issues differ depending on the catchment, all cases involve monitoring to define and understand what specific actions are needed. The advisers then assist with agronomic advice and with the development of agricultural management plans (for soil, manure, fertiliser, and crop protection). More specifically, solutions include assisting farmers with agri-environment schemes, fertiliser spreader and pesticide sprayer calibration, and provision of locally derived data to improve management plans and agricultural practices. These plans allow local farmers and landowners to safeguard the quality of ground and surface waters, by aiming to stabilise and then reduce the levels of contaminant (nitrate or pesticides) at each source so that no additional treatment is required. The company calculated that the cost of this approach is one sixth the cost of a conventional treatment alternative. Furthermore, it found that catchment management has a significantly lower carbon footprint than building and operating treatment plants.

For example, in Eagle Lodge, water from the boreholes failed the nitrate standard several times between 1999 and 2001. Initially, Wessex Water planned and designed a nitrate removal plant in 2004. However, the high costs associated with the project led the company to opt for a source water protection approach instead between 2005 and 2008. The catchment adviser made contact with farmers in the catchment, explained the nitrate problem, and identified specific issues and a course of action: improved nutrient and manure management, calibration of fertiliser spreaders, altered drilling dates of autumn-sown crops, use of winter cover crops, and the adoption of resource protection measures under environmental stewardship. The farmers took up the plan, with funding from a European project, Water Resources Management in Cooperation with Agriculture (WAgriCo). Since 2006, nitrates levels have been consistently lower than the drinking water standard limits.

Wessex Water also supported the creation of EnTrade, a trading tool that creates online auctions to deliver environmental improvements, such as reducing the nutrient load in catchments. Through the online trading platform, farmers can bid for payments via a reverse auction mechanism to carry out measures that reduce the amount of nitrogen that leaches from the soil into groundwater and runs off into surface water. Measures they can bid for include planting cover crops or arable reversion, whereby arable land is reverted to grassland to reduce nutrients and increase the variety of habitat.

In 2015, Wessex Water negotiated with the Environment Agency and Natural England to offset 40 tonnes of nitrogen from entering Poole Harbour by working with farmers in the catchment, instead of building a nitrogen removal plant at Dorchester sewage treatment works. The company decided to use the EnTrade platform to implement the scheme. The first auction was run in June 2016 with the objective of removing 20 tonnes of nitrogen. The EnTrade platform estimates the savings for the buyer (Wessex Water in this case) associated with measures that sellers (farmers and landowners) choose to bid for. Sellers can enter their own costs from which they can see the resulting pound per unit of saving on which their bids will be judged. Sellers can adjust their bids at any point; once the auction closes, the buyer of the offsets can calculate the most cost-effective combination of bids to meet its target. EnTrade received 147 bids from 19 farmers, to make nitrogen savings of 47.5 tonnes through cover crops. The auction saved the company 30 percent on costs related to nitrogen reduction, compared to previous methods of working with farmers, demonstrating that such a market-driven approach can bring efficiency gains.

Following the pilot auction's success, two further auctions were run in February 2017, followed by another two in January and June 2018. These cover crop auctions received bids for a further 125 tonnes of nitrogen savings against a target of 70 tonnes, at a lower price than the previous auction. Further auctions for arable reversion received bids for 24 tonnes of savings over three years across 270 hectares. Overall, as of mid-2019, Wessex Water had received 557 bids from 63 farmers and achieved 153 tonnes of nitrogen savings across 2,993 hectares of land. The EnTrade platform operates now as a separate entity. Initially used only for nitrogen reduction, it is now looking for applications beyond nutrient trading, such as phosphorous and biodiversity offsetting.

The type of measures they can bid for including ***planting cover crops or arable reversion,*** *whereby arable land is reverted to grassland to reduce nutrients and increase the variety of habitat.*

Financing

The efforts led by Wessex Water to identify nature-based solutions that bring both environmental and cost benefits have already brought the company £100 million of savings, which have been incorporated into the new investment plan. The Wessex Water business plan for 2020-2025 establishes a £1.4 billion capital investment programme that incorporates its largest programme of environmental improvements to date (32 percent of total investment). Ofwat draft determinations on the plans, published in July 2019, allowed Wessex Water to invest £463 million to service resilience and the environment. In this allowance are included £372 million to improve the environment by efficiently delivering its obligations as set out in the Water Industry National Environment Programme (WINEP) and £10m million to address the impacts of deteriorating raw water quality. In December 2019, Ofwat will publish its final determinations setting price limits and allowed investment plans for water companies in England and Wales, which will provide the basis for Wessex Water's investments in nature-based solutions for 2020-2025.

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7. Waternet

Natural water filtration through sand dunes system

Geographic Location	Nature based solution	Lead agency
Amsterdam, Netherlands	Aquifer recharge, targeted land protection	Waternet

Description

To address water quantity and environmental challenges linked to overabstraction, artificial recharge has been in operation in the dune area to the west of Amsterdam for more than 55 years and has constantly been improved and fine-tuned over the decades. This system is managed by Waternet, a water company that provides water services to 1.3 million people in the municipality of Amsterdam and surrounding region. The company is a non-profit organization, jointly owned by the City of Amsterdam and the Regional Public Water Authority, Amstel, Gooi en Vecht. Waternet covers the entire water cycle, including drainage, drinking water supply, treatment and transport of waste water, keeping surface water clean, and flood control.

One of its main tasks is the management of the Amsterdam Water Supply Dunes (AWD) system, the primary drinking water source for Amsterdam. Waternet produces 90 million cubic metres of drinking water per year on average and pre-treats almost two-thirds of Amsterdam's tap water in the dune area of Harlem.

Challenges

In the municipality of Amsterdam and its surroundings, water has been sourced through pipes from the dune area of Haarlem since 1847. However, starting in the 1930s, over-abstraction led to saltwater intrusion in the dune area, which also caused severe ecological impacts. Large-scale artificial recharge was initiated in the 1950s to address these issues. Today, the sand dune filtering system and artificial groundwater recharge is a fundamental piece of green infrastructure that the city relies upon for its drinking water. Over eight decades, several conservation and restoration projects have been carried out to ensure adequate management of this nature-based solution.

90 million m^3 of drinking water produced

Waternet re-treats almost two-thirds of Amsterdam's tap water in the dune area of Harlem.

Actions and impacts

The Amsterdam Water Supply Dunes system covers an area of around 3,500 hectares in the Noord-Holland province. It is part of the Natura 2000 network of protected sites. Though supplemented by natural dune water, the main source of water is river water from the Lek Canal, situated 55 kilometres away and originating in the Rhine river. This surface water is pretreated close to the intake in Nieuwegein and then transported to the Amsterdam Water Supply Dunes at Vogelenzang. Once the water has percolated through the shallow groundwater system in the dunes, post-treatment takes place in the Leiduin water treatment plant. High-quality drinking water is produced through a 14-step process, with the dune sand acting as a natural filter for suspended particles and as an environment rich in bacteria that facilitates the decomposition of certain substances, such as pesticides and pathogens. The sand works as a natural barrier against some bacteria and viruses. Sand filtration also breaks down organic micro-compounds. The aquifer recharge system is based on the principle of using groundwater only for storage, removal of pathogens, and attenuating pollution peaks. The recharge system is combined with nature restoration goals and pollution prevention of the water source, which implies quality control in the upper catchment.

Since 1990, Waternet has carried out conservation measures and further large-scale projects to restore the natural dune systems and wetland habitat types. The overall aim of the Amsterdam dunes project was to restore and improve the characteristics and habitat types of the Natura 2000 site. Large-scale restoration was required to reverse the effects of long-term dehydration, eutrophication and the impact of invasive alien species. Specific actions have included removing the nitrogen-rich top layer of soil and invasive species, restoring ponds, mowing, grazing, and other nature management measures.

Financing

The land (36 square kilometres of dune area) was acquired by the city of Amsterdam piece by piece over the second half of the 19th century and the first quarter of the 20th century. These initial investment costs are now considered to be a sunk cost. The natural system delivers both large-scale storage and chlorine-free, natural removal of pathogens. Additional ozone treatment has been added to break down organic compounds but is not essential. As a result, the costs to operate and maintain the systems are low, and total costs of water production are below EUR 1 per square metre. There are no external subsidies, and all costs are paid by water users.

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8. Eau du Grand Lyon

Protecting water quality through an urban forest

Geographic Location	Nature based solution	Lead agency
Greater Lyon, France	Targeted land protection	Eau du Grand Lyon

Description

Eau du Grand Lyon, Veolia's fully owned subsidiary, provides and distributes drinking water in the Grand Lyon area. The region—established in 2015 to improve integrated planning and services throughout the metropolis—comprises 59 municipalities with a population of 1.3 million. Veolia is a French multinational that provides strategies related to water, wastewater, energy, and waste management, with a particular focus on promoting the transition towards a circular economy. The first contract won by the Compagnie Générale des Eaux, Veolia's ancestor, was with the city of Lyon, to which it has been providing water services without interruption since 1853. On behalf of Grand Lyon municipality, the operator is protecting 375 hectares around water well fields in the heart of the city. It has found this to be more cost-effective than a more complex water filtration plant— and it generates significant biodiversity benefits.

Challenges

Eau du Grand Lyon was created in February 2015 when Veolia signed an eight-year contract with Grand Lyon for a larger geographical area than previous contracts covered. Grand Lyon metropolis owns the land and the water infrastructure assets; it also decides on the investment programme and sets water tariffs. Day-to-day operations and maintenance are outsourced to Eau du Grand Lyon.

Water for the Grand Lyon area comes mainly from wells in the Rhone River alluvial aquifer in the heart of the city, through river bank filtration and managed aquifer recharge (peak production 450,000 cubic metres per day from 112 wells). Protecting water at the source is paramount to avoid the need for an expensive filtration plant and to prevent accidental pollution. The objective is to conserve the natural recharge area (a forest), which is also valuable local biodiversity.

Actions and impacts

Eau du Grand Lyon created artificial recharge ponds as a pollution barrier, and it has entrusted a reforestation and conservation program to the National Office of Forests to protect the natural recharge area for the well fields. Biodiversity monitoring and invasive species control actions are in place. Introducing these NbS for source water protection led to water being 100 percent compliant. These actions also created a natural habitat reserve at the heart of the metropolis, hosting 32 percent of the flora of Greater Lyon (including 24 orchid species) and sensitive heritage species such as wildcats, beavers, and otters. The area is also a migration corridor and a reproduction site for birds. Economic benefits also resulted from these actions, by increasing the attractiveness of the nearby area and generating green jobs; five wardens work at the site.

Financing

Veolia assessed benefits generated from this natural infrastructure by modelling the avoided production costs when compared to a theoretical grey infrastructure that would deliver similar water production capacity (1 million m3/ day). It found that total annualized costs associated with a typical coagulation and filtration plant would be in the range of Euros 52 to 74 million per year, as opposed to the annualized costs of the existing green infrastructure (Euros 32 million per year). Significant savings are achieved on operating costs, which stand at Euro 0.04 per m3 for green infrastructure (wellfields and source protection) as opposed to Euros 0.15 to 0.25 per m3 for a typical plant. This assessment confirmed that, in this case, source protection is likely to be more cost-effective than grey infrastructure. Managing the natural infrastructure enables the operator to keep water tariffs down through cost savings.

The objective is to ***conserve the natural recharge area*** *(a forest), which is also valuable in terms of local biodiversity.*

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9. Eau de Paris

Supporting farmers to shift to organic farming

Geographic Location	Nature based solution	Lead agency
Paris and surrounding areas, France	Targeted land protection, improved agricultural practices (reduced fertiliser, alternative plant protection), Land use change from farmland to pastureland	Eau de Paris

Description

Eau de Paris is the public water service provider which serves 3 million consumers in the city of Paris, France's capital. The company has initiated wide-ranging efforts to transition towards sustainable agriculture models where it obtains water, with expected long-term benefits on water quality via a reduction in diffuse pollution from agriculture.

Challenges

Water sources for the city of Paris are both surface water (50 percent) and groundwater (50 percent). Groundwater is abstracted from 102 wells and distributed across a vast area that extends up to 150 kilometres from the city. Most of these wells are located in farming areas, which are affected by diffuse agricultural pollution from nitrates and pesticides.

Actions and impacts

Eau de Paris has developed a multi-pronged initiative to protect its critical water resources in a sustainable manner over the long term. The initiative has taken various forms, including selective land acquisition and financial support and technical assistance to farmers, both on an individual basis and through group activities. Since 2008, Eau de Paris has been supporting farmers with financial assistance programs to help them reduce fertiliser and pesticide use and adopt organic farming practices. Five of its staff disseminate good agricultural practices. The company has helped develop market opportunities for farmers' products, including school canteens managed by the City of Paris. Eau de Paris has also purchased land where there is a specific risk of contamination, with a total of 574 hectares acquired by 2018. Eau de Paris leases the land to farmers for one symbolic euro. In exchange, farmers engage in agricultural models protecting water quality, including organic farming and grass-fed cattle rearing. The combination of these complementary levers has produced significant changes in agricultural practices. In one target area, the percentage of land cultivated with organic farming practices increased from 1 percent in 2010 to 15 percent in 2018. Overall, 4,365 hectares have been converted to organic farming and 9,470 hectares to sustainable farming practice. Improvements in water quality have been observed and will need to be confirmed through monitoring.

4,365 ha
have been converted to organic farming

Financing

Since 2007, subsidies for the adoption of agri-environmental practices have been provided under the Common Agricultural Policy (CAP). They have been complemented by funds from several projects successfully submitted to the Seine Normandie River Basin Agency—for instance, to support reduced nutrient use in farming through diversification and the adoption of crops that need fewer nutrients (such as leguminous crops or hemp) and stronger cooperation with farmers. Other projects support conversion of conventional cattle farms to grass-fed cattle systems. While funding for agri-environmental measures reached more than 130 farmers between 2012 and 2014 in target areas, it dwindled over the last few years due to payment delays and reduced relevance for local agronomic situations. Alternative funding sources are needed. Due to European Union restrictions on public subsidies, Eau de Paris is not allowed to make Payment for Ecosystem services to farmers from its own funds. It is considering notifying the European Union that it would use a new financial support scheme that would be compliant with EU agricultural guidelines so farmers can be paid. The company is also part of an EU-funded Interreg project with partners based in the UK and France to develop common approaches to payments for ecosystem services (CPES – Channel Payment for Ecosystem Services).

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10. swa Augsburg

Cooperating with farmers to protect medieval forest

Geographic Location	Nature based solution	Lead agency
Augsburg, Germany	Targeted land protection, improved agricultural practices	Stadtwerke Augsburg

Description

Stadtwerke Augsburg (swa) was established in 2000 as an independent company fully owned by the City of Augsburg. It provides water to approximately 350,000 people in Augsburg and neighbouring areas. In addition, swa runs the city's gas and electricity supplies and manages the public transport system in Augsburg. The nearby Siebentisch forest and the Lechau-meadows (Lechauen) provide the City of Augsburg with very high-quality water that requires zero treatment on its way from source to user. In the early 1980s, water quality was deteriorating due to agricultural and industrial activities in the surrounding area. To prevent investment in costly downstream treatment, swa took action to protect the water at its source with a three-point action plan.

swa provides water to **350,000 people** in Augsburg

Challenges

Water supply for the city of Augsburg comes from groundwater stored in Ice Age limestone gravel in the Siebentisch forest and in the Lechau-meadows south of Augsburg. The latter is the city's main water catchment area, with more than t60 wells for water abstraction. .It has been a Natura 2000 site under the Habitats Directive since November 2004. The city started acquiring forests in 1602 and has been managing them in a near-natural state ever since, jointly with the city's Forestry Administration. Nowadays, however, the catchment area for the city includes farmland, gardens, and even some industrial areas. In the early 1980s, concerns over water quality grew due to increased nitrate content in the groundwater from pesticides and chemicals from neighbouring industrial and farming activities.

Actions and impacts

In 1988, the city and swa recognised the urgent need to protect groundwater at source in both catchment areas to eliminate costly downstream treatment. That year, swa developed and launched a management plan based on three pillars: water protection zones, land acquisition, and cooperation with farmers. As a first step, swa systematically set out to acquire farm and industrial land in the water protection zones to convert it into green spaces. This land was then leased out to farmers under certain restrictions, including limitations on the use of pesticides and fertilisers. By 2019, swa had acquired 500 hectares for EUR 70 million. In 1991 swa significantly expanded the water protection zone south of the city in the Lechau-meadows) in response to a new Bavarian state regulation and by imposing strict limitations on farmers' use of pesticides and manure in these zones.

Swa established a cooperation model with farmers in the water protection zones, providing consultation services, financial incentives, and subsidies for acquiring equipment. A cost-benefit analysis in 2013 showed that the costs of groundwater quality monitoring and natural protection at source would be approximately 5 percent lower than the costs associated with water treatment.

The impact of these actions on groundwater quality has been impressive. Nitrate concentration in groundwater has decreased by 5-10mg/l between 1990 and 2018 from an original level of 40mg/l. Of the 1,400 hectares of farmland in the water protection zones, 45 obtained an eco-certificate, 600 apply groundwater protection measures but are not eco-certified, and 500 (32 percent) are owned by swa and leased out to farmers under strict restrictions limiting the use of fertilisers and pesticides.

Governance

Critical to success was swa's approach to establishing cooperation with farmers. This traces back to a joint research project financed by the German Ministry for Research and Technology in 1989. It established a forum for dialogue between experts and practitioners in farming and water resources management to explore collaboration opportunities for protecting water resources. At first, only three farmers took part in Augsburg's cooperation model, but this number had risen to 75 percent of all farmers in the area by 2019.

Augsburg's cooperation model is based on consultation as well as contractual agreements with farmers. It starts with deploying specialised swa staff and agricultural experts to conduct individual and group consultations with farmers, as well as mineral balances for their land. Consultation is complemented by an assortment of voluntary contractual agreements. The most common and foundational contract is the basic package (Grundpaket), which includes financial incentives to facilitate the transition to agricultural practices that protect groundwater. The Grundpaket consists of a complex mix of agricultural best practices and monitoring measures that the swa developed with the Technical University of Munich in Weihenstephan. Payments consist of a minimum amount of EUR 60 per hectare, which can then be supplemented by an additional nitrate premium of up to EUR 200 per hectare, varying according to reductions achieved. Conversely, if monitoring reveals high nitrate levels, fees are deducted from the payment to farmers.

In combination with or independent of the Grundpaket, farmers can sign additional agreements which commit other defined pieces of land to certain protective practices. These include abstaining from the use of triazine herbicides on maize fields, cultivating clover grass as soil cover for a continuous period of five years, and converting to organic farming. Further financial support is given in the form of subsidies of up to 50 percent for procuring environmentally friendly technologies, such as harrows for mechanical weed control or band sprayers for maize plantations.

The adoption of this approach required no legal or regulatory changes. This can be attributed in part to swa's legal status: despite being fully owned by the municipality, swa has maintained relative independence since its establishment as a public company in 2000.

Augsburg's cooperation model is based on ***consultation as well as contractual agreements*** *with farmers.*

Financing

The city of Augsburg ranked as one of the top 10 cheapest water providers among big cities in Germany in 2010. Water in Augsburg is sold for EUR 1.44 per cubic metre, of which 15 percent is used to finance all groundwater protection measures, including direct payments to farmers, monitoring and administration, and land acquisition (2010). The additional 15 percent to finance source water protection remains less than what would have been incurred should water treatment have been implemented.

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11. Vittel

Paying farmers to reduce nitrates in groundwater

Geographic Location	Nature based solution	Lead agency
Vosges, France	Improved agricultural practices (reduced fertilizer use, land use change); Forestry Best Management Practices (BMP)	Vittel (Nestlé Waters)

Description

Vittel is one of the leading bottled water companies in France. In 1992, it was acquired by Nestlé Waters, the largest bottled water company in the world. Water comes from the Vittel catchment, a 6,000-hectares aquifer 80 metres below ground at the foot of the Vosges Mountains in north-eastern France. It comes naturally to the surface through a natural geological fault. Since the 1990s, the company has established a series of private-public partnerships with farmers in the area to maintain desirable levels of nitrates in the catchment through good agricultural practices and a strategic use of soil resources.

Challenges

: In the early 1980s, concerns about rising nitrates concentration in the aquifer caused by agricultural intensification in the catchment posed a serious risk to the Vittel spring. Legislation on the quality of natural mineral waters in France is very strict: to be labelled as natural mineral water, no treatment should be applied except to eliminate natural unstable elements such as iron and manganese. As a result, the company was facing an existential threat to its business and needed to take action.

Actions and impacts

In 1989, Vittel started to study the relationship between farming practices and nitrate rates in the aquifer. The goal was to identify and test practices to reduce or maintain the rate of nitrates at the desired level, as well as to identify incentives for farmers to change their practices. The research programme, called Agriculture-Environnement-Vittel (AGREV), was a partnership with the French National Agronomic Institute (Institut National de la Recherche Agronomique – INRA). Vittel began a payment for ecosystem services (PES) programme for farmers with the goal of maintaining groundwater quality at acceptable levels (nitrate levels below 4.5 milligrams per litre). Key measures included incentives for farmers to reduce fertiliser use, to cut animal waste and manure application in the catchment area, and to give up maize cultivation for animal feed (land used for maize production shows nitrates rates of up to 200 milligrams per litre in the root zone). As the changes required heavy investment and the adoption of land and labour-intensive production systems, it took 10 years of engagement with farmers before the PES process turned into a successful partnership.

In 1992, Nestlé Waters created Agrivair, an intermediary responsible for negotiating and implementing the programme. This proved to be a pivotal point in programme implementation. Agrivair is located just outside the town of Vittel, close to farmers and farmers' associations. The director of Agrivair was well known to the farmers and stakeholders in the area. This contributed to ensuring continuity between design and implementation of the project and was critical to fostering communication among parties. By 2004, all 26 farms in the area had adopted the new farming system: 1,700 hectares had been switched from maize cultivation to alternative crops, and 92 percent of the sub-basin was protected. The programme led smaller farmers to retire and sell their land to Agrivair. The number of farms in the sub-basin declined from 37 to 26, whilst average farm size increased to 150 hectares, given that extensive production methods require additional land. As of 2006, all farmers had signed 30-year contracts that give them the usufruct of the land, provided they comply with the new farming system.

Over time, new challenges have required the programme to evolve and include non-farm municipal lands such as city parks, golf courses, a horse racing

track, and the city's thermal park. This allowed the company to maintain groundwater quality in the catchment amidst increasing urbanisation in the area. Nestlé Waters also expanded the approach to a total of 10,000 hectares by including the contiguous Contrex and Hépar catchments. These areas are rich in forest, and Agrivair introduced a forest management programme which aims to maintain a balance of trees to maximise nitrate uptake. The scheme was also replicated in the Perrier spring in Vergèze in southern France.

Today, the programme allows for the conservation of more than 90 percent of the land in the Vittel, Contrex, and Hepar catchments and has become an important factor influencing the economy of the region, thanks to Nestlé paying considerable mineral water taxes and having created more than 1,000 jobs in an area with 12,000 inhabitants. However, this has also raised concerns regarding water resources overexploitation. As the company extracts substantial volumes (with 740,000 cubic metres sold in 2017 alone), the groundwater table has been falling by up to 36 centimetres annually. The municipality is concerned and had to build a pipeline to source water from 15 kilometres east of the area to ensure adequate municipal water supply. Nestlé has agreed to cover the expenses for any related additional water costs for the population. This has generated a substantial debate among the company, the municipality, NGOs, and the public.

Financing

Nestlé Waters pays for ecosystem services through its intermediary, Agrivair. Within the programme, a package of incentives was developed in collaboration with farmers, with the following terms:

- Long-term security through 18- or 30-year contracts.
- Abolition of debt linked to land acquisition, whilst land acquired by Vittel can be used in usufruct by farmers for up to 30 years;
- Up to 150,000 euros per farm upfront grant to cover the cost of all new farm equipment and modernisation, followed by a payment of about 200 euros per hectare each year over five years;
- Free labour to apply compost in farmers' fields;
- Free technical assistance, including annual individual farm plans and introduction to new social and professional networks.

The farmers incurred no direct financial cost but bore substantial transaction costs, such as the cost of learning new practices and participating in the identification and testing of practices and in the incentive system and negotiations. They benefitted from secured long-term arrangements and from the cancellation of short-term and long-term debt. The costs to Vittel-Nestlé Waters in the first seven years of the programme amounted to EUR 1.14 million for farm acquisition; EUR 3.81 million for farm equipment; and EUR 11.3 million for farm financial compensation (this does not include the costs linked to establishing and operating Agrivair). In total, t the company spent an estimated more than EUR 24.5 million during the 1990s alone.

The programme allows for the conservation of more than ***90% of the land in the Vittel, Contrex and Hepar***

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12. Volvic

Public-private partnership for watershed protection

Geographic Location	Nature based solution	Lead agency
Department of Puy-De-Dôme, Clermont-Ferrand, France	Targeted land protection	Société des Eaux de Volvic

Description

Société des Eaux de Volvic (SEV) is a subsidiary of Danone, a leading global food company. SEV produces the natural mineral water Volvic, which comes from Auvergne, a region in France at the heart of the Chaîne des Puys-Limagne Fault, recognized as a UNESCO World Heritage Natural Site. To preserve the quality of this natural mineral water, Volvic co-created in 2006 the Environmental Committee for the Protection of the Volvic Impluvium (CEPIV), a public-private partnership with the four municipalities of the impluvium (catchment area) and local stakeholders. Its mission is to develop actions to enable local development, while protecting the impluvium and its biodiversity.

Volvic has been committed to operating in a sustainable way, always seeking to take actions for the environment and the preservation of biodiversity

Challenges

The catchment area from which Volvic draws water covers 3,800 hectares. Forest covers 60 percent of it, while the remaining 30 percent is heath and prairie. Most of the forested area (86 percent) is privately owned and unmanaged. Agricultural land is mainly pasture, supporting extensive cattle raising (mostly for meat production, as well as dairy). While no significant problem regarding groundwater has yet been observed, Volvic has been committed to operating in a sustainable way by taking actions for the environment, preserving biodiversity, and implementing a management strategy to prevent future risks. Regulations regarding mineral water in France dictate that Volvic maintain a constant mineral content, which calls for implementing measures to prevent contamination of water resources.

Actions and impacts

Since 2006, SEV initiated a water catchment strategy in its impluvium through a public-private partnership with the CEPIV. The partnership focuses on conserving the whole resource system, including groundwater resources, forests, and farmland, through solutions that benefit local communities. It has three main action areas: preserving the natural environment and biodiversity; developing environmentally friendly agricultural practices, including transition to organic farming; and promoting careful planning and management of villages, roads, and railways infrastructures.

Since its creation, the CEPIV has sought to preserve biodiversity in the catchment and taken concrete actions in that respect, including by sponsoring—financially and technically—NGOs that work on preserving the rich biodiversity in the area. For example, CEPIV has a longstanding partnership with the League for the Protection of Birds to protect the red kite, and a partnership with BeeOdiversity measures, through the settlement of beehives and the collection of pollen samples, the environmental quality of the area.

The CEPIV has also supported changes in agricultural practices by providing local farmers with financial, scientific, and technical support to help them implement sustainable practices for crop and land management. Additionally, it supports them with their transition towards organic agricultural practices. The CEPIV also provides funding for the transformation of agricultural effluents into compost and the protection of watercourses. Similar approaches have been adopted by other Danone water brands, such as evian, Badoit and La Salvetat.

Although only 10 percent of the area is built up, the CEPIV also works with residents and communities to ensure infrastructures protect the environment. These actions have focused on sanitation, as well as traffic and energy network management across the whole area. For instance, the CEPIV concluded a partnership with the French National Railway Company (SNCF) to maintain the railway tracks in the source area mechanically and without the use of chemicals. The CEPIV is also working on implementing and financing road improvements to limit the risk of accidents and resulting pollution in the catchment area.

Financing

Financial support to the programs comes from CEPIV member partners, including SEV and the municipalities. Other funding sources have included the state (for example, for the purchase of machinery or support for conversion to organic agriculture) and a grouping of municipalities. Financial support covers investments (sometimes collective) as well as operating costs (such as for shared equipment) and service costs (for example, advisory services for fertilisation. Local economic incentives and investments have been an important change factor for agricultural practices in the area, as these changes needed to be economically attractive for the farmers. The process also needed to be participatory and leave freedom of choice to the farmers. The public-private partnership does not include regular payments for ecosystem services, however, as it could be too costly for local public authorities to maintain such payments over time.

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13. Barcelona

Developing a river park to boost urban resilience

Geographic Location	Nature based solution	Lead agency
North Metropolitan Area of Barcelona, Spain	Constructed wetlands and targeted land protection	Barcelona City Council in cooperation with the Catalonian Water Agency and the Besòs-Tordera Consortium

Description

The metropolitan area of Barcelona, with a surface of 636 square kilometres, is amongst the most populated in Europe: 48 percent of its territory is urbanised land. It includes 36 municipalities, with approximately 3.2 million inhabitants.

Together with the Ter and the Llobregat, the Besós River is one of the main watercourses in the Barcelona area. With a basin of 1,039 square kilometres, it serves a population of more than 2 million and crosses 11 municipalities. Its water is used mainly for urban and industrial purposes. Although the region's drinking water is sourced primarily from the Llobregat and Ter basins, a small subterannean aquifer in the Besós acts as an auxiliary catchment area.

The Besós has undergone a process of ecological restoration over the last two decades. Main nature-based solutions include wetlands constructed to support water sanitation and a river park in the last section of the Besós featuring restored grasslands, pluvial meadows, recreational areas, and artificial ponds. Thanks to these measures, water quality of the river has drastically improved over the years. Nowadays, the River Park contributes to improved water quality and has increased the share of municipal green areas, offering a variety of recreational opportunities for citizens and acting as a refuge for local and migratory flora and fauna. However, it is still not suitable for recreational uses such as swimming and fishing.

Actions and impacts

The Besós River restoration efforts, instigated by citizen pressure, began in the late 1980s with the adoption of the Sanitation Plan of the Generalitat de Catalunya and the creation of the Consortium for the Defense of the Besós River Basin. An institutional agreement signed by the Consortium and the municipalities of Barcelona, Santa Coloma de Gramenet, Sant Adriá de Besós, and Montcada i Reixac set the basis for focused action and crystallized in a common project, the Environmental Recovery of the final stretch of the Besós River. Starting in 1999, it aimed to restore a nine-kilometres river stretch in three phases (2000, 2004, and 2007) and concluded with the creation of 1.15-kilometres river park.

The measures include the following elements:

1 Constructed wetlands

60 plots (total of 0.08 square kilometres) over a 3.8-kilometres transect of artificial wetlands to support Montcada's water treatment plants, using reed as the main plant species to allow water purification;

2 Public-use areas

a combination of natural areas (0.22 square kilometres of grassland and fluvial meadows) and pedestrian and bike trails through a five-kilometres transect;

3 Natural protected area

it extends over 450 metres and includes an artificial pond and a variety of plants of elevated ecological interest. The project aimed at providing a **combination of environmental and social benefits**. The measures have led to a partial recovery of the water quality, substantial recovery of local and migratory fauna (especially birds, fishes and amphibians) and flora (some displaced species have been reintroduced, such as the water lily), adaptation to flooding (increasing water retention capacity of river banks), an increase in available urban green space, more recreational opportunities, and enhanced landscape aesthetics.

Challenges

The Besós River experienced serious environmental deterioration during the second half of the 20th century as a consequence of intense industrial activity, rapid population growth, and accelerating urbanisation in Barcelona's metropolitan area. By the 1980s, it had become one of the most polluted rivers in Europe. Additionally, its torrential character (has caused fatal hazards, such as extreme flooding in 1962. During dry periods, the region's hydrological needs require water transfers from nearby rivers, such as the Ter and the Llobregat— whereas in rainy periods, the river swells drastically, posing a serious flood risk. Measures taken to tackle this in the past have included the canalization of the riverbed (including retention walls). However, these steps have restricted the ability to try other solutions, including nature-based ones. Another significant challenge: the river flows through an urban area comprising many municipalities, so different governance levels, supra-municipal bodies, and other collectives need to work in a coordinated manner to manage it.

Governance

The Consortium for the Defense of the Besós River Basin has been a key player in the restoration. Twenty-five municipalities and the Metropolitan Entity of Hydraulic Services and Waste Treatment formed the consortium to improve the river's environmental quality. The consortium defined an integrative management system of the river, working with the Catalonian Water Agency and Barcelona's City Council. The consortium, which is still active, changed its name in 2016 to Consortium Besós-Tordera, and currently includes 64 municipalities, the Barcelona City Council, the AMB (Metropolitan Area of Barcelona administrative body), the Comarcal Council of Vallés, and the Consortium for East Vallés Waste Management.

Although the Catalonian Water Agency is responsible for the Besós River as a whole, the management of the river park has been delegated to the Barcelona City Council, which must follow the instructions stated in three regional plans (River Use Plan, Exploitation and Maintenance Plan, and Emergency Plan) and in the Agreement for the Conservation of the Besós River. Barcelona City Council has a specific body in charge of this task, the Technical Office for Territorial Action in Natural Protected Areas—which subcontracts external parties for specific services (such as gardening, maintenance, and monitoring). Additionally, Barcelona City Council is open to support initiatives proposed by municipalities and external entities such as schools as long as they align with the park regulation.

It was constituted through a statement of commitment of **25 municipalities and the Metropolitan Entity of Hydraulic services and Waste Treatment** to improve the Besòs environmental quality.

Financing

In 1999, the environmental recovery of the final stretch of the Besós River was assigned an initial budget of EUR 36 million from public sources (80 percent from the European Regional Development Fund/Cohesion Fund and 20 percent from municipal funds). In 2007 it received EUR 1 million from the AMB to finalise the ecological restoration of the last 450 metres, corresponding to the river mouth. Since the completion of the river park, Barcelona City Council assigns approximately EUR 750,000 per year to cover maintenance costs, such as gardening, watering, paving, and infrastructure repair and improvement), communication, and evaluation and monitoring. The results of regular monitoring are captured in periodic reports. Barcelona City Council is in charge of the flora and fauna monitoring programmes (fish, birds, invertebrates) and the wetlands' chemical composition programme (in collaboration with the University of Barcelona), and the Catalonian Water Agency monitors water quality. They work together to determine where and when to do more substantial monitoring.

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14. Room for the River

Making room for the four main rivers

Geographic Location	Nature based solution	Lead agency
The Rivers IJssel, Rhine, Lek, and Waal	Reconnecting rivers to floodplains	Room for the River (Ruimte voor de Rivier)

Description

Room for the River is a government-led programme addressing the issue of flood protection and the improvement of ecological conditions of catchment areas for rivers in the Netherlands. In 2006, the Dutch government approved Room for the River, a multi-level partnership of the Dutch government, the provinces, regional water boards, and municipalities. The programme ran between 2007 and 2018 and led to the implementation of 34 projects across the Netherlands in the catchment of the country's four main rivers: IJssel, Rhine, Lek, and Waal.

Challenges

In 1993 and 1995, the Netherlands experienced severe flooding, which inundated farmland and led to the evacuation of 250,000 people and a million animals. Total damages amounted to over EUR 400 million. Following these floods, the Dutch government started exploring how to safeguard flood-prone areas by enabling the rivers to safely absorb far greater volumes of water. Previously, the country relied mainly on the construction of dykes and berms for flood mitigation, so the adoption of nature-based solutions for flood risk management represented a major shift in national policy.

Financing

The project was entirely funded by the Dutch government. The total budget allocated for the project was EUR 2.3 billion. This figure does not take into account ongoing costs, such as future flood protection, as well as maintenance costs of completed projects. An example of these costs is that, after the creation of floodplains, tree growth must be kept in check to make sure that growing vegetation does not reduce the speed of river flow.

Actions and impacts

The projects focused on creating "room for the river" through nine methods that restore landscapes along rivers so that they can better absorb water. Methods include floodplain excavating, depoldering, relocating dykes, lowering breakwater spurs, strengthening dykes, excavating riverbeds, removing obstacles, creating high water channels, and adding water storage. Interventions included a mix of green and grey infrastructure. The catchment areas became safer and more attractive, thereby generating opportunities for improved urban and rural development and creating more recreational areas.

Three ministries—the former Ministry of Transport and Water Management; Ministry of Agriculture, Nature Management and Fisheries; and the Ministry of Housing, Spatial Planning and the Environment—worked together on one plan to give "room to the river" in each of the identified rivers. The ultimate responsibility for the projects resides with the Minister of Infrastructure and the Environment and is shared by the Secretary of State for Economic Affairs. The stakeholders involved in the project included the provinces, municipalities, water authorities, and the Directorate General for Public Works and Water Management (Rijkswaterstaat). All stakeholders were jointly responsible for carrying out the Room for the River programme.

The programme office was assigned responsibility for completing all projects by 2015 at the latest in collaboration with multiple partners at the central and decentralised levels of government, as well as with the private sector. This multi-level water governance means that the programme was not seen as a series of isolated projects but as a series of interventions connected by the same targets and budget.

While the overall Room for the River programme has been applauded internationally, it encountered some challenges at the national level at first. The programme required buying agricultural land from farmers and transforming it into floodplain areas, which generated resistance from farmers. However, because the project included the participation of municipalities and local citizens in the decision-making process, farmers became increasingly supportive over time. Local communities could choose between alternative plans, as long as those met the same programme targets. This helped gain and spread the support for this initiative at the municipal level.

An example of how this multi-level governance worked is the project Room for The River Waal. Here, the city of Nijmegen—the project coordinator—worked closely with the Rijkswaterstaat, the Rivierenland Water Authority, and the Province of Gelderland to implement flood protection measures in the occurrence of high water (see case study 14 on Nijmegen).

The projects focused on creating "room for the river" through nine different methods to restore landscapes along rivers so that they can better absorb water in case of floods

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15. Nijmegen

Making room for the river by widening the floodplain

Geographic Location	Nature based solution	Lead agency
Nijmegen, Netherlands	Reconnecting rivers to floodplains	Public Works Department (Ministry of Infrastructure and Water Management) in cooperation with the City of Nijmegen

Description

Nijmegen is a growing Dutch city with a population of 173,556 in 2016 and a total area of 57.63 square kilometres. Located in the east of the Netherlands close to the German border, it is known for being proactive in sustainability issues and won the European Green Capital Award in 2018. The city faces a double challenge: an urgent need for geographical expansion to accommodate the growing population, and heightened risk of fluvial flooding.

Room for the River Waal Nijmegen is intended to address these challenges. It is part of the Dutch government's Spatial Planning Key Decision Room for the River developed in 2006 to deal with the increasingly large volumes of water that rivers flowing through the Netherlands have to handle. It is a good example of the new and ongoing movement in the Netherlands to include both regional and municipal levels more actively in the decision-making and funding of water management measures, and it provides a multifaceted example of successful multi-level cooperation involving national, regional, and local authorities as well as water boards.

Challenges

The River Waal, the Netherlands' largest river with an average width of 350 to 400 metres, passes through Nijmegen and generates a flood risk. The risk is increased by the fact that the land behind the river embankments is becoming increasingly populated and used. Projected water level increases due to climate change are likely to further compound the risk.

The River Waal is a lowland river, originating where the River Rhine crosses the German-Dutch border, and runs wide and broad until it reaches Nijmegen. The river and the floodplains then become significantly narrower and the meandering decreases, thereby creating a serious bottleneck and one of the narrowest bends in the Dutch river system, with an almost 90-degree angle. This leads to a heightened risk of rising water, as the historic floods of 1993 and 1995 demonstrated. Some quays were flooded along the river, and the entire dike ring at the northern part of the river had to be evacuated in 1995 as a precautionary measure. Furthermore, the river is 'trapped': the southern shoreline where the city of Nijmegen is located has no room for the river to expand due to extensive land use, whereas the northern side is blocked as a result of a dike installed. Additional pressures are created by the city's urgent need to expand and accommodate more development.

Actions and impacts

The programme for Room for the Waal Nijmegen was implemented by the Department of Public Works (Netherlands) in cooperation with the City of Nijmegen and included the relocation of the existing dike 350 metres inland, thereby widening the floodplain. This was coupled with digging a secondary meander or ancillary channel (with a length of 4 kilometres and a width of 150 to 200 metres) to protect the area at the bend of the river from flooding. The result was the creation of a new island, which was turned into an urban park. The natural vegetation (grassland) on the island is managed naturally by grazing, thereby slightly contributing to flood reduction (vegetation can increase flood risk if becomes too high).

To integrate the City's need for expansion with the flood protection measures, three bridges were built to connect Nijmegen with Lent (the latter officially becoming part of Nijmegen and being called Nijmegen-Lent), and a quay was constructed.

Governance

Traditionally in the Netherlands, water management projects are the responsibility of the national government (the Department of Public Works within the Ministry for Infrastructure and Water Management) and are implemented top-down with funding largely provided by the national government. One of the goals of Room for the River is to change this and to adopt a more collaborative approach to flood reduction by involving regional and local governments and other stakeholders in the process. This includes exploration of alternative investment options, decision making, design, implementation, funding, maintenance, and monitoring. The result has been a participatory and collaborative approach new in the Netherlands.

In this case, the City of Nijmegen played a particularly proactive role in co-creating the project and pushing for the integration of its development agenda with the flood protection measures. The national government, which owns the land on the shorelines of the River Waal, financed the project and was responsible for implementing and monitoring the project. The City was responsible for developing plans for the project and for integrating its planned expansion and development into these plans (for example, its expansion in the direction of Lent on the other side of the river).

Cooperation and dialogue between the parties continue to this day. Whereas conflicts occasionally arise, the collaboration has been on the whole successful and has resulted in impressive collaborative solutions. The new bridges feature a challenging and spectacular design, and the threshold that dams the upper part of the ancillary channel was specifically designed to create some flowing water during low water levels, in addition to minimizing the impact of sedimentation in the main channel.

The water board Rivierenland is in charge of dike maintenance. On the other hand, the Province of Gelderland (the regional government) has a minor but regulatory role in the project by providing permits to ensure that the natural environment is preserved and protected.

Other projects in the wider Room for the River Waal have included a more active role for the regional governments. There is a clear movement in the Netherlands to include

both the regional and municipal levels more actively in the decision making and funding of water management measures.

An additional important success factor was Nijmegen's collaboration with other cities such as those in the European Network of Flood Resilient Cities, which provided inspiration for the city's plans.

Financing

The entire programme was concluded in 2015 with a total cost of EUR 350 million financed by the government of the Netherlands. Whereas no major flood has since occurred to test the efficiency of the measures, the water levels at maximum discharge were reduced to 34.6 centimetres.

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16. Navarra

Riparian restoration to reduce flood risk

Geographic Location	Nature based solution	Lead agency
Navarra, Spain	Riparian zone restoration, reconnecting rivers to floodplains	Government of Navarra

Description

Navarra has developed Flood Risk Management Plans with the integration of nature-based solutions to reduce the risk and effects of flooding. These plans contain actions in six areas:

1. Climate change monitoring
2. Adaptive water management; forests, agriculture, health, infrastructures, and territorial planning
3. Strategic capacities to address climate change adaptation
4. Flood Early Warning System in practice
5. Flood risk local management with self-protection plans for 16 municipalities
6. River restoration projects

Challenges

Navarra is highly susceptible to flooding, with multiple types of events that can lead to flooding. Throughout its history, Navarra populations have been located in dominant places with agricultural potential, many of which were in flood risk areas. As a consequence, there are reports of serious damages caused by floods since the year 827. With the approval of the European Directive 2007/60/EC on the assessment and management of flood risks, the need and opportunity to create a flood plan for Navarra emerged.

Actions and impacts

In 2011, the Flood Risk Management Plans for Navarra sub-basins were approved. This included the development of hazard and risk maps, as well as the adoption of actions in the six areas previously described. The sixth area includes a series of actions based on the protection and restoration of rivers as a natural solution to mitigate risks, with focus on the protection of riverbeds and banks within the 10-year flood return period zone, the establishment of preferential river territory, and gradual regulations in the area with a return period of 500 years.

Financing

These actions have been financed by public funds and the European Regional Development Fund (ERDF) through the Operational Cooperation Program Territorial Spain - France - Andorra (POCTEFA 2014-2020), such as the project "H2OGurea, cross-border watersheds integrated management".

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17. Glasgow

Constructing artificial wetlands to reduce flood risk

Geographic Location	Nature based solution	Lead agency
Glasgow and Clyde Valley, Scotland	Construction of artificial wetlands, targeted land restoration (peatland)	Glasgow and Clyde Valley Green Network Partnership

Description

The lochs and wetlands within the Gartloch and Gartcosh area are natural heritage sites. The area has a history of flooding, and there are some water quality concerns. These areas are home to a rich assortment of wildlife and habitat, whilst also holding significant housing potential for a growing population. The Seven Lochs Wetland Park was established in July 2016 on 16 square kilometres of this land. It is managed by a unique partnership among Glasgow City Council, North Lanarkshire Council, Forestry and Land Scotland, Scottish Natural Heritage, The Conservation Volunteers Scotland, and two local community development trusts. The partnership started off as a steering group in 2012 and evolved to become The Seven Lochs Partnership in 2016 to consider how best to manage the site. This case study shows how the integration of nature-based solutions into existing local planning, the assimilation of cross-sectoral co-benefits, and a partnership governance structure can pave the way for innovative financing solutions and open the door for a wide range of new opportunities.

Challenges

Surface water is a central feature of the Gartloch and Gartcosh site, which is composed of a complex network of lochs, wetlands, seasonal water bodies, and drainage ditches. The area is in large part low lying and is the headwaters of four catchments draining into four main watercourses, making it prone to flood risks. These watercourses all drain into urban areas and have a history of flooding. The presence of residential developments and fragmented farmland further heightens this risk. Water quality is an additional concern. Whereas the general water quality is good, a couple of downstream sites are affected by diffuse pollution and do not meet good ecological status as per the Water Framework Directive. Other non-water-related challenges include loss of biodiversity and natural habitat, high development pressure, and endangered natural heritage, among others.

Actions and impacts

A mapping exercise of various flood scenarios was conducted as part of the Seven Lochs Hydrological Study. The study indicated that improvement and better management of natural wetlands, and the creation of wetland habitat linked to planned development, would help mitigate flood risk as well as improve water quality.

As of mid-2019, the project was in its initial implementation phase. The following measures were in place to help reduce flood risk in the surrounding communities as well as in downstream areas: creating new areas of wetland habitat, installing floating islands, restoring peatland , and de-culverting a watercourse. Further actions include the preservation and expansion of reedbeds and marsh, including planting the floating islands with reedbed vegetation to facilitate removal of nutrients and improve water quality. Water quality is regularly monitored to assess these measures, but no conclusions can yet be drawn as to whether water quality has already improved.

Governance

Key to the success of this initiative was the incorporation of multiple benefits across multiple policy agendas (flood mitigation, climate adaptation, recreation, heritage, biodiversity, education), with existing local policies for regeneration and development (such as the Glasgow and Clyde Valley Strategic Development Plan, 2012) to develop a shared, long-term vision for the area. The Seven Lochs Vision and Masterplan (2013) has been adopted by both Glasgow and North Lanarkshire Councils, and will inform and support future development and regeneration activity.

This wide spectrum of interests paved the way for the formation of a unique partnership to govern the project. This was further strengthened by the need for co-decision-making between the Glasgow and North Lanarkshire Councils regarding the management of publicly owned land and planning of development within the park boundary. The councils gave the project additional anchoring and legitimacy by committing to include the park vision in their strategic development frameworks for the area. (North Larnarkshire has already done so, and Glasgow will soon follow suit). This means that developers must work with the partnership to identify how new development can contribute to delivering new green infrastructure. The new green infrastructure within the development boundary—such as Sustainable urban drainage (SuDS), walking and cycling routes, and new greenspace—is a requirement for planning permission and will be delivered by developers. Glasgow and North Lanarkshire councils can also request a contribution from developers towards new green infrastructure on adjacent land.

Financing

Both the partnership governance structure and the multi-sector approach were essential for securing £6.8 million funding for the project, including a £4.5 million grant from the national Lottery Heritage Fund. Other funding is being provided by the project partners, Scottish government, and charitable trusts. The partnership also continues to nurture an enabling environment by providing a wide range of opportunities for local people to learn about and help manage heritage and nature in the park.

Key to the success of this initiative was the incorporation of multiple cross-cutting benefits across multiple policy agendas with existing local policies for regeneration and development.

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18. Copenhagen

Reducing the impact of urban flooding

Geographic Location	Nature based solution	Lead agency
Copenhagen, Denmark	Blue-green spaces (bio-retention and infiltration) for flood reduction	City of Copenhagen and the Greater Copenhagen Utilities (HOFOR)

Description

The Greater Copenhagen Utility (HOFOR) is the metropolitan area's utility company and is in charge of water and waste water services, district heating and cooling, and gas supply for eight municipalities representing approximately 20 percent of Denmark's population. HOFOR operates as a private company that is 100 percent owned by the eight municipalities it serves, with the City of Copenhagen owning a 73 percent share. Copenhagen is a pioneer in the area of nature-based solutions for climate adaptation. It has captured its achievements and objectives in 'Climate adaptation and urban nature' (2016). HOFOR is also known for being forward-thinking in water management practices—having, for example, rehabilitated Copenhagen's polluted harbour in cooperation with the City of Copenhagen, to transform it into a recreational space for citizens.

Challenges

Serious pluvial flooding and extreme precipitation events are central challenges that the City of Copenhagen is increasingly grappling with, especially as the impacts of climate change unfold and test the resilience of the city and its infrastructure. The city experienced five major rainfall events between 2010 and 2016, including a 100-year storm in 2010 and a 1,000-year storm in 2011, the latter of which resulted in damages of more than EUR 800 million—excluding infrastructure repairs and indirect costs as reported by Insurance and Pension Denmark. This sent a clear signal that change was needed.

Financing

HOFOR is usually the entity responsible for financing flood reduction and mitigation measures. However, as the City and HOFOR set out to implement the Cloudburst Management Plan, they encountered a legal roadblock. National legislation at the time (2011) clearly distinguished between mandates for 'below the ground' (largely grey infrastructure) and surface projects. HOFOR had the mandate to finance traditional grey water infrastructure, but any surface measures—such as parks, swales, and roads—had to be financed and owned by the City of Copenhagen, even if those measures were to reduce flooding. In close collaboration, the City and HOFOR approached national authorities to request a change in the law to allow the city to plan and build the surface projects and still have the water utility pay. The petition was successful, especially given existing political will at the national level and the fact that catastrophic floods were still very present in everyone's memories. The legislation was amended in 2013 to allow 100 percent funding by HOFOR until 2015; from 2015 onwards HOFOR's funding would be reduced to 75 percent and the city would be expected to contribute the remaining 25 percent.

Following this legal change, nature-based solutions in public areas were implemented jointly by the city and HOFOR, with HOFOR financing the flood protection measures. In a park, for example, the city finances tree planting and playgrounds and HOFOR finances a swale or drainage hole. To offset the costs, HOFOR can raise the water tariffs by 10 to 15 percent after conducting a political meeting and a public hearing to garner support.

Since 2015, Danish municipalities have had to pay 25 percent of the hydraulic cost for new surface projects. This has made the implementation of the Cloudburst Management Plan very difficult as the program competes with other municipal responsibilities. The city has therefore again asked for a revision, and the decision is currently being revised with the hope that 100 percent funding by HOFOR will be allowed again.

Actions and impacts

In 2010, the City of Copenhagen conducted feasibility and economic assessments of different measures for flood protection (conventional, blue-green, and a combination of both) as part of its newly prepared Climate Change Adaptation Plan to decide on the most appropriate way to protect the city. The plan was further developed in a Cloudburst Plan in 2012, addressing the decisions and actions that can be undertaken at a services level for protecting the city against a statistical 100-year storm event.

This provided the basis for preparing the Cloudburst Management Plan, which addresses flood protection for seven central city catchment areas through the integration of existing and new grey infrastructure and a selection of blue-green solutions. The plan includes 300 surface projects to be implemented based on priority over 20 years through 2035.

In 2018, Copenhagen's seven catchments were further divided into 60 sub-catchments based on the natural water catchment areas to facilitate project implementation. Each of the sub-catchments is to have its own master plan with respective projects for flood protection: of these plans, three had already been completed and nine were under development by mid-2019. At that date, eight surface projects, along with 25 pipes and tunnels projects, have been completed. The surface projects range from bigger parks to retention ponds and squares. One of the projects in the central part of the city uses Enghave Park as a reservoir for rainwater during a cloud burst.

The city monitors progress every year and adjusts the Cloudburst formula to increase accuracy. A new and more scientific calculation and modelling is now available for the entire city, including projections of the numbers of citizens affected in each area.

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19. Duero basin

Natural aquifer recharge to restore natural wetlands

Geographic Location	Nature based solution	Lead agency
Castilla y Leon, Spain	Natural aquifer recharge	Duero Hydrographic Confederation

Description

The Duero Hydrographic Confederation manages the international basin district of the Duero River in Spain and coordinates the efforts towards the natural recharge of the Medina del Campo shallow aquifer in Spain. The H2020 NAIAD project (Nature Insurance Value: Assessment and Demonstration) is a European project funded by Horizon 2020. Started in December 2016, it aims to demonstrate the potential of NbS to reduce water-related risks—specifically extreme water-related disasters. The project's goal is to operationalize the concept of nature insurance value, recognizing the contribution of ecosystems to society's resilience to water risks. The aim of the project is to explore and promote the potential role of NbS as a natural insurance against extreme hydrological events, such as floods and droughts, as well as the provision of additional benefits. The project has designed a series of methodologies that have been applied in nine sites across Europe. The case of Medina del Campo is the only one that focuses on drought risks. One of the two adaptation strategies considered by the project consists in the implementation of a natural drainage-based NbS to support natural recharge in the Medina del Campo shallow aquifer. This aquifer is seriously overexploited, which in turn impacts regional water availability and the integrity of the aquifer-fed surface aquatic ecosystems. This measure is part of an Integrated River Basin Management Plan designed by the Duero River Basin Authority, which comprises a set of green, hybrid, and soft measures aimed at achieving high quality standards for the Duero water bodies while safeguarding regional economic and social sustainability.

Irrigated agriculture has a great influence on the economy and the subsistence of the rural areas, accounting for ***96 percent of annual water withdrawals.***

Challenges

The Duero basin is an international watershed basin that spans seven regions. Most of the territory is in Castilla y León (98.32 percent), whilst remaining areas are distributed among the autonomous regions of Galicia, Cantabria, La Rioja, Castilla-La Mancha, Extremadura and Madrid. The Medina del Campo aquifer in the Duero basin occupies an area of 3,700 square kilometres that includes 154 municipalities in Castilla y León. Irrigated agriculture has a great influence on the economy and the subsistence of the rural areas, accounting for 96 percent of annual water withdrawals and being linked to 5,495 concessions for use of underground water for irrigation. Extensive and excessive extraction has caused a significant decrease in groundwater levels in recent decades, causing a degradation of water quality and a deterioration of riverine ecosystems. Two rivers and several wetlands associated with the aquifer have disappeared, thereby greatly reducing provided ecosystem services. According to the Duero Hydrological Plan, the aquifer water quantity is in bad condition.

Actions and impacts

Within the NAIAD project's Medina del Campo demo, two NbS based adaptation strategies have been co-designed and explored with the main local stakeholders. The first strategy included two action areas:

- NbS consisting of a natural-drainage based recharge of the shallow aquifer through a transfer to reinforce the flows of the main river feeding the aquifer, which will stimulate a gradual increase in the infiltration and natural recharge of the aquifer
- Groundwater management measures: the creation of Groundwater User Associations, the control of groundwater abstractions, and the raising of environmental awareness.

Another strategy of interest considered by the project is the introduction of agricultural alternatives, including crop changes and soil water retention practices that could allow reducing water requirements without leading to economic loss for farmers in the long term. These strategies were analysed to assess their potential to reduce the impacts of recurrent droughts as a result of climate change and restore the quality of the aquifer and associated ecosystems. The analysis assessed potential avoided drought-related damages and estimated additional values created as co-benefits. The resulting socio-economic and environmental impacts are being estimated through modelling, economic evaluations, and participatory valuation of intangibles, as well as the inclusion of multidimensional quantitative indicators.

Financing

This project is promoted by the Duero Hydrographic Confederation and the Autonomous Community of Castilla y León, with European funding via the H2020 NAIAD and LIFE-IP RBMP programs. The LIFE-IP RBMP Duero project will finance the implementation of the NbS and its monitoring. The implementation of the NbS for the recharge of the aquifer will cost EUR 12.5m. Of these, LIFE funds will cover EUR 6.7 million and EUR 5.8 million will be contributed by the Autonomous Community of Castilla y León.

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Annex B-1

European policies and financial instruments supporting NBS-WS: summary overview

Table B-1 *Key Directives relative to European water policy and examples of how they support NbS-WS*

Title	Description
Water Framework Directive (WFD) (2000/60/EC)	EU's central piece of legislation for water management. Set out rules to halt deterioration in the status of EU water bodies and achieve 'good status' for Europe's rivers, lakes and groundwater, which include: protecting all forms of water (surface, ground, inland and transitional); restoring the ecosystems in and around these bodies of water; reducing pollution in water bodies; guaranteeing sustainable water usage by individuals and businesses. Required management at river basin level and preparation of River Basin Management Plans by Member States on a catchment level with periodic updates every six years. Targeted land protection, revegetation, riparian restoration, improved agricultural practices, wetland restoration and creation
Sewage Sludge Directive (86/278/EEC)	Specified that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired. The Sewage Sludge Directive is part of the basic measures under WFD.
Nitrates Directive (ND) (91/676/EEC)	Aimed to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution; and to protect human health and living resources and aquatic ecosystems and to safeguard other legitimate uses of water.
Urban Waste Water Treatment Directive (91/271/EEC)	Protected the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors. It applies to the collection, treatment and discharge of domestic, mixed and industrial wastewater.
Habitats Directive (1992/43/EEC) and Birds Directives (2009/147/EC)	Provided the legal framework for a comprehensive system of protected natural areas across the EU, the Natura 2000 network, to address the continuing degradation of natural habitats and threatened wild species. Promoted the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements.
Drinking Water Directive (DWD) (98/83/EC)	Concerned the quality of water intended for human consumption. Recent amendment included the updating of water quality standards, the introduction of a risk-based approach to the monitoring of water, the improvement and harmonisation of information on water quality and services to consumers, the harmonisation of standards for products in contact with drinking water and the introduction of obligations to improve access to water.
Bathing Water Directive (2006/7/EC)	Aimed to safeguard public health and protect the aquatic environment in coastal and inland areas from pollution. Bathing waters can be coastal waters or inland waters (rivers, lakes). The Bathing Water Directive is part of the basic measures under WFD.
Groundwater Directive (GWD) (2006/118/EC)	Set groundwater quality standards and required Member States to undertake measures to prevent or limit input of pollutants into groundwater, to help achieve environmental objectives of WFD. Reviews of the directive's technical provisions to be undertaken every six years. It is a technical directive without the holistic approach of the WFD. Focus lies on parameters for groundwater to fulfil rather than source water protection.
The Pollutant Release and Transfer Register	Aimed to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution; and to protect human health and living resources and aquatic ecosystems and to safeguard other legitimate uses of water.
Regulation (No 166/2006)	Regulated the reporting requirements and supply of data to the EU for a European Pollutant Register, providing access to information on pollution. Under this regulation, operators must report emissions of pollutants if those exceed specified thresholds.
Floods Directive (2007/60/EC)	Aimed to prevent adverse impacts of floods on human health, safety and the environment. Defined the steps to take when assessing risks and requires the adoption of flood risk management plans in parallel to river basin management plans under the Water Framework Directive.
Directive on Environmental Quality Standards (EQSD) (2008/105/EC)	Defined the EQSs of priority substances that apply across the EU. Regular review of the EQSD includes review of the list of priority substances (Annex 10 of the WFD). This was first done in 2013, when 12 substances and groups of substances were added to the existing 33 priority substances. Among the priority substances of the WFD, some are defined as priority hazardous substances, which should be 'phased out', i.e. all discharges, emissions and losses must be ceased.
Directive on Sustainable Use of Pesticides (2009/128/EC)	Aimed at reducing the risks and impacts of pesticide use on human health and the environment, and at promoting the use of integrated pest management and alternatives such as non-chemical approaches.

Title	Description
Industrial Emissions Directive (2010/75/EC)	Set out rules on the integrated prevention and control of pollution arising from selected industrial activities. The Directive for Integrated Pollution and Prevention Control, which is part of basic measures of WFD, was transformed to Directive on industrial emissions.
Plant Protection Products Regulation	Specified that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired. The Sewage Sludge Directive is part of the basic measures under WFD.
(No. 1107/2009)	Set out rules for the authorisation of plant protection products and their marketing, use and control. The Plant Protection Products Regulation is part of the basic measures under WFD.

Annex B-2

European policies and financial instruments supporting NBS-WS: summary overview

Table B-2 *Key policy instruments guiding adoption of NBS-WS in Europe*

Title	Description
Common Agricultural Policy (CAP)	First introduced in 1962 and reformed several times since. Aims to safeguard the production of safe, high-quality food, regulate the impacts of farming on the environment, and provide investment in rural areas. The regulatory side includes requirements that farmers comply with environmental, animal health and welfare and land management requirements (called cross-compliance): "good agricultural and environmental conditions" are among the elements linked to EU environmental legislation. The economic side of the CAP includes direct payments to farmers as well as the European Agricultural Fund for Rural Development (EAFRD) (see Box 73 for details). Specified that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired. The Sewage Sludge Directive is part of the basic measures under WFD.
EU Biodiversity Strategy to 2020 (COM (2011) 244)	Aimed to halt biodiversity loss and facilitate the creation of a green, resource efficient economy. It constituted an important part of the Europe 2020 Strategy. It called, among other elements, for greater attention to ecosystem services and to green infrastructure (though it does not contain a particular emphasis on freshwater).
A Blueprint to Safeguard Europe's Water resources COM (2012) 673	Provided a long-term framework for EU water policy. Emphasized key themes which include: improving land use, addressing water pollution, increasing water efficiency and resilience, and improving governance by those involved in managing water resources, adopting economic mechanisms such as funding and market-based instruments to improve water use efficiency. Main recommendations included: improved implementation of existing policies and enhanced integration of water aspects into other policy sectors such as the CAP, the Cohesion and Structural Funds.
Green Infrastructure (GI) strategy (COM (2013) 249)	Outlined the multiple benefits provided by GI, and how these contribute to the achievement of various EU policies - such as those relating to water quality.
7th Environmental Action Programme to 2020 (1386/2013/EU)	Included protecting the Union's natural capital and safeguarding its citizens from environmental risks. Pointed out the need for wiser investments and appropriate funding and encourages public-private initiatives. Stated that a mix of policy mechanisms is needed to ensure the understanding and engagement of actors at different levels, such as market-based instruments and information. Described and pushed for the full implementation of existing legislation and policies.
An EU Strategy on adaptation to climate change (COM/2013/0216)	Targeted to address the consequences of climate change at all governance levels. Set out how the Commission should support and coordinate the work of Member States, increase the knowledge base for better informed decision-making, and prioritise adaptation in key sectors such as energy and transport. Among the actions to be taken, Member States are expected to prepare their own adaptation strategies at either national or regional level.
EU Forest Strategy (COM (2013) 659)	Addressed the role of forests in ensuring water quality and quantity and made the link between forestry and the implementation of the WFD and Rural Development Programmes. Co-financing of forestry measures under the Rural Development Regulation has been the main means of EU-level funding.
Urban Agenda for the EU (2016)	Aimed at being an integrated and coordinated approach to deal with the urban dimension of EU and national policies and legislation. It represents a new multi-level working method promoting cooperation between Member States, cities, the European Commission and other stakeholders in order to stimulate growth, liveability and innovation in the cities of Europe and to identify and successfully tackle social challenges. Better regulation, funding and knowledge are the three policy aspects focused on. Partnerships are formed to bring stakeholders together (including NGOs and business) to focus on concrete themes. Relevant partnerships are: "Climate adaptation" and "Sustainable Use of Land and Nature-Based Solutions". The orientation paper of the NBS partnership states as an objective to identify best practices for funding schemes.
Action Plan for Sustainable Finance (COM (2018) 97)	Set out the way to enhance the uptake of sustainability aspects in the financial system. Key points include creating a labelling system for financial products and integrating sustainability in prudential requirements. Focus lies on transitioning to a low-carbon, circular economy.

Annex C

Databases relative to NbS-WS in Europe

Title	Link	Description
Forest Trends	Ecosystem Markets Map	Forest Trends is a global NGO that works to conserve forests and other ecosystems through the creation and adoption of a range of environmental finance, market, and other payment and incentive mechanisms. Forest Trends' Ecosystem Markets Map tracks projects and initiatives to protect forests, conserve watersheds, and benefit biodiversity. As of October 2019, the database contained 66 watershed conservation projects in Europe (years 1902 to 2018).
NWRM	NWRM catalogue of case studies	The NWRM initiative is a project supported by DG Environment to collaboratively build knowledge and promote best practice on Natural Water Retention Measures in Europe. The website includes a catalogue of case studies along with a practical guide to implement NWRMs. As of October 2019, the catalogue of case studies included 130 case studies specifically related to NWRM across Europe.
Oppla	Oppla Case Studies	Oppla aims to provide a virtual hub where the latest thinking on natural capital, ecosystem services and nature-based solutions is brought together from across Europe. The web portal provides access to a wide range of resources and features an online marketplace where tools, data and services can be advertised and obtained, thereby creating opportunities for collaboration between different sectors and disciplines. Over 60 universities, research institutes, agencies and enterprises are currently developing the Oppla prototype as part of a joint activity between the OPERAs and OpenNESS projects, funded by the European Commission FP7 Programme. As of October 2019, Oppla included a database of 250 case studies on NbS in Europe. Only 69 cases related to water and 11, more specifically, to catchment-based approaches.
Restoring Europe´s Rivers	RiverWiki	The RiverWiki website was established with funding from RESTORE (Restoring Europe's Rivers, a project funded by funding from the LIFE, a financial instrument of the European Union). This site is supported by the Environment Agency (England) and managed by the River Restoration Centre (RRC, UK). As of October 2019, it held data on 1,260 river restoration case studies from 31 countries, including in most MS and some neighbouring countries (e.g. Norway, Russia or Bosnia-Herzegovina). These case studies are focused on restoring river connectivity rather than NbS-WS per se as described in this report. Many of these case studies lacked basic information about scheme costs, however, or an assessment of the cost-effectiveness of these schemes versus alternative options.
ThinkNature	NbS Project Map	The ThinkNature project is part of Horizon 2020, the EU Framework Programme for Research and Innovation. It is a multi-stakeholder communication platform supporting the understanding and promotion of Nature based Solutions (NbS). The platform includes a NbS Projects Map (Horizon 2020 Environment and resources data hub), which lists existing NbS initiatives globally and including Europe. These are not specifically focused on NbS-WS, however.

Annex D

Glossary

Table D-1 NbS-WS definitions and potential water security benefits

Term	Definitions	Potential water security benefits
Afforestation	The process of establishing forests in areas that have not been forested before.	• Reduce downstream flood risk • Prevents soil erosion • Reduce nutrient and pesticide pollution (surface water and groundwater) • Reduce sediment run-off • Increase low river/groundwater levels • Reduce drought risk
Alternative plant protection	Methods that help control weed and pest population while reducing pesticide use. Include mechanical weed control (e.g. additional tilling work steps that uproot weeds), biological pest control (use of a pest's natural predator), and natural chemical control (such as pheromones and hormones, e.g. to lure pests into traps).	• Reduce surface water and groundwater contamination with pesticides
Aquifer recharge	A manmade or natural process that replenishes groundwater resources in an aquifer. Interventions may include the recovery/restoration of topsoil in eroded and sealed areas; the removal of impervious surfaces and the restoration or construction of landscape features like wooded or vegetated areas, retention basins, depressions and infiltration ponds.	• Reduce surface runoff, promote percolation into the aquifer and groundwater recharge.
Artificial (constructed) wetlands	Newly created wetlands that seek to emulate aspects of their natural counterparts.	• Remove nutrients: biological wastewater treatment "technologies", to complement or substitute treatment plants. • Reduce sediment runoff. • Reduce flow velocity and risk of small intensity flooding events
Conservation tillage	Tillage systems to conserve soil and water by reducing their loss. For example, this may include a tillage and planting combination that retains a 30% or greater cover of crop residue on the soil surface.	• Reduce fertilizer use
Cover crops	Crops grown between two main crops to protect the soil against erosion and minimise the risk of surface runoff by improving infiltration.	• Reduce sediment run-off
Crop rotation	Practice of growing different types of crops in the same area in sequential seasons. It seeks to improve soil structure and fertility, for example by alternating deep-rooted and shallow-rooted plants.	• Reduce downstream flood risk by reducing erosion and infiltration. • Reduce pesticide us, by mitigating the build-up of pathogens and pests.
Flood bypass	A constructed waterway built to carry excess water from a stream so that it is translocated into the lower parts of the same stream or into another stream with the ability to accept a large amount of excess water.	• Protect urban and rural agricultural areas from flooding.
Forest fuel reduction	Activities to reduce forest fuels and reduce risks of catastrophic fire. These may include mechanical thinning and/or controlled burns. Abrupt removal of forest cover and damage to ground cover and soils from catastrophic fires can cause large-scale erosion of unsecured hillsides, particularly if followed by rain.	• Reduce future risk of increased sediment and nutrients into streams
Forestry Best Management Practices (BMP)	Practices used in forest management to achieve goals related to water quality, silviculture, wildlife and biodiversity, aesthetics, and/or recreation.	• Reduce soil erosion and capture sediments before they enter streams • Prevent or reduce nutrient run-off • Keep streams cool • Generate large woody debris that can improve aquatic habitat

Term	Definitions	Potential water security benefits
Improved agricultural practices	Approaches to support improved agricultural production with a range of on- and off-farm benefits. This report focuses on practices with water quality benefits (reduced soil and fertilizer runoff), such as catch and cover crops or conservation tillage. A number of years of continuous practices can enable organic farming certification.	• Reduce surface water and groundwater contamination with nutrients and pesticides • Reduce sediment run-off • Reduce local flood risk by improving infiltration
Land-use change from farmland to pasture land	Switch from cultivated land to pasture land. Particularly deployed in sensitive areas, such as groundwater recharge areas for drinking water.	• Reduce flood risks
Ponds and basins	Water bodies storing surface run-off. A detention basin is free from water in dry weather flow conditions. A wet pond (e.g. retention ponds, flood storage reservoirs, shallow impoundments) contains water during dry weather and is designed to hold more water when it rains.	• Reduce sediment and nutrient loads (phosphorus, nitrogen)
Reconnecting rivers to floodplains	Re-connecting brooks, streams and rivers to floodplains can be achieved by approaches such as the creation of new floodplain ponds or backwaters, the reconnection of backwaters and wetlands, setting back embankments, levees or dikes, or removing hard engineering structures that impede lateral connectivity of the river to the floodplain.	• Reduce risk and impact of floods
Reduced fertilizer use	Improved accuracy and / or certainty of estimations can lead to fertilisation that is more in line with actual plant requirements	• Reduce excess fertilisation and nitrogen leaching.
Reforestation	Restoration of forests in areas where forests were previously removed or destroyed.	• Slow, store and reduce runoff water • Reduce nutrient and pesticide pollution surface water and groundwater) • Reduce sediment run-off • Increase low river/groundwater levels • Reduce drought risk
Riparian buffers	Riparian buffers are strips of land (vegetated and woodland) located in and around cropped fields and alongside watercourses.	• Reduce nutrient and pesticide pollution • Reduce sediment run-off.
Targeted land protection (including forest protection)	All conservation activities undertaken to protect targeted ecosystems, such as forests, grasslands or wetlands. Typically undertaken as a preventative measure.	• Reduce the risk of future adverse environmental impacts that may result from changing land uses
Wetland restoration/ conservation	The return of a wetland and its functions to a close approximation of its original condition, i.e. as it existed prior to disturbance due to drainage or degradation. Wetlands include marsh, fen, peatland or water, whether natural or artificial, permanent or temporary.	• Remove nutrients: biological wastewater treatment "technologies", to complement or substitute treatment plants. • Reduce sediment runoff. • Reduce flow velocity and risk of small intensity flooding events

Annex E

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Connecting Nature	https://connectingnature.eu/
European Union	http://nwrm.eu/
Grow Green	http://growgreenproject.eu/partners/
Horizon 2020	http://ec.europa.eu/programmes/horizon2020/
LIFEProgramme	http://ec.europa.eu/environment/life/contact/nationalcontact
Living Planet Index (LPI)	http://livingplanetindex.org/home/index
Nature4Cities	https://www.nature4cities.eu/
Nature4Climate	https://nature4climate.org/about/purpose/
Nature-based Solutions Policy Platform	https://www.nbspolicyplatform.org/
Naturvation	https://naturvation.eu/
OpenNess	http://www.openness-project.eu/cases
OPPLA	http://www.openness-project.eu/oppla
Revolving Water Fund	https://www.revolvingwaterfund.com/
RiverWiki	https://restorerivers.eu/wiki/index.php?title=Main_Page
Susdrain	www.susdrain.org
Unalab	https://www.unalab.eu/
Urban GreenUp	https://www.urbangreenup.eu/

Annex F

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