Harnessing the Power of Nature-based Solutions Concerning Water Security Challenges in Croatia

The Nature Conservancy

Harnessing the Power of Nature-based Solutions Concerning Water Security Challenges in Croatia

The Nature Conservancy

Harnessing the Power of Nature-based Solutions Concerning Water Security Challenges in Croatia

Photo credits: Branka Spanicek

Disclaimer
This document has been produced with the financial support of the European Investment Bank. The views expressed herein cannot be taken to reflect the official position of the European Investment Bank. The Nature Conservancy is responsible for the content of this document.

Table of Contents

Main contributors

Prepared by: Tree Simplicity (Ivana Korn Varga) and The Nature Conservancy (Irma Popović Dujmović, Max Ricker, Rob Cunningham). with inputs from European Investment Bank (Catherine McSweeney, Stephen Hart and Sladjana Cosic)

Acknowledgments

This report was developed with the financial support of the European Investment Bank.

We would like to thank Catherine McSweeney, Sladjana Cosic and Stephen Hart from the European Investment Bank for their engagement throughout this process, valuable feedback and review of the report.

We also thank for their support and feedback the Advisory Board Members from: Hrvatske vode, Josip Juraj Strossmayer Water Institute, Ministry of Environment and Green Transition – Directorate for Water Management and Sea Protection, Directorate for Nature Conservation, and Institute for Nature Conservation, Croatian Association of Experts in Nature and Environmental Protection, and Croatian Association of Cities.

List of abbreviations

CAP – Common Agricultural Policy

CBD – Convention on Biological Diversity

CBNRM - Community-based Natural Resource Management

CEE – Central and Eastern Europe

EbA - Ecosystem-based Adaptation

EC – European Commission

EIB - European Investment Bank

EU – European Union

GI - Green Infrastructure

GIB – Global Infrastructure Basel

HBOR – Croatian Bank for Reconstruction and Development

IUCN – International Union for Conservation of Nature

NbS - Nature-based Solutions

NGO – Non-governmental Organization

NWRM - Natural Water Retention Measures

PE – Population Equivalent

SDG – Sustainable Development Goals

SLM - Sustainable Land Management

TEFOP – TNC Europe Freshwater Outcomes Prioritization Tool

TNC – The Nature Conservancy

UNCCD – United Nations Convention to Combat Desertification

UNEP – United Nations Environmental Programme

UNFCCC – United Nations Framework Convention on Climate Change

WFD – Water Framework Directive

WWTP - Wastewater Treatment Plant

1 Executive summary

Croatia is a water-rich country with abundant biodiversity, however, in recent years, it has experienced extreme weather events which resulted in severe floods, droughts, and consequently extensive economic losses. In the escalating climate change and biodiversity crisis, Nature-based Solutions (NbS) have emerged as an ecosystem-based approach to address societal challenges such as flooding and droughts, while involving local communities and protecting biodiversity.

Despite the effectiveness of NbS, they are often overlooked due to insufficient awareness and a lack of investments. **In 2023, the EIB partnered with The Nature Conservancy and started a project to assess the potential for nature-based approaches to water security in Croatia.** Through this collaborative effort, the EIB and TNC aim to **demonstrate the practical benefits and feasibility of NbS, while promoting their wider adoption in Croatia.** The partnership aims to identify opportunities for the EIB to support nature-based approaches to address water security challenges such as drought, flooding, and water quality in Croatia. **The partnership is supported by an Advisory Board** (Hrvatske vode, JJ Strossmayer Water Institute, Ministry of Environment and Green Transition – Directorate for Water Management and Sea Protection/ Directorate for Nature Conservation/ the Institute for Environment and Nature Protection, Association of Cities, Croatian Association of Experts in Nature and Environment Protection and WWF Adria as observer).

Yet despite evidence that NbS and hybrid (mixed green/grey) approaches can provide more adaptive and resilient services often at lower cost, and with more co-benefits than pure 'grey' measures, opportunities to integrate NbS into infrastructure projects are often overlooked in favor of traditional 'grey' interventions such as concrete barriers, dykes, and dams[1.] **A key challenge is that local, regional, and national public authorities often find it difficult to consider nature in their decisions on infrastructure planning and investment;** and the wider public, and private sector stakeholders and landowners, have limited understanding of the benefits, performance, predictability, and financial viability of different NbS and hybrid options[2].

Water is vital for direct and indirect human use and is key to ecosystem function.[3] This project represents a commitment to preserving Croatia's freshwater ecosystems while addressing societal challenges, focusing on water security. Integrating NbS into water management practices protects our diverse ecosystems and builds **more resilience toward climate change challenges.** Through this collaborative effort, the EIB and TNC aim to demonstrate the practical benefits and feasibility of NbS, while promoting their wider adoption in Croatia.

Due to the severity of climate change and biodiversity crisis impacts, **it has become evident that implementing conventional engineering practices and grey infrastructure alone does not prepare us to address current and future water security challenges**. Biodiversity declined by an average of 69% in the relative abundance of monitored wildlife populations around the world between 1970 and 2018.[4] Climate change projections suggest that many regions in Europe will experience more frequent extreme events, including droughts, heavy rainfall, and an increasing variability in precipitation.[5]

This report provides an overview of Croatian water resources, a review of the Croatian policy framework as it relates to nature-based approaches, the status of NbS in the Croatian legal framework, as well as barriers and opportunities for NbS implementation in Croatia. To address climate change, water security, and biodiversity conservation effectively the **report identifies suitable NbS measures for the Croatian context as well as potential locations for NbS deployment.**

---

1 Browder, G., Ozment, S., Rehberger Bescos, I., Gartner, T. and Lange, G-M., 2019. Integrating Green and Gray: Creating Next Generation Infrastructure. Washington, DC: World Bank and World Resources Institute. Available at: http://hdl.handle.net/10986/31430

2 Ruangpan, L., Vojinovic, Z., Plavšić, J., Curran, A., Rosic, N., Pudar, R., Savic, D. and Brdjanovic, D., 2024. Economic assessment of nature-based solutions to reduce flood risk and enhance co-benefits. Journal of Environmental Management, 352, p.119985.

3 Magnier, J., Fribourg-Blanc, B., Lemann, T., Witing, F., Critchley, W. and Volk, M., 2024. Natural/Small Water Retention Measures: Their Contribution to Ecosystem-Based Concepts. Sustainability, 16(3), p.1308. Available at: https://doi.org/10.3390/su16031308.

4 WWF (2022) Living Planet Report 2022 – Building a nature-positive society. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. and Petersen, T. (eds). Gland, Switzerland: WWF.

5 Keizer, J.J. and Hessel, R., 2019. Quantifying the Effectiveness of Stakeholder-Selected Measures against Individual and Combined Soil Threats. Catena, 182, 104148.

A catalogue of proposed NbS measures (Annex 1) provides **a selection of potential NbS measures that are advised to be integrated into regular water management practices to target water security challenges** and build resilience towards climate change. The proposed measures can support and amplify each other. The International Union for Conversation of Nature (IUCN), a global membership organization with both government and civil society organizations, including the membership of the Croatian Ministry of Environment and Green Transition, states that Nature-based Solutions (NbS) are defined as actions to protect, sustainably manage, and restore natural and modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.[6]

This report follows the IUCN definition and proposes different NbS measures that adhere to the IUCN NbS Global Standard, adapted to the Croatian context and can be implemented as a stand-alone measure but also effectively complement grey infrastructure to address the increased frequency of severe weather events, such as floods and droughts, alongside mitigating the critical issue of biodiversity decline.

Drawing lessons from previously conducted NbS report under the Natural Capital Financing Facility for Croatia[7] the report underscores the importance of strategic planning to enhance the success rate of NbS initiatives and delves deeper into specific NbS measures targeting water security challenges and screening through potential locations for NbS projects.

In essence, **this report serves as a foundation for further NbS development** aiming to catalyse a paradigm shift in how natural capital and ecosystem services are integrated into Croatia's water management practices to support financially viable climate change adaptation practices. It represents **a call to action for Croatian stakeholders at all levels to reimagine the role of dealing with today's societal challenges** through the targeted promotion of Nature-based Solutions.

[6] Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds) (2016) Nature-based Solutions to Address Global Societal Challenges. Gland, Switzerland: IUCN. Available at: https://doi.org/10.2305/IUCN.CH.2016.13.en.

[7] EIB at al. (2022) Development of a pipeline of projects promoting biodiversity and applying nature-based adaptation in Croatia under the Natural Capital Financing Facility Final Progress and Evaluation report, September 2022.

2 Methodology and process for selection of proposed NbS and locations in Croatia

The main objective of the collaboration between the TNC and EIB was to define the most **suitable NbS measures** to correspond to Croatian circumstances, **open a dialogue with stakeholders** and decision-makers, and **jointly define locations with high potential for NbS implementation.** In the scope of this report, **we were focused on potential NbS projects** related to **floods, water quality**, and droughts, however, primarily **hydrological droughts** since that type of drought is directly connected with reduced streamflow and groundwater levels (more can be found in Annex 2).

Table 1 below offers an overview of the most relevant steps in the process of preparation of the report on the potential for NbS deployment in Croatia (please see Annex 2 for a detailed description of the preparation of the report).

There are already multiple NbS concepts available on the global level, among the most relevant and widely used is the IUCN Global Standard of NbS[8] which sets the basis for the design and implementation of NbS projects while tackling one or several societal challenges.

Table 1. Steps in identifying the proposed NbS measures and potential locations

Identification of proposed NbS measures and potential locations
Step 1: Defining typology of NbS measures suitable in Croatian circumstances
Several sources were used to define the potential NbS measures. Firstly, Croatian Waters' "lineslines for Technical Design and Assessment of Socio-Economic Feasibility of Green Infrastructure Measures"[9] focused on flood protection, erosion, and sediment control as well as flash flood management were used. Additional measures were also proposed and explained in short within the **Catalogue of proposed NbS measures in Croatia** (see Annex 1). The IUCN Global Standard for **NbS Self-assessment Tool[10] was used to assess potential NbS** measures and their adherence with the IUCN Global Standard of NbS. while including **Croatian circumstances and legislation** as the basis of assessment. We also used available knowledge and experiences from multiple Horizon projects[11] being implemented under the European Green Deal[12] "umbrella". The third major source of existing data on NbS measures which was used is the University of Oxford Nature-based Solutions Initiative[13].

[8] IUCN (2020) Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN.

[9] VITA projekt (2021) Smjernice za tehničko projektiranje i procjenu socioekonomske izvedivosti mjera zelene infrastrukture u smanjenju rizika od poplava. RN/2021/002. Zagreb: Hrvatske vode.

[10] Available at: https://www.surveygizmo.com/s3/5785977/IUCN-Global-Standard-for-NbS-Sharing-Results

[11] European Commission & European Research Executive Agency (2022) Nature-based solutions – EU-funded NBS research projects tackle the climate and biodiversity crisis. Publications Office of the European Union. Available at: https://data.europa.eu/doi/10.2848/42098

[12] Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[13] Available at: https://www.naturebasedsolutionsinitiative.org/what-are-nature-based-solutions/

Step 2: Prioritising suitable river-basins and sub-basins for implementation of NbS measures

The **TNC Europe Freshwater Outcomes Prioritization Tool[14] (TEFOP) was used** to have a clear and scientifically based overview of possible basins/sub-basins for NbS deployment in Croatia. TEFOP supports the identification of priority areas for freshwater ecosystems and the services they provide as well as biodiversity. Given this prioritization, it aims to guide the selection of areas where conservation interventions are best suited to make a positive impact. The **TEFOP tool was then overlayed with the flood risk and the drought risk data to Natura 2000 and protected areas maps** to define where the biggest threats from floods and droughts occur as well as where we could have positive impacts on protected freshwater biodiversity. Since the TEFOP is most relevant at the European level, we additionally used the flood maps from **the River Basin Management Plan 2022-2027[15]** to define potential rivers for implementation of proposed measures. Those maps were used in the next step when inputs from an Advisory Board were gathered.

Step 3: Engaging crucial Advisory Board members

To ensure that proposed NbS measures and proposed potential basins/sub-basins and specific locations correspond to Croatian circumstances, on January 25th the TNC, in collaboration with the EIB, organized a **workshop with Advisory Board members** (Croatian Waters, JJ Strossmayer Water Institute, Ministry of Environment and Green Transition – Directorate for Water Management and Sea Protection, Directorate for Nature Conservation and the Institute for Nature Conservation representing the same Ministry, and WWF Adria as Observer). During the workshop participants where very engaged and **provided valuable input about 18 potential locations where NbS projects could be deployed** (more details about proposed locations is available in the Annex 3).

Step 4: Initial engagement with local stakeholders in 8 prioritised locations

After the workshop, **we selected eight priority NbS projects and checked local interests for NbS implementation**. Due to available resources we had to choose projects of the "higher priority" against once which we didn't select although they are still very relevant. Reasons for not selecting some are: already existing work on restoration of the site, or very local impact, or being privately owned, or very challenging situation with local stakeholders, or very high nature degradation present therefore very difficult to restore, etc. Within Annex 3 more details can be found. For the eight short-listed projects we provided more insights about ongoing project activities, and we communicated (e-mail, phone meetings) with Public Institutions responsible for protected areas for those specific locations. Those phone meetings aimed at learning more details about local circumstances, projects, the degree of collaboration with local stakeholders, including the relationship with the local water management authority. With clarifying more about local circumstances, also the willingness for future implementation of NbS projects was checked and Public Institutes responsible for protected areas are willing to further explore whether they are interested in potential preparation of NbS projects in the area of their jurisdiction. In person meeting were also held with six Public Institutes to define potential NbS projects and willingness to uptake the work on the topic of NbS.

Step 5: Presentation of the NbS report to the Advisory Board members and gathering feedback

The meeting with the Advisory Board members was held on **18th June to present the NbS report** and overview of potentials for NbS deployment related to water security challenges in Croatia. It was a continuation after the workshop in January and a second opportunity to receive direct **feedback from the members of Advisory Board** and participants interested into the topic.

[14] Available at: https://tnc-app-dd8a4.web.app/

[15] River Basin Management Plan, 2022-2027. Available at: https://mingo.gov.hr/UserDocsImages/Uprava_vodnoga_gospodarstva_i_zast_mora/PLAN%20UPRAVLJANJA%20VODNIM%20PODRU%C4%8CJIMA%20DO%202027..pdf.

3 Overview of Croatian Water Security Challenges

Croatia is relatively rich in water, but not in water supply because of its geological structure with a large share of the surface with karst structures and large spatial-temporal heterogeneity of runoffs. Namely, the karst areas that occupy about half of the territory of the Republic of Croatia generally have a small possibility of accumulation of water reserves over a long period during critical dry periods. The state of freshwater and sea resources is **largely dependent on transboundary impacts** due to the global impact of climate change on the dynamics of ocean and sea level change as well as the high share of cross-border and transboundary watercourses that shape Croatia's total water resources**. The deterioration of hydrological conditions due to climate change is expected to increase the frequency and duration of dry periods and the frequency and intensity of flood situations.**[16]

Table 2. The surface of Croatia is hydrographically divided into the Adriatic Sea Basin and the Black Sea/Danube River Basin.[17]

River Basin	Area (km²)	Percentage of Croatian Land Territory
Danube River Basin	35,111	60%
Adriatic Sea Basin	35,307	40%
- Terrestrial Area	18,196	
- Islands	3,263	
- Sea	13,848	
State Territory (outside water area)	17,722	
- Territorial Sea	17,718	
- Uninhabited Offshore Islands and Rocks	~4	
Sava River Watershed	25,752	73% (within Danube River Basin)
Drava River Watershed	9,359	27% (within Danube River Basin)

The country belongs to the group of three European countries with the highest cumulative share of damage from extreme weather and climate events affecting the gross national product (GNP). Due to the increased frequency of **forest fires and the occurrence of strong winds, floods, pest attacks**, and similar, higher damage to forest ecosystems is expected, such as a reduction in the value of wood varieties and loss of forest functions of general benefit. It is estimated that these losses in the period from 1980 to 2013, i.e. over 33 years amounted to approximately EUR 2.25 billion, or approximately EUR 68 million per year on average. **The total damage from extreme weather events** reported in the period from 2013 to 2018, i.e. over 6 years, amounted to **approximately €1.8 billion, or approximately €295 million a year.[18] The annual average population affected by flooding is about 100,000 and the annual average GDP at risk is $1 billion.**[19] Croatia has experienced a **large variability in precipitation trends across the country,** over the last decades. Particularly, the mountainous region and the coastal zones are mostly affected by **reduced rainfall, especially during the summer season,** while the mainland is subjected to wetter precipitation conditions.[20] In the northeastern Mediterranean Region (or Adriatic-Ionian

[16] Republic of Croatia, Ministry of Environment and Energy. (2018). Seventh National Communication and Third Biennial Report of the Republic of Croatia under the United Nations Framework Convention on Climate Change (UNFCCC).

[17] River Basin Management Plan, 2022-2027. Available at: https://mingor.gov.hr/UserDocsImages/Uprava_vodnoga_gospodarstva_i_zast_mora/PLAN%20UPRAVLJANJA%20VODNIM%20PODRUČJIMA%20DO%202027..pdf.

[18] Climate change adaptation strategy in the Republic of Croatia until 2040 with a view to 2070. Available at: https://mingo.gov.hr/UserDocsImages/KLIMA/Climate%20change%20adaptation%20strategy.pdf

[19] Available at: https://www.gfdrr.org/sites/default/files/Croatia.pdf

[20] Ministry of Environmental Protection, Physical Planning and Construction. (2010). Strategy for Sustainable Development of the Republic of Croatia. [Online] Available at: http://extwprlegs1.fao.org/docs/pdf/cro105236.pdf

region, which encompasses Croatia), **heat wave events have become more frequent, longer lasting, and more severe.**[21]

The country is renowned for its rich biodiversity, geodiversity, and landscape diversity, showcasing significant protection levels, especially within the context of Western and Central Europe. **Despite these protective measures, trends of biodiversity, geodiversity, and landscape diversity loss persist.** The country is home to nearly 40,000 species, with estimates suggesting the actual number could be significantly higher, potentially exceeding 100,000. About 3% of these species are endemic, with approximately 70% of these endemic species being cave fauna, highlighting a unique aspect of Croatia's natural heritage. **Despite biodiversity conservation efforts, many wild species remain endangered, mirroring a global trend.** Of the over 3,000 species (around 8% of known species) assessed for IUCN threat status in Croatia, **fully 42.3% face high risks of extinction. Freshwater fish are among the most endangered groups assessed.**[22]

By **implementing nature-based solutions, Croatia can achieve higher resilience against environmental threats** while unlocking a myriad of co-benefits. These approaches not only **mitigate the impacts of flooding, water scarcity, and declining water quality but also lower costs**. It's a win-win scenario, where Croatia can **safeguard its natural resources while simultaneously supporting its economy and protecting the well-being of its citizens.** Together with other EU Member States, Croatia has a good chance of becoming a leader in sustainable development and participating in further elaboration and establishment of global standards, while gaining social and economic benefits.[23]

4 NbS as an Ecosystem-Based Approach

The role of ecosystems in addressing societal challenges such as flooding and drought, while providing human well-being and biodiversity benefits, is at the heart of this report, which adapts to the Croatian context the IUCN definition of nature-based solutions as actions to protect, sustainably manage, and restore natural and modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.[24]

The concept of nature-based solutions belongs to a family of ecosystem-based approaches, which address the human use of nature, natural functions, and ecosystem services, defined as "the benefits people obtain from ecosystems". These include Natural Water Retention Measures (NWRM), Green Infrastructure (GI), Sustainable Land Management (SLM), Ecosystem-based Adaptation (EbA), and Nature-based Solutions (NbS). The resilience and multifunctional nature of these methods allow them to fulfil human needs while benefiting the ecosystem functions.[25]

Ecosystem-based Adaptation approaches such as urban greening, and restoration of wetlands and upstream forest ecosystems reduce a range of climate change risks, including flood risks, and urban heat, and provide multiple co-benefits. Some land-based adaptation options provide immediate benefits (e.g., conservation of peatlands, wetlands, rangelands, mangroves, and forests); while afforestation and reforestation, restoration of high-carbon ecosystems, agroforestry, and the reclamation of degraded soils take more time to deliver

---

21 Climate Adapt. (2021). Adriatic-Ionian Area. Available at: https://climate-adapt.eea.europa.eu/countries-regions/transnational-regions/adriatic-ionian

22 The Nature Protection Strategy and Action Plan of the Republic of Croatia for the Period 2017-2025. (OG 72/2017).

23 Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G. and Fuller, G., 2019. Sustainable Development Report 2019. New York: Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).

24 Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds) (2016) Nature-based Solutions to Address Global Societal Challenges. Gland, Switzerland: IUCN. Available at: https://doi.org/10.2305/IUCN.CH.2016.13.en.

25 Millennium Ecosystem Assessment, 2003. Ecosystems and Human Well-Being: A Framework for Assessment. REV Updated Edition. Washington, DC, USA: Island Press. ISBN 978-1-55963-402-1.

measurable results.[26] There are many environmental management practices and structural measures available to adapt to these challenges[27].

In summary, multifunctionality is at the core of all of the above concepts, to a greater or lesser extent, with a set of different dimensions for each, which may be specific to one concept or shared with several. This means that they are not easy to characterize or compare. However, it is possible to show, broadly, where they overlap—to what extent and in which dimensions, and this is presented in a simplified manner for scale and ecosystems in Figure 1.[28]

Whether standalone or combined with other forms of solutions (e.g. technology and engineering), conservation approaches (e.g. protection, restoration, and sustainable management) can also be implemented with human well-being as a primary objective. This evolution in thinking about conservation has led to the recognition of **two broad domains of conservation interventions,** those whose **primary aim is to safeguard biodiversity** for its inherent values, and those whose **primary purpose is to safeguard society – what is now called Nature-based Solutions (NbS).** Both domains adhere to the same set of conservation norms and principles, and while there are occasions where they overlap operationally, the starting points are often quite distinct.[29]

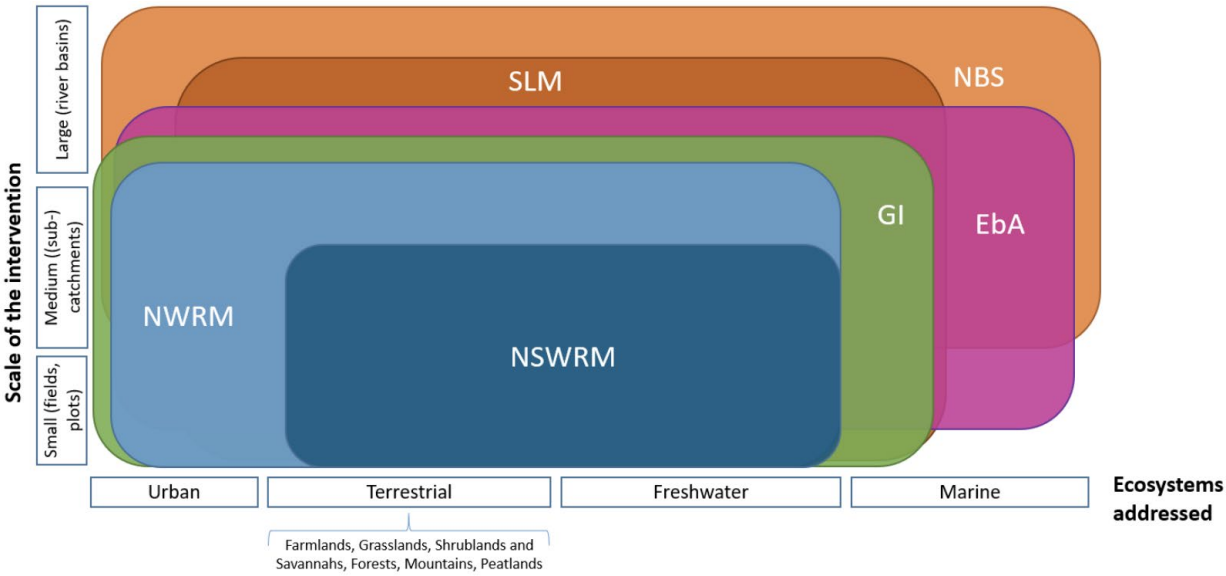


Figure 1. How the ecosystem-based concepts overlap with respect to scale and key ecosystems. The following concepts were considered: Natural/Small Water Retention Measures (NSWRM), Natural Water Retention Measures (NWRM), Green Infrastructure (GI), Sustainable Land Management (SLM), Ecosystem-based Adaptation (EbA), Nature-based Solutions (NbS)

As shown in the scope of multiple NbS projects already, and research projects there is still a lack of understanding of different ecosystem-based approaches, as well as NbS. **The number of online platforms with different case studies is rising,** e.g. OPPLA[30], Climate-ADAPT[31], WOCAT[32], Urban Nature Atlas[33], and Network Nature[34]. All

---

[26] Intergovernmental Panel on Climate Change (IPCC), 2023. Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.

[27] Alvar-Beltrán, J., Elbaroudi, I., Gialletti, A., Heureux, A., Neretin, L. and Soldan, R., 2021. Climate resilient practices: typology and guiding material for climate risk screening. *FAO: Rome, Italy*.

[28] Magnier, J., Fribourg-Blanc, B., Lemann, T., Witing, F., Critchley, W. and Volk, M., 2024. Natural/Small Water Retention Measures: Their Contribution to Ecosystem-Based Concepts. Sustainability, 16(3), p.1308. Available at: https://doi.org/10.3390/su16031308.

[29] IUCN (2020). Guidance for Using the IUCN Global Standard for Nature-Based Solutions. A User-Friendly Framework for the Verification, Design and Scaling Up of Nature-Based Solutions. First edition. Gland, Switzerland: IUCN.

[30] Available at: https://oppla.eu

[31] Available at: https://climate-adapt.eea.europa.eu

[32] Available at: https://www.wocat.net/en/

[33] Available at: https://una.city

[34] Available at: https://networknature.eu

those different platforms provide different information, typically a combination of semi-quantitative and descriptive benefits, and to a lesser extent costs to which the NbS is applied. The successful case studies from the Netherlands and Austria are presented below.

Examples of NbS measuresfor water security:

CASE STUDY: Room for the River Regge, Netherlands - restoring the river dynamics (2010 – 2025)[35]

Before	After
	

- In 1935, the river was almost completely canalised, reducing its length from roughly 70 km to 50 km
- Most old meanders in the (former) floodplain were filled up to make room for agriculture
- Natural flow dynamics and associated morphological processes were lost and heavy rainfalls caused flooding while in dry periods, agriculture and the wetlands suffered from the lack of water
- In 1998, the 25 million re-naturalisation programme for the entire river, the 'Reggevisie' was launched by the local water authorities with involvement of stakeholders (NGOs, municipalities, land-owners, etc.)
- It aims at: (i) reintroducing river dynamics, (ii) creating more space for water buffering during peak discharges, (iii) facilitating nature development in the floodplain of the river, (iv) making the river more attractive from a recreation perspective
- The programme is still ongoing and expected to be finished in 2025

[35] Available at: https://adaptecca.es/en/room-river-regge-netherlands-restoring-dynamics

CASE STUDY: The LIFE-Project: Life vein Upper Drau river (2006-2011)[36]

Before	After
	

- The area on the Upper Drau river" (1999-2003) was an incentive follow-up project prepared for all involved under the title “Life vein Upper Drau river
- Three further major river widening measures were carried out along a total length of approximately 5 km from 2006 until 2011
- The project acquired over 14 ha of land for key interventions, such as replacing hard embankments with gravel banks, restoring a sediment retention dam, widening the river, and connecting side channels and oxbows. This created 42 ha of new alpine river habitats, surpassing the target by 22 ha.
- New habitats included dynamic gravel banks and tamarisk and willow pioneer communities, which will evolve into alluvial forests.
- **These habitats provided:**
  - Improved spawning grounds for amphibians and fish, like the Danube salmon, varione, European bullhead, Ukrainian brook lamprey, and Atlantic stream crayfish.
  - Extended habitats for 140 bird species, including 51 on the red list, such as the common kingfisher, common sandpiper, grey wagtail, lesser spotted woodpecker, and golden oriole.
  - Habitats for nearly extinct plants in Austria: German tamarisk and dwarf bulrush.
  - Potential habitats for Bechstein's bat and the Barbastelle bat.

[36] Available at: https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE06-NAT-A-000127/life-in-upper-drau-river

NbS in the global, EU, and Croatian policy framework

Globally, **NbS is observed** as a critical **asset in the fight against climate change, biodiversity loss, and water security**. It is incorporated into major international conventions including the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD).[37] All these **Conventions advocate for NbS implementation to mitigate climate change impacts, enhance ecosystem resilience, and secure water resources.**

At the European level, **NbS is an integral part of the European Green Deal**, which aims to make Europe the first climate-neutral continent by 2050. The EU Strategy on Adaptation to Climate Change promotes NbS for sustainable and resilient socio-ecological systems. Additionally, the **EU Biodiversity Strategy for 2030 sets ambitious targets for ecosystem restoration and protection, emphasizing NbS's role in achieving these objectives.**

The Water Framework Directive (WFD), transposed into Croatian law, **indirectly supports NbS** through its emphasis on integrated river basin management and the protection of aquatic ecosystems. Similarly, **the Floods Directive,** aimed at managing flood risks, provides a policy framework conducive to NbS by **advocating for the preservation and restoration of natural floodplains and wetlands.**

Furthermore, **Croatia's** commitment to the Sustainable Development Goals (SDGs) underlines its **dedication to sustainable water management, climate action,** and life on land (SDGs 6, 13, and 15, respectively), all of which are **directly linked to the successful implementation of NbS.**

[37] Available at: https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

5 Opportunities and challenges to NbS implementation in Croatia

Several factors hamper the use of nature-based approaches in Croatia. Firstly, **the NbS approach is relatively new for Croatian stakeholders**. Knowledge about NbS and the benefits of its implementation still needs to be fully accepted by water management, forestry management, and other local stakeholders.

Obtaining **permits can take a couple of years**, therefore due to very high costs, and sometimes lack of understanding of the benefits that type of projects provide, the **NbS project is often not selected compared to the gray solution.**

The steps **of NbS project implementation should be more user-friendly,** the approach should be broadly promoted, and knowledge and understanding of those crucial sectors should be raised to truly start with NbS deployment on the strategic level.

NbS aims to address societal challenges while also benefiting biodiversity and engaging local communities, but **its incorporation into mainstream practices just started to evolve**. The concept of nature-based solutions (NbS) is gaining recognition and support from various stakeholders, including the EU, national nature conservation sectors, NGOs, and others. With increasing promotion and awareness, the implementation of NbS projects is anticipated to rise in the coming years. **At the European Commission level, there is a clear priority to scale up the implementation of nature-based solutions (NbS)** projects across the EU. This is facilitated through various financial mechanisms[38], including loans from the EIB or grants from EU-funded programs such as Horizon, LIFE, Interreg, and Structural funds.

In the scope of the Nature Restoration Law, the EU countries are expected to submit **National Restoration Plans** to the Commission within two years of the Regulation coming into force (by mid-2026), showing how they will deliver on the targets. They will also be required to monitor and report on their progress[39]. Therefore, the Croatian authorities have an excellent opportunity to support all the initiatives in the scope of the work on nature restoration within NbS projects.

Table 3. An overview of the challenges and opportunities associated with implementing Nature-based Solutions (NbS) in Croatia

Opportunities	Challenges
Enhancing resilience to climate change	Insufficient inclusion of NbS terminology in Croatian legislation
Higher resilience against floods	Legislative procedure is very long (up to five years) before the project can start with the implementation
Mitigation of hydrological drought	Land registry is still not harmonised with cadastre in some counties/municipalities (ongoing process)
Water quality improvement	Multiple owners of small land-plots (app. 40 owners on 10 ha of land and sometimes up to 100)
Scalability and replicability	Some landowners are deceased and their inheritants are not listed as owners which takes time to resolve
Providing more suitable habitats and improvement of biodiversity status	High costs of the land (app. 5-10 k€/ha for agriculture land and for forests from app. 15-50 k€/ha depending on the value of tree species)

[38] Available at: https://www02.eib.org/attachments/lucalli/20230095_investing_in_nature_based_solutions_en.pdf
[39] Available at: https://www.consilium.europa.eu/en/meetings/env/2024/06/17/

Supported ecosystem services	Missing targeted financial mechanisms for NbS implementation
Economic viability in the long term (after project implementation, there is much less need for maintenance and total cost is lower)	Although general financial mechanisms do exist (LIFE, Interreg, Horizon, loans) the process of project preparation is rather complex and can take up to more years therefore it is difficult to keep the interest high
NbS projects create possibilities for close stakeholder collaboration therefore opportunities to resolve some other challenges	The CAP financing process is rather complex, and knowledge of farmers is lacking although it could be used for smaller measures
Positive feeling from community engagement	Insufficient knowledge about the NbS and benefits it provides
General improvement of well-being	Tendencies to use conventional and well-known engineering practices
	Limited technical expertise and sometimes willingness to learn about NbS practices of more nature-positive water resources management
	Knowledge supporting system is missing (for farmers, municipalities, water managers, foresters, etc.)

As shown in the scope of multiple NbS projects already, and research projects there is still a lack of understanding of different ecosystem-based approaches, as well as NbS. Although the number of online platforms with different case studies is rising (OPPLA[40], Climate-ADAPT[41], WOCAT[42], Urban Nature Atlas[43], and Network Nature[44]). All those different platforms provide different information, typically a combination of semi-quantitative and descriptive benefits, and to a lesser extent costs, and context in which the NbS is applied. In practice, the performance of NbS highly depends on the local context (type of the NbS measure, location in the landscape, soil type, interaction with other landscape elements and water uses, water quality, climate, governance, etc.). The difficulties of NbS implementation originate from the **need for co-creative stakeholder processes to have a successful NbS implementation and that is very often challenging to achieve in Croatia.**

[40] Available at: https://oppla.eu
[41] Available at: https://climate-adapt.eea.europa.eu
[42] Available at: https://www.wocat.net/en/
[43] Available at: https://una.city
[44] Available at: https://networknature.eu

6 Review of Croatian policy, legislative and institutional framework related to NbS

The term "NbS" is not yet prominently used in national legislation compared to EU level, nor is NbS implementation prioritized to the same extent. Nevertheless, there is **increasing recognition of NbS importance in Croatia,** although it is currently only partially mentioned in legislation related to water security, as indicated in the table below.

Table 4. Analysed legislation/documents for the term NbS, green/blue infrastructure, or any other used ecosystem-based approach terminology that could be related to the positive outcomes for nature

Title	Type of document	Term green/blue infrastructure	Term NbS	Other ecosystem-based approach term
Water Act (OG 66/19, 84/21, 47/23)	Act	-	-	-
Croatian Water Management Strategy (Hrvatske vode, 2009)[45]	Strategy	-	-	natural water retention measures
River Basin Management Plan 2022-2027 (OG 84/2023)	Planning document	√	√	
Environmental Protection Act	Act	-	-	-
The Nature Protection Act (OG 80/2013)	Act	√	-	-
Strategy and Action Plan for the Protection of Biological and Landscape Diversity of the Republic of Croatia	Strategy	√	-	-
Law on Climate Change and Protection of the Ozone Layer (OG 127/19)	Act	-	-	-
Climate Change Adaptation Strategy in the Republic of Croatia for the Period Until 2040 with a view to 2070	Strategy	√	√	-
National development strategy of the Republic of Croatia until 2030	-	-	-	-
Selected Chapters Eighth National Report of the Republic of Croatia According to the United Nations Framework Convention on Climate Change (UNFCCC)	Report	-	-	-

[45] Croatian Water Management Strategy (OG , https://narodne-novine.nn.hr/clanci/sluzbeni/2008_08_91_2900.html).

Since Croatia acceded EU in 2013, there has been a mandatory commitment to align with EU legislation, necessitating adjustments to its laws and regulations. **In adherence to multiple Conventions** (CBD[46], UNCCD[47], UNFCCC[48], etc.), **and EU obligations,** Croatian **laws** must **comply with the Croatian Constitution.**

The Ministry of Environment and Green Transition is the responsible institution for the management of water security challenges tackled within this report through the Directorate of Water Management and Sea Protection with the implementing body responsible for water management (national, county levels), Hrvatske vode, and supported by JJS Water Institute.

Table 5. Ministries involved in water management

Ministry	Responsibilities
Ministry of Environment and Green Transition	Managing water security challenges through the Directorate of Water Management and Sea Protection, along with Hrvatske vode as the implementing body. Collaborates with other relevant ministries to ensure water security and manage water resources. Article 4 of the Water Act outlines the scope of water management activities
Ministry of Agriculture	Oversees water resources pertinent to agriculture, including irrigation systems, agricultural land management, and forestry
Ministry of Regional Development and EU Funds	Oversees the planning and implementation of regional development policies
Ministry of Physical Planning, Construction, and State Assets	Responsible for urban planning, including water infrastructure development in urban areas
Ministry of the Sea, Transport, and Infrastructure	Addresses issues related to water transport and waterway safety
Ministry of Health	Monitors drinking water quality and ensures compliance with health standards

[46] https://www.cbd.int/countries?country=hr
[47] https://www.unccd.int/our-work-impact/country-profiles/croatia
[48] https://unfccc.int/documents/627738

Table 6. State levels of responsibilities

Level	Responsibilities
Ministerial/National	Adoption and transposition of EU legislation; implementation and monitoring of laws; approval of strategies; inclusion of environmental protection in other sectors; setting up the institutional framework for implementation of nature conservation mechanisms
Regional/Local/Municipality	Implementation of relevant legislation on the regional/local level; support for information systems concerning water security issues; collaboration with county and national levels to resolve water security issues
Municipalities	Collaboration with county and national levels to resolve water security issues; limited possibilities to resolve issues independently; recommended implementation of constructed wetlands for water purification

7 Identification of potential NbS measures and suitable locations for NbS deployment in the Croatian context

This chapter provides an overview of a key deliverable of this partnership: a prioritized set of nature-based solutions and proposed geographic locations to be implemented in the Croatian context.

All the proposed potential NbS projects increase resilience towards climate change impacts and can be integrated jointly with grey infrastructure on Croatian river courses. Many grey infrastructure projects have already been implemented. **The proposed locations for NbS deployment already have grey infrastructure present and for some, there is an ongoing implementation of additional grey infrastructure**, e.g. Karlovac flood defence system. Therefore, an important task in the next phase of partnership will be to identify existing and ongoing grey infrastructure and propose ways to integrate nature-based approaches.

In order to estimate indicative costs of the proposed measures, the site needs to be visited and specific NbS measures need to be defined. Each of the measures listed in the Catalogue (Annex 1) has an assumed approximate cost, however, local circumstances have a big impact on the cost of implementation.

Table 7. List of proposed NbS measures that adhere to the IUCN Global Standard of NbS (more details in Annex 1)

No.	NbS measure	Landscape type
1	FLOODPLAIN RESTORATION	Lowland
2	RE-MEANDERING	Lowland
3	SIDE-BRANCH AND OXBOW RECONNECTION	Lowland
4	WETLAND & PEATLAND RESTORATION	Lowland
5	FLOODPLAIN FOREST RESTORATION	Lowland
6	RIVER-BANK RESTORATION	Lowland
7	COASTAL WETLAND RESTORATION	Lowland/Coastal
8	DAM/BARRIER REMOVAL	Lowland
9	LAKE RESTORATION	Lowland
10	RETENTION PONDS	Lowland
11	CONSTRUCTED WETLANDS	Lowland
12	SINKHOLES	Karstic

The following map indicates the proposed geographic locations for the deployment of NbS projects. All the listed sites are within the EU ecological network, Natura 2000.

Map 1: Google Earth Map with marked potential NbS sites in Croatia

The following section provides an overview of each of the eight proposed locations to be further screened to check their potential for NbS implementation and for each location, we provide the following information:

- The water security challenges addressed by the implementation of NbS project
- Proposed NbS measures
- A short description of the ecological, economic, and social features of the site, as well as relevant projects implemented there
- Stakeholders that can potentially be engaged
- Reasons for selecting the site
- Criteria for site selection

7.1 Potential NbS site – Lonjsko Polje Nature Park

Potential NbS site	Location of the site
Lonjsko Polje Nature Park	Located along the Sava River, in the lowland part, south-east from Zagreb
WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE	**PROPOSED NbS MEASURES**
Hydrological drought **Floods** **Water quality**	Side-branch reconnections Oxbow restoration Dam/barrier removal Floodplain forest restoration
DESCRIPTION OF THE SITE	**RELEVANT STAKEHOLDERS**
Lonjsko Polje Nature Park is the biggest wetland along the Sava River which is still free flowing in its middle and lower courses, Natura 2000 area, and a Ramsar site. It serves as a natural retention area during high waters. Over 67% of the park is covered by alluvial forest, representing the most integral complexes of oak and ash, as well as valuable communities of alder floodplain forests. Together with wet meadows and pastures they make a mosaic of the most integral floodplain ecosystem in the whole biogeographic region (European Continental region). Due to the fact that many local people live there in a rather traditional way, using extensive pastures for cattle, horses and pigs (including several indigenous breeds) and conserving the unique traditional architecture of wooden houses, this area also represents a unique feature of the natural, landscape with cultural heritage.[49] Since parts of the floodplains are used for agriculture from previously uncultivated areas and flood dykes where built, mostly in the 20th century, it had negative impact to the river system.[50] Many projects are implemented or under implementation including SavaTies[51], DanubeParks[52], Protection of Sava River/EuroNatur[53] to retain previously fully functional ecosystem services.	Hrvatske vode (national or local water management authority), Croatian Forests, Sisak-Moslavina County, Lonjsko Polje Nature Park
	REASONS FOR SELECTING THIS SITE
	Whole Sava River in Croatia is under priority for NbS deployment, however in the Sava River basin there are multiple sites, with different management authorities and therefore it is not observed as one case, although it could become a priority basin with multiple NbS projects implemented jointly with different management authorities. Sava River with its adjacent floodplain is already observed by nature conservation sector as one of the most important to be restored due to riverbed incision and loss of the connection with the adjacent floodplain which leads to lower resilience to droughts and floods. Therefore, studies researching restoration potential have been prepared already (e.g. Sava restoration from Brežice to Rugvica[54]) and the TNC could build on already implemented projects and high interest for implementation of NbS from the side of conservation sector.

[49] RSIS (2020) Lonjsko Polje Nature Park, Information Sheet on Ramsar Wetlands (RIS), Update version, previously published on 1 January 2012, Site number 584. Available at: https://rsis.ramsar.org/RISapp/files/RISrep/HR584RIS_2002_en.pdf

[50] Schwarz, U. (2016) The River Sava: Threats and Restoration Potential. Sava White Book. Radolfzell/Wien: EuroNatur/Riverwatch. Available at: https://pp-lonjsko-polje.hr/wp-content/uploads/2019/04/euronatur_SavaWhite-Book-Study.pdf.

[51] Available at: https://www.interreg-danube.eu/approved-projects/sava-ties

[52] Available at: https://danubeparks.org/projects/danubeparks-step-20-2012-2014

[53] Available at: https://www.euronatur.org/en/what-we-do/news/launch-for-transnational-programme-to-protect-the-sava-river

[54] EuroNatur - Stiftung Europäisches Naturerbe(2021) Sava River restoration from Brežice to Rugvica - feasibility study: River restoration concept based on calculations of optimal river width. Available at: https://www.balkanrivers.net/uploads/files/5/sava-river-restoration-feasibility-study-full.pdf.

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	++
Water quality improvements	+
Mitigation of hydrological drought	++
Mitigation of agricultural drought	+
Expected improvement of biodiversity status	++
Increase in resilience to climate change	++
Possibility of integration with grey infrastructure	+++
Already existing successful stakeholder collaboration	+++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

7.2 Potential NbS site – Spačva forest - Sava River floodplain

<table>
<tr><th>Potential NbS site</th><th>Location of the site</th></tr>
<tr><td>Spačva forest near Sava River</td><td>In eastern, lowland part of Croatia, in the floodplain of Sava and its tributary Bosut River</td></tr>
<tr><td>WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE</td><td>PROPOSED NbS MEASURES</td></tr>
<tr><td>1. Floods
2. Hydrological droughts
3. Water quality</td><td>Side-branch reconnections
Oxbow restoration
Dam/barrier removal
Floodplain forest restoration</td></tr>
<tr><td>DESCRIPTION OF THE SITE</td><td>RELEVANT STAKEHOLDERS</td></tr>
<tr><td rowspan="2">Spačva is an oak forest covering more than 40000 ha in Croatia, however also a part in Serbia.[55]
The dominant tree species is
Pedunculate oak (Quercus robur L.) with a significant share of common hornbeam (Carpinus betulus L.), and narrow leaved ash (Fraxinus angustifolia Vahl.) and black alder (Alnusglutinosa (L.) Geartn.).[56] It is one of the biggest oak forests still existing in Europe. Within a cross-border area, bordering with Bosnia and Herzegovina, and Serbia. On Croatian side that part is under Natura 2000 (HR2001414, HR2001415, and HR1000006).[57]</td><td>Hrvatske vode (national or local water management authority), Croatian Forests, Vukovar-Srijem County, Public Institution for protected areas of Vukovar-Srijem County</td></tr>
<tr><td>REASONS FOR SELECTING THIS SITE</td></tr>
<tr><td></td><td>This is a very important potential NbS case since it would be very important to mitigate potential future flooding as well as improve the ecosystem status of Spačva forest. In 2014 there was a severe flooding event with human causalities and big economic losses. Spačva forest could be used as water retention for the flood protection in parts of the year. That would improve the oak production as well, since oak grows at slower rate due to drying when groundwater levels are too low. The feasibility study of Spačva restoration is already published and could be used for future work on NbS.[58] The whole ecosystem should be observed on transboundary level.</td></tr>
</table>

[55] Croatian Waters & Public Water Management Company ''Vode Vojvodine'' (2017) Integrated Cross-Border Monitoring and Management Systems for Flood Risks, Environmental and Biodiversity Protection and Forestry Through Transboundary Forest Retentions and Other Measures. Croatian Waters & Vode Vojvodine.

[56] Ostrogović Sever, M.Z., Paladinić, E., Barcza, Z., Hidy, D., Kern, A., Anić, M., & Marjanović, H. (2017). Biogeochemical modelling vs. tree-ring measurements - Comparison of growth dynamic estimates at two distinct oak forests in Croatia. South-east European Forestry, 8(2), 71-84.

[57] *Management Plan for the Ecological Network and Protected Areas of the Spačva Area (PU 019).* Development of a Framework for Managing the Natura 2000 Ecological Network. Project Code: KK.06.5.2.03.0001. Zagreb: Ministry of Economy and Sustainable Development. Executor: Particip GmbH.

[58] Glatz-Jorde, S., Köstenberger, L., Jorde, K., Grigull, M., Berger, V. and Kirchmeir, H. (2021) Sava.Restore - Connecting the Floodplains for a healthy alluvial forest. Feasibility Study for Spačva - Bosut Forests Restoration. Final Report. Klagenfurt: E.C.O. Institute of Ecology.

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	++
Water quality improvements	+
Mitigation of hydrological drought	+++
Mitigation of agricultural drought	++
Expected improvement of biodiversity status	++
Increase in resilience to climate change	+++
Possibility of integration with gray infrastructure	+++
Already existing successful stakeholder collaboration	+++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	++

7.3 Potential NbS site – Orljava River

Potential NbS site	Location of the site
Orljava River	Eastern lowland part of Croatia
WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE	**PROPOSED NbS MEASURES**
1. Water quality 4. Hydrological droughts 5. Floods	Constructed wetlands Oxbow restoration Side-branch reconnections Dam/barrier removal
DESCRIPTION OF THE SITE	**RELEVANT STAKEHOLDERS**
Orljava-Londža river basin in Požega-Slavonia County, which covers 1,815 km² is a key area in central Slavonia between the Sava and Drava rivers. This region, with Orljava and Londža rivers being Sava's tributaries include two main catchment areas: "Orljava-Londža" (70% of the county) and part of the "Ilova-Pakra" watershed (30%). The "Orljava-Londža" catchment area is notable for its natural surroundings, bordered by several mountains and three cities as well as 203 settlements. Flood defence currently includes 69,622 km of embankments. [59]	Hrvatske vode (national or local water management authority), Croatian Forests, Požega-Slavonija County, Public Institution for protected areas of Požega-Slavonija County
	REASONS FOR SELECTING THIS SITE
	Currently the grey solution is under development therefore it might be beneficial to work on this case, although the impact would be more on the local level. There is a potential to include NbS measure into the current project. In the area of Orljava river we have highly intensive agriculture as well as factories, therefore the biggest challenge is water quality which is currently very poor. To tackle the water quality issue the agreement with the industry should be made. There is potential for implementation of oxbow reconnections in the channelised part which would also have a positive impact to water quality and flood mitigation.

[59] Hrvatske vode (2014) Provedbeni plan obrane od poplava branjenog područja sektor D – Srednja i Donja Sava, branjeno područje 3: Područje maloga sliva Orljava-Londža. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_3_-_provedbeni_plan_obrane_od_poplava.pdf.

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	++
Groundwater recharge	++
Water quality improvements	+++
Mitigation of hydrological drought	++
Mitigation of agricultural drought	++
Expected improvement of biodiversity status	++
Increase in resilience to climate change	++
Possibility of integration with grey infrastructure	+++
Already existing successful stakeholder collaboration	+
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

7.4 Potential NbS site – Odransko Polje

Potential NbS site	Location of the site
Odransko Polje	Central part of Croatia, south-east from Zagreb
WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE	**PROPOSED NbS MEASURES**
1. Floods 6. Hydrological droughts 7. Water quality	Side-branch reconnections Oxbow restoration Dam/barrier removal Floodplain forest restoration
DESCRIPTION OF THE SITE	**RELEVANT STAKEHOLDERS**
Odransko polje and Turopolje are located in Posavina, an alluvial plain along the Sava River. This floodplain, which receives water from the surrounding higher ground, is characterized by micro-relief forms that condition the emergence of different alluvial habitats of wet meadows and forests that depend on the flooding regime, as well as levels of underground water.[60] Odransko Polje is a protected area under the category of significant landscape.[61] The Sava River shaped the main characteristics of the lowland relief by deepening its bed and raising the banks on which the settlements were located, and then the relief gradually descends towards the flooded pastures and forests that surround the banks of the Odra River.[62] Some of the implemented projects are: SavaParks I and II.[63] SavaParks is the international network of protected areas that advocates for the restoration of Sava River.[64] Water management authorities are already working on establishing the flood protection within the scope of Odransko Polje[65] [66]and creating conceptual solution. [67] and the EIA was already conducted.[68]	Hrvatske vode (national or local water management authority), Sisak-Moslavina County, Zagrebačka County, and Public Institution responsible for protected areas of those two Counties
	REASONS FOR SELECTING THIS SITE
	Construction of the whole system of flood defence is already undergoing, but due to high complexity and big financial costs, in somewhat slower pace. Therefore, is advised to be further researched with the responsible stakeholders. This is the floodplain of the Odra River which has in impact on Lonjsko Polje downstream Sava River as well. Odransko Polje is connected with Sava with a channel which is used to store higher water waves from the area upstream from Zagreb and is already being used for flood protection. However, due to increase of Sava riverbed incision the connection with the floodplain is becoming more severe as with many lowland rivers in Croatia.

[60] Available at: https://zastita-prirode-smz.hr/zastcena-podrucja/odransko-polje/
[61] Available at: https://savaparks.eu/znacajni-krajobraz-odransko-polje-585
[62] Chamberlain, L. (2018) Eco-Masterplan for the "Save the Blue Heart of Europe" campaign. Available at: https://balkanrivers.net/sites/default/files/Eco-Masterplan%20for%20Balkan%20Rivers-PRESS-REVISION%201-2018%20November%2026-WEB.pdf
[63] Available at: https://www.savaparks.eu/sava-parks-4282
[64] SavaParks Guiding Principles on Nature Conservation, River Rehabilitation and Flood Prevention and Sustainable Regional Development (2015). Available at: https://savaparks.eu/guiding-principles-on-nature-conservation-river-rehabilitation-flood-prevention-and-sustainable-regional-development-7172
[65] Hrvatske vode (2015) Flood Protection Implementation plan. (Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_10_-_provedbeni_plan_obrane_od_poplava.pdf)
[66] Available at: https://hrcak.srce.hr/file/58805
[67] Available at: https://www.vpb.hr/2017/06/30/koncepcijsko-rjesenje-zastite-od-poplava-odranskog-polja/
[68] Available at: https://mingor.gov.hr/UserDocsImages/UPRAVA-ZA-PROCJENU-UTJECAJA-NA-OKOLIS-ODRZIVO-GOSPODARENJE-OTPADOM/Puo/17_02_2020_Sazetak_Sisacko_podrucje.pdf

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	++
Water quality improvements	++
Mitigation of hydrological drought	++
Mitigation of agricultural drought	+
Expected improvement of biodiversity status	++
Increase in resilience to climate change	++
Possibility of integration with grey infrastructure	++
Already existing successful stakeholder collaboration	++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

7.5 Potential NbS site – Sava River floodplain from upstream from Zagreb to Ivanja Reka

<table>
<tr><th>Potential NbS site</th><th>Location of the site</th></tr>
<tr><td>Sava River section (from upstream from Zagreb to Ivanja Reka)</td><td>Sava, from upstream to downstream from Zagreb</td></tr>
<tr><td>WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE</td><td>PROPOSED NbS MEASURES</td></tr>
<tr><td>1. Floods
8. Hydrological droughts
9. Water quality</td><td>Study which proposes concrete measures is already published in Sava River Restoration Study[69]
• building “initial channels”
• restoring soft banks
• widening the river
• flattening or lowering of river foreland areas
• reinforcement and reset of existing bank protection</td></tr>
<tr><td>DESCRIPTION OF THE SITE</td><td>RELEVANT STAKEHOLDERS</td></tr>
<tr><td rowspan="2">City of Zagreb is using water from Zagreb aquifer as the drinking water. Due to high number of hydropower dams upstream in Slovenia, and conventional water management practices, the Sava riverbed incision is increasing. The analysis of historical groundwater levels has shown that since the 70-ies of the past century in Zagreb groundwater levels have declined approximately by 3 m.[70] Due to Sava riverbed incision and high water demand the ground water levels are getting lower and a solution should be found to mitigate the problem. There were more initiatives already active to manage this issue, like “Zagreb on Sava”.[71] International organisation Euronatur was advocating restoration measures, but both initiatives are no longer active mainly due to lack of interest from local stakeholders.</td><td>Hrvatske vode (national or local water management authority), City of Zagreb, Zagrebačka County, Public Institution responsible for protected areas of Zagrebačka County (PI Zeleni Prsten)</td></tr>
<tr><td>REASONS FOR SELECTING THIS SITE

With restoration activities on Sava River, from upstream from Zagreb to Rugvica, we would improve current issues with groundwater recharge of Zagreb aquifers. This is a priority since it is very important for ground water recharge to implement a project in line with nature and it should be the most sustainable solution. Already conducted, the Sava River Restoration Study can be used as the starting point to implement an NbS project.</td></tr>
</table>

[69] REVITAL. (2021). Sava River restoration from Brežice to Rugvica - feasibility study: River restoration concept based on calculations of optimal river width. Available at: https://www.savaparks.eu/Files/Dynamic/Dokumenti/sava-river-restoration-feasibility-study-full-00b3320caa414b98a2fda5ff614bd4af.pdf

[70] Vujević, M. and Posavec, K., Identification of Groundwater Level Decline in the Zagreb and Samobor-Zaprešić Aquifers since the Sixties of the Twentieth Century. University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, available at: https://hrcak.srce.hr/ojs/index.php/rgn/article/view/6776/4677

[71] Available at: http://www.casopis-gradjevinar.hr/assets/Uploads/JCE_65_2013_12_5_Reagiran je.pdf

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	+++
Water quality improvements	+
Mitigation of hydrological drought	++
Mitigation of agricultural drought	+
Expected improvement of biodiversity status	+++
Increase in resilience to climate change	+++
Possibility of integration with grey infrastructure	+++
Already existing successful stakeholder collaboration	+++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

7.6 Potential NbS site – Karlovac-Sisak flood protection system

Potential NbS site	Location of the site
Karlovac-Sisak flood defence system	Central part of Croatia, in Karlovac and Sisak-Moslavina Country
WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE	**PROPOSED NbS MEASURES**
1. Floods 10. Hydrological droughts 11. Water quality	Side-branch reconnections Oxbow restoration Dam/barrier removal Floodplain forest restoration
DESCRIPTION OF THE SITE	**RELEVANT STAKEHOLDERS**
Karlovac and Sisak region, where four rivers (Kupa, Korana, Mrežnica, and Dobra) meet near Karlovac, and three rivers (Sava, Kupa, and Odra) near Sisak, faces complex flood risks. This area struggles with flood defence due to the challenging and sometimes impossible task of completing the flood protection system. Climate change has increased extreme flooding in these areas. From 2014 to 2018, Karlovac and Sisak experienced ten significant high-water events, requiring extraordinary flood protection measures. Record-breaking water levels were observed on Kupa and Korana rivers during this period. [72] The flood defence system of the city of Karlovac is the only one in the area whose construction was started but due to its incompleteness and slow expansion, only the narrow part of the city centre is protected. The rest of the area is still unprotected.[73]	Hrvatske vode (national or local water management authority), Karlovac County, Sisak-Moslavina County and Public Institution responsible for protected areas of those two Counties.
	REASONS FOR SELECTING THIS SITE
	Although Sisak and Karlovac where at the beginning observed as separate potential NbS cases, since they are connected, and their flood management as well we merged it under one, however very sizable case. Sisak-Karlovac flood defence is merged. This could also be connected to Odransko Polje which tor the time being is observed as s separate case to also have options for smaller NbS cases. The interest to work on this exist since the project is still not fully funded and open for potential implementation of NbS solution to already planned grey flood defence solutions.

[72] Hrvatske vode. (2019) Dokument Studija o utjecaju na okoliš – ne-tehnički sažetak: Projekt Sustav zaštite od poplava karlovačko-sisačkog područja II. faza – sisačko područje. Izrađivač: Geateh d.o.o. Available at: https://mingor.gov.hr/UserDocsImages/UPRAVA-ZA-PROCJENU-UTJECAJA-NA-OKOLIS-ODRZIVO-GOSPODARENJE-OTPADOM/Puo/09_12_2019_Sazetak_Sisacko_podrucje.pdf.

[73] Hrvatske vode (2014). Provedbeni plan obrane od poplava branjenog područja sektor D – Srednja i Donja Sava, branjeno područje 11: Područje maloga sliva Kupa. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_11_-_provedbeni_plan_obrane_od_poplava.pdf.

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	++
Water quality improvements	+
Mitigation of hydrological drought	++
Mitigation of agricultural drought	+
Expected improvement of biodiversity status	++
Increase in resilience to climate change	++
Possibility of integration with grey infrastructure	+++
Already existing successful stakeholder collaboration	+++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

7.7 Potential NbS site – Bregana River

<table>
<tr><th>Potential NbS site</th><th>Location of the site</th></tr>
<tr><td>Bregana River</td><td>Bordering area between Slovenia and Croatia, northern from Zagreb</td></tr>
<tr><td>WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE</td><td>PROPOSED NbS MEASURES</td></tr>
<tr><td>1. Floods
12. Hydrological droughts
13. Water quality</td><td>Side-branch reconnections
Dam/barrier removal
Floodplain forest restoration</td></tr>
<tr><td>DESCRIPTION OF THE SITE</td><td>RELEVANT STAKEHOLDERS</td></tr>
<tr><td rowspan="2">Bregana River is a transboundary river between the Republic of Croatia and Republic of Slovenia. It is a small river, 26 km long with a catchment area of 92 km^2 most of which is located in Croatia. According to flood maps, 0,84 km^2 of the basin is threatened by high probability floods (10-year return period), while 2,22 km^2 is threatened by floods of low probability of occurrence (500 years return period). The flood events that occurred in 2005., 2014. and 2015. show the distinctive torrential character of Bregana, with specific flood sites.[74] Hydrographically, this area belongs to the Sava River basin. The watershed is mostly covered by forest and steep slopes that give a relatively large base flow of Bregana with an average flow of 1.36 m^3/s and consequently result in pronounced erosion processes. A smaller part of the area is under agriculture or inhibited.[75]</td><td>Hrvatske vode (national or local water management authority), Zagrebačka County, and Public Institution responsible for protected areas within the County (Zeleni Prsten).</td></tr>
<tr><td>REASONS FOR SELECTING THIS SITE</td></tr>
<tr><td></td><td>There is an issue with floods and many retention areas where previously planned. Bregana is a collaborator case in an NbS project, RECONECT already therefore upscaling of current efforts could be implemented. There are challenges due to unresolved border issues with Slovenia.</td></tr>
</table>

[74] Available at: http://www.reconect.eu/network-of-cases/.
[75] Available at: https://frisco-project.eu/hr/slivna-podrucja-rijeka/bregana/

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	++
Water quality improvements	+
Mitigation of hydrological drought	++
Mitigation of agricultural drought	+
Expected improvement of biodiversity status	+++
Increase in resilience to climate change	+++
Possibility of integration with gray infrastructure	+++
Already existing successful stakeholder collaboration	++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

7.8 Potential NbS site – Mirna River

<table>
<tr><th>Potential NbS site</th><th>Location of the site</th></tr>
<tr><td>Mirna River</td><td>In northern part of Croatian coastal area, in Istria</td></tr>
<tr><td>WATER SECURITY CHALLENGES PRIMARILY ADDRESSED AT THE SITE</td><td>PROPOSED NbS MEASURES</td></tr>
<tr><td>1. Floods
14. Hydrological droughts
15. Water quality</td><td>Side-branch reconnections
Dam/barrier removal (embankment)
Providing more space to the river where not inhibited</td></tr>
<tr><td>DESCRIPTION OF THE SITE</td><td>RELEVANT STAKEHOLDERS</td></tr>
<tr><td rowspan="2">Mirna is the largest river in Istrian County, which results not only from the size of its catchment area, which is about 725 km^2 (influential, i.e. hydrogeological catchment, of which approximately 380 km^2 is the immediate surface basin), but also from its water balance which makes up about 30% of the total water balance of the Istrian area. About 7% of the basin (45 km^2) is located in Slovenia.[76] A large part of the water balance is provided by karstic springs, of which Bulaţ and Mlini partly supplement from the territory of Slovenia.[77] River Mirna is embanked throughout almost all of its length, and groundwater of this watershed is being illegally used (wells) for drinking water, which is highly above sustainable capacities during summer and tourism season.</td><td>Hrvatske vode (national or local water management authority), Croatian Forests, Istria County, Public Institution responsible for protected areas of the same County (Natura Histrica).</td></tr>
<tr><td>REASONS FOR SELECTING THIS SITE</td></tr>
<tr><td>This is a priority since in Istria this is a main watercourse, and the water from aquifer is being used heavily during tourism season. Some more sustainable solution should be found, as well as for management of the river to be more nature positive. There is a high potential for NbS project development due to interest of Public Institution responsible for protected area management. Collaboration between nature and water management sector already started and this case should be more researched with relevant local stakeholders.</td></tr>
</table>

[76] Popijač, A. (2013) Definiranje ekološki prihvatljivog protoka Mirne. Stručna studija. Ugovor broj: 23-125/10 (Oikon 683-10). Zagreb: HRVATSKE VODE. Available at: https://www.voda.hr/sites/default/files/dokumenti/prateca-dokumentacija/definiranje_ekoloski_prihvatljivog_protoka_mirne.pdf.

[77] Available at: https://www.istrapedia.hr/en/natuknice/291/mirna.

CRITERIA FOR SITE SELECTION (+ low. ++ medium, +++ high)	
Flood retention capacity increase	+++
Groundwater recharge	++
Water quality improvements	++
Mitigation of hydrological drought	++
Mitigation of agricultural drought	+
Expected improvement of biodiversity status	++
Increase in resilience to climate change	+++
Possibility of integration with gray infrastructure	++
Already existing successful stakeholder collaboration	++
Possibility of replicability	+++
Following policy recommendations (nature restoration law, Biodiversity strategy, WFD, etc.)	+++

8 Next steps and recommendations

This report outlines the role of NbS in tackling the interconnected issues of climate change, water security, and the loss of biodiversity in Croatia. By adopting the NbS approach, Croatia can effectively reduce the negative impacts of environmental degradation while simultaneously improving both, the status of ecosystems and community well-being.

The NbS approach offers a cost-effective alternative to conventional grey infrastructure and/or can be used in addition to grey infrastructure measures. This report proposes potential NbS measures (within Annex 1) that can be deployed in close collaboration between water management and relevant stakeholders (nature conservation, forestry agriculture, spatial planning, NGOs, etc.). In some of the locations proposed within this Report, NbS projects are already being implemented and in all proposed locations, NbS can be integrated with grey solutions.

On 18th June 2024 the 2nd workshop with an Advisory Board and a broader range of participants was held and their opinions were gathered during the discussion part to be integrated with the conclusions and recommendations of this Report.

Recommendations

- Ensure that the Croatian authorities support the implementation of NbS on the policy level and harmonize the integration of NbS into water management, agriculture, forestry, and spatial planning while following the EU legislation and the EU Green Deal (Conservation Strategy 2030, Forestry strategy, Nature Restoration Law, WFD, Bird and Habitats Directive, etc.)
- Water management should consider NbS solutions in comparison to grey infrastructure during the planning of grey infrastructure projects, as well as strengthen integrating NbS solutions as a part of grey infrastructure projects
- Integrate NbS projects into spatial planning documents on the national/county/municipality level as well as in River Basin Management Plans and the corresponding water management maintenance plans
- Adaptation of legal procedures to prioritize public interests as a priority instead of private properties (e.g. in a case of flooding expropriation law should be used to reconnect the side branch and increase natural water retention instead of protecting private land) however in close collaboration with landowners and appropriate subsidies/payment scheme provided to the private landowner
- Build capacities and educate water management/forestry/agriculture practitioners about options on how the NbS can be integrated with the grey infrastructure, as well as solely implemented (NbS planning, design, implementation, maintenance, and monitoring)
- Raise awareness of policymakers, the private sector, and the public about the NbS and use all possible opportunities for NbS promotion
- Encourage partnerships among governmental bodies, research institutions, NGOs, and the private sector to enhance NbS project design, implementation, and scalability
- Support NbS Champions at Hrvatske vode (the water management authority), as well as at the Ministry of Environment and Green Transition to implement more pilot NbS projects
- Provide supporting mechanisms for NbS implementation while targeting land-ownership challenges
- Explore diverse financing models, including public-private partnerships, financing institutions, and international funding mechanisms
- Secure funding for NbS initiatives through public-private partnerships, financing institutions, and international mechanisms
- Create an NbS funding mechanism which blends different funding streams to increase implementation of NbS projects (WFD for water resources costs, CAP, carbon credits eventually)
- Implement national monitoring and evaluation frameworks to efficiently assess performance of NbS (to enable data collection to validate the effectiveness and impact of implemented NbS, inform adaptive management strategies, and adapt project design for further implementation)
- Plan for future involvement of NbS into coastal projects due to their relevance, though they are not included in the current scope due to resource limitations
- Exchange of NbS experiences among practitioners and participating in study visits focused on NbS projects
- For each of the NbS cases, it is suggested to follow the steps of NbS implementation prepared within the Catalogue of NbS measures (detailed design of the NbS project, involving local stakeholders, etc.)
- Translate the IUCN NbS Global Standard into Croatian language and make it broadly available

Next steps

Out of eight potential locations the plan is to continue working with three-four locations from Autumn 2024 onwards and to support them in their strategic implementation of NbS to tackle water security challenges.

The criteria for the selection of locations is listed below:

- Locations where successful stakeholder collaboration (water management, forestry, nature conservation, agriculture, etc.) already exists and potentially collaboration with local communities as well
- Continue working with locations where some form of restoration activities or NbS projects have already started
- Where willingness and proactivity for NbS implementation exists
- The improvement of biodiversity status is expected
- The potential for replicability of NbS

In the next phase of the EIB/TNC project, it is advised to:

- Follow the steps of NbS implementation prepared within the Catalogue of NbS measures (detailed design of the NbS project, involving local stakeholders, etc.)
- To define the costs (comparing to the grey solution) to see the economic benefit of NbS – "price ticket" of the project, and then it should be easier to engage the funding
- To prepare a detailed Guideline on what is needed for the NbS implementation within the scope of the specific case
- Prepare the stakeholder analysis
- Design of an NbS project
- Check the land ownership distribution at the planned NbS sites

For NbS to become a basis of environmental and water management policies and practices in Croatia, a broad advocacy effort is needed. This includes enhancing policy coherence across sectors, building the capacity of institutions and stakeholders to design and implement NbS, and fostering partnerships to finance NbS projects. As Croatia continues to develop its policy framework, embedding NbS principles can provide a pathway to not only meet environmental targets but also enhance societal well-being and economically viable climate resilience.

In the next phase of the partnership, the TNC's Financing Nature for Water Security: A How-To Guide to Develop Watershed Investment Programs[78] will be used as guidance towards NbS deployment as visually shown below.

[78] The Nature Conservancy (TNC), 2022. Financing Nature for Water Security: A How-To Guide to Develop Watershed Investment Programs. Version 1. Arlington, VA: The Nature Conservancy.

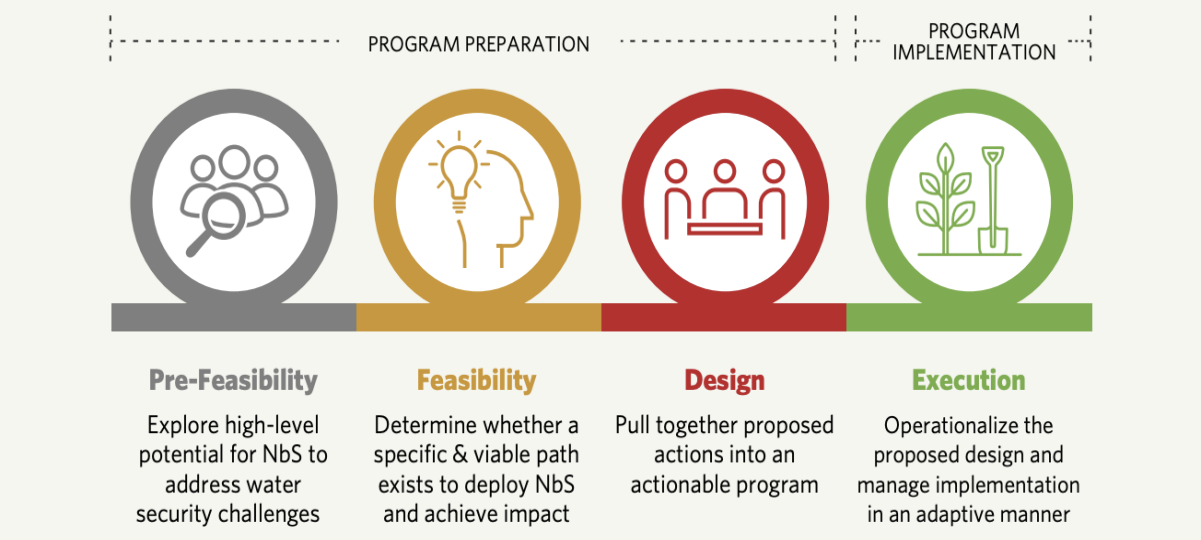


Figure 1. The Watershed Investment Program Development Lifecycle

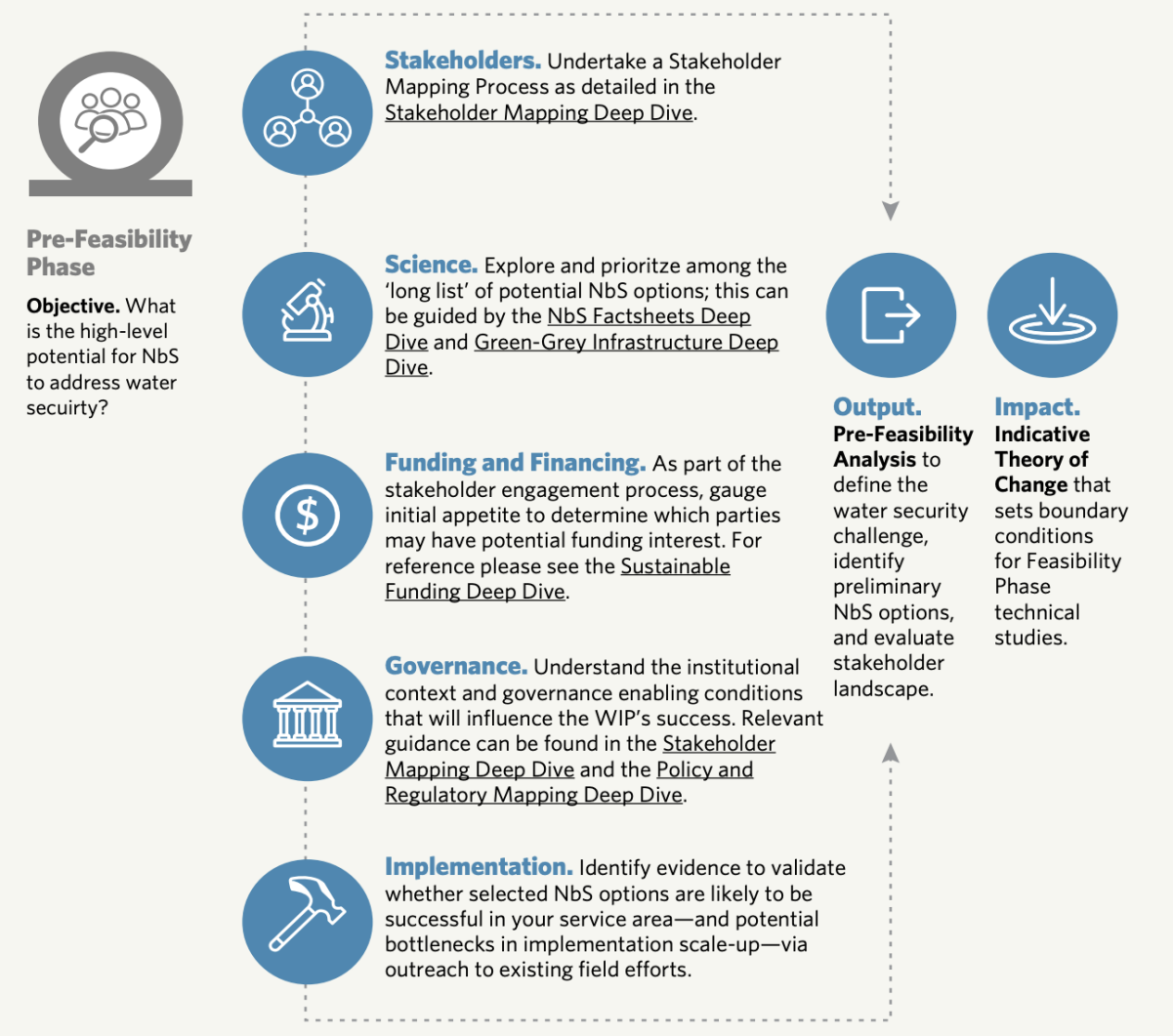


Figure 2. Example of schematic introducing each phase of the WIP development cycle

9 Bibliography

1. Treasury, H. The Economics of Biodiversity: The Dasgupta Review.
2. Promoviranje zeleno-infrastrukturnih mjera (VEPAR) GRUPA 2. www.strukturnifondovi.hr.
3. Springer, J., Campese, J. & Nakangu, B. *The Natural Resource Governance Framework Improving governance for equitable and effective conservation*. https://twitter.com/IUCN/.
4. Zagreb, G. *RJEŠENJA UTEMELJENA NA PRIRODI PRIRUČNIK za primjenu u urbanom području Grada Zagreba*.
5. Larbodière, L. *et al. Common ground Restoring land health for sustainable agriculture*. https://twitter.com/IUCN/.
6. Royal Society (Great Britain). *Resilience to extreme weather*.
7. Commission on Environment, W. *Report of the World Commission on Environment and Development: Our Common Future Towards Sustainable Development 2. Part II. Common Challenges Population and Human Resources 4*.
8. Ranjan Sinha, V. & Bimson, K. *Nature-based Solutions in the Ganges Brahmaputra Meghna (GBM) river basin Case studies and lessons learned Building River Dialogue and Governance (BRIDGE)*. www.iucn.org/resources/publications (2021).
9. Penning, E., Peñailillo Burgos, R., Mens, M., Dahm, R. & de Bruijn, K. Nature-based Solutions for Floods AND Droughts AND Biodiversity: do we have sufficient proof of their functioning? *Cambridge Prisms: Water* 1–34 (2023) doi:10.1017/wat.2023.12.
10. *Nature-based solutions to address global societal challenges*. *Nature-based solutions to address global societal challenges* (IUCN International Union for Conservation of Nature, 2016). doi:10.2305/iucn.ch.2016.13.en.
11. *Nature-based solutions to address global societal challenges*. *Nature-based solutions to address global societal challenges* (IUCN International Union for Conservation of Nature, 2016). doi:10.2305/iucn.ch.2016.13.en.
12. Dumitru, Adina. & European Commission. Directorate-General for Research and Innovation. *Evaluating the impact of nature-based solutions ǂa ǂhandbook for practitioners*. (Publications Office of the European Union, 2021).
13. *IUCN Global Standard for Nature-based Solutions: a user-friendly framework for the verification, design and scaling up of NbS: first edition*. (IUCN, International Union for Conservation of Nature, 2020). doi:10.2305/IUCN.CH.2020.08.en.
14. Hilty, J. *et al. Guidelines for conserving connectivity through ecological networks and corridors Best Practice Protected Area Guidelines Series No. 30 Developing capacity for a protected planet*. www.iucn.org/pa_guidelines.
15. *Gender-responsive restoration guidelines A closer look at gender in the Restoration Opportunities Assessment Methodology Global Forest and Climate Change Programme*.
16. Pakeman, R. J., Waylen, K. A. & Wilkinson, M. E. *Evaluating Nature-based Solutions-a synthesis A SEFARI project with NatureScot*.
17. Monty, F., Murti, R., Miththapala, S. & Buyck, C. *Ecosystems protecting infrastructure and communities Lessons learned and guidelines for implementation*. https://twitter.com/IUCN/.
18. Raymond, C. M. & Centre for Ecology and Hydrology (Great Britain). *An impact evaluation framework to support planning and evaluation of nature-based solutions projects : prepared by the EKLIPSE Expert Working Group on nature-based solutions to promote climate resilience in urban areas*.
19. Eib. *EIB Group Climate Bank Roadmap 2021-2025*. (2020).
20. Andrade, A. *et al. Principles and Guidelines for Integrating Ecosystem-based Approaches to Adaptation in Project and Policy Design: 1*. http://www.iucn.org/about/.
21. *Factsheets of Nature-based Solutions for Water Security Financing Nature for Water Security: A How-to Guide to Develop Watershed Investment Programs Factsheets of Nature-based Solutions for Water Security Introduction and scope*.
22. Cohen-Shacham, E. *et al.* Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science and Policy* vol. 98 20–29 Preprint at https://doi.org/10.1016/j.envsci.2019.04.014 (2019).
23. *Sharing the benefits from river basin management*. www.iucn.org/resources/publications (2021).

24. *A guide to the Restoration Opportunities Assessment Methodology (ROAM) Assessing forest landscape restoration opportunities at the national or sub-national level*. www.iucn.org/publications.
25. *Synopsis of consultation and feedback process for the development of the IUCN Global Standard for Nature-based Solutions*. https://www.iucn.org/theme/nature-based-solutions/iucn-global-standard-nbs.
26. *Nature-based Solutions in the Post-2020 Global Biodiversity Framework Targets*. https://www.carbontrust.com/resources/briefing-what-are-scope-3-.
27. Mace, G. M. Whose conservation? *Science* vol. 345 1558–1560 Preprint at https://doi.org/10.1126/science.1254704 (2014).
28. Kareiva, P. & Marvier, M. What is conservation science? *Bioscience* 62, 962–969 (2012).
29. Seddon, N. *et al.* Global recognition of the importance of nature-based solutions to the impacts of climate change. *Global Sustainability* 3, (2020).
30. *COMMISSION STAFF WORKING DOCUMENT First Flood Risk Management Plans-Member State: Croatia Accompanying the document REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the implementation of the Water Framework (2000/60/EC) Directive and the Floods Directive (2007/60/EC) Second River Basin Management Plans First Flood Risk Management Plans*.
31. flow_allocations_in_a_river_system_final.
32. Eib. *The EIB Environment Framework*.
33. Eib. *EIB water sector orientation - Building climate-resilient water systems*. (2023).
34. Potočki, K., Bekić, D., Bonacci, O. & Kulić, T. Hydrological Aspects of Nature-Based Solutions in Flood Mitigation in the Danube River Basin in Croatia: Green vs. Grey Approach. in *Handbook of Environmental Chemistry* vol. 107 (2022).
35. *Modelling Nature-based Solutions*. (Cambridge University Press, 2020). doi:10.1017/9781108553827.
36. *Promoviranje zeleno-infrastrukturnih mjera (VEPAR) GRUPA 2*. www.strukturnifondovi.hr.
37. Zagreb, G. *RJEŠENJA UTEMELJENA NA PRIRODI PRIRUČNIK za primjenu u urbanom području Grada Zagreba*.
38. Eib. *EIB Group Climate Bank Roadmap 2021-2025*. (2020).
39. Pakeman, R. J., Waylen, K. A. & Wilkinson, M. E. *Evaluating Nature-based Solutions-a synthesis A SEFARI project with NatureScot*.
40. *COMMISSION STAFF WORKING DOCUMENT First Flood Risk Management Plans-Member State: Croatia Accompanying the document REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the implementation of the Water Framework (2000/60/EC) Directive and the Floods Directive (2007/60/EC) Second River Basin Management Plans First Flood Risk Management Plans*.
41. Raymond, C. M. & Centre for Ecology and Hydrology (Great Britain). *An impact evaluation framework to support planning and evaluation of nature-based solutions projects : prepared by the EKLIPSE Expert Working Group on nature-based solutions to promote climate resilience in urban areas*.
42. Eib. *The EIB Environment Framework*.
43. *Nature-based Solutions in the Post-2020 Global Biodiversity Framework Targets*. https://www.carbontrust.com/resources/briefing-what-are-scope-3-.
44. Eib. *EIB water sector orientation - Building climate-resilient water systems*. (2023).
45. Strategija prilagodbe klimatskim promjenama u Republici Hrvatskoj za razdoblje do 2040. godine s pogledom na 2070. godinu.
46. Eib. *EIB Group Climate Bank Roadmap 2021-2025*. (2020).
47. Pakeman, R. J., Waylen, K. A. & Wilkinson, M. E. *Evaluating Nature-based Solutions-a synthesis A SEFARI project with NatureScot*.

Annex 1

Draft catalogue of proposed NbS measures in Croatia

This Catalogue of proposed NbS measures was prepared based on existing and available information about green infrastructure projects and their implementation in Croatia. One of the new developments concerning green infrastructure is the recently published document "*Guidelines for Technical Design and Assessment of Socio-Economic Feasibility of Green Infrastructure Measures*", (*the Guidelines*) prepared in the scope of the VEPAR project implemented by Hrvatske vode (national water management authority) and Croatian Hydrometeorological and Hydrological Service.

The *Guidelines* include recommendations for 18 types of green infrastructure measures, specifically focused on flood protection, erosion, and sediment control as well as flash flood management. This catalogue has scored those measures, alongside other potential NbS applicable in Croatia, to define how closely they align to the IUCN Global Standard on NbS. It should be noted that this assessment has been undertaken at a strategic level and therefore does not consider site specific factors that should be evaluated to ensure interventions are appropriate and align with the IUCN definition of NbS at the programme or project scale.

Such site specific evaluation should draw on local data (e.g. climate change scenarios, land ownership, biodiversity data, etc.) and, crucially it requires the involvement of local stakeholders and local communities. Local knowledge and buy-in from stakeholders is vital in developing NbS that can address stakeholders needs, are deliverable within the local farming / land use systems and thus have a high chance of success in tackling water security issues.

Ultimately the goal of NbS for Water Security is to address societal challenges, e-g. floods, droughts, water quality, while delivering co-benefits for biodiversity, ecosystems and local communities. In order to achieve this at scale we need to adopt a landscape/ strategic approach to identify water security issues and opportunities from the "top down", and develop NbS with involvement of local knowledge, and local communities from the "bottom-up". Only then can we deliver appropriate and robust NbS that deliver improved water security over the long-term and benefits for local communities and the environment.

Roadmap of steps proposed for implementation of NbS project

STEP 1: DEFINE THE SOCIETAL/WATER SECURITY CHALLENGE YOU WOULD LIKE TO ADDRESS
Many challenges need to be addressed in the era of climate change and the biodiversity crisis. Within the scope of this document, we are addressing the issue of water security while focusing on floods, droughts, and water quality in order to create more resilience towards climate change impacts. When an NbS project is in question, a practitioner dealing with an issue needs to think strategically, involving all relevant sectors, while addressing the local issues. We cannot address all the problems within the scope of one project. Still, we can think strategically and in the long term increase resilience towards climate change and biodiversity crisis. Through our approach we should ensure that activities are strategic and maximise benefits to people and ecosystems while mitigating climate change impacts on ecosystems and human population.
STEP 2: THINK BROADLY AND DEFINE WHO ADDITIONALLY SHOULD BE INVOLVED IN THE PLANNING STAGE
Think outside the scope of your sector, who would you need to involve, farmers, nature conservation, local NGOs, etc. Within the scope of an NbS project, it is crucial to have a holistic approach while addressing societal issues. Links between a range of sectors to broaden the scope of the response to societal challenges may be identified to support synergies amongst different solutions. Such joint approaches enhance ownership of the approach, reduce the risks of negative unintended consequences, and facilitate the overall mainstreaming of NbS into multiple policies and sectors. If there is no involvement of the local circumstances, local knowledge, and local communities the project isn't truly an NbS project even though it provides biodiversity benefits.

STEP 3: PRELIMINARY DESIGN OF THE NbS PROJECT

While addressing a water security challenge, e.g. the issue of floods, observe the situation on a broader scale. Think about the projects that have already been implemented, the ones under implementation, and the ones for which you already have financial resources, while observing the situation on the catchment level. While having that in mind, think how you could best support local communities with the project implementation. Are there any direct benefits they will have after the project implementation? If you know that there will be less floods downstream and that drought will be mitigated to some percentage on the local level, have that in mind and design the project to enhance the benefits for local communities already in the earlies stages of design planning.

STEP 4: EXAMINE THE DATA OF YOUR POTENTIAL NbS PROJECT

Conduct a thorough assessment and data collection regarding the project site, considering biodiversity, hydrology, soil quality, land ownership, etc. while including as stated below:

- Consult the local/county and national spatial planning documentation and the land registry
- Consult the CORINE land cover classification system as well as a local land cover registry if available
- Examine land ownership situation as well as the current land prices since most probably part of land plots will need to be purchased
- Gather data/necessary permits from the water management authority, providing an overview of the condition of water resources and water management infrastructure
- Gather data/necessary permits concerning nature conservation (Natura 2000, protected areas, environmental aspects)
- Gather data on local climatic conditions while including the available data on future climate change scenarios (mean precipitation, temperature, etc.)
- Gather data on all other sectors who are using the area (e.g. forestry, agriculture, industry, etc.)
- Gather data/necessary permits regarding cultural and traditional values and goods
- Think about the potential risks and try to prepare adaptation plans ahead as well as keep a financial buffer in case of potential increase in prices since NbS projects can last many years
- Think about whether an NbS design is sufficiently robust to absorb anticipated economic, demographic, and climate-related changes
- Consult any other resource you might find as a useful source of information

STEP 5: ORGANISE STAKEHOLDER MEETINGS ON THE LOCAL LEVEL

People always like to be aware of what is going on in their vicinity and they like to know their voice is heard. Speak with the local authorities and ask them to invite local people when you will be presenting the initial idea of an NbS project. Their input will be valuable. Maybe they have some knowledge which is not monitored until now in the scope of any sector, and that might also be relevant for the successful project implementation. There is some time you will need to plan to include stakeholders, however people need to understand what you will be doing to support you in the process of project preparation and implementation.

STEP 6: GATHER ALL THE INPUTS AND START WITH THE IMPLEMENTATION PROCESS

When all that data is available to you, and you involve the local community you can start with the legally obligated procedures. You should contract an expert to support you with the exact design of the measure and then follow up with the permitting procedure(Prescreening/Appropriate Assessment, possibly Environmental Impact Assessment) and preparation of all the needed studies and measurements (geodetic, etc.) to be able to implement an NbS project. If the land needs to be purchased, start the process as soon as possible since it can take a couple of years to obtain the land.

STEP 7: MONITOR AND EVALUATE

Monitor and evaluate the project during its implementation, while gathering what you learned and what you might want to adapt in the scope of the next NbS project implementation. Alongside with that you are obligated to include biotic and abiotic monitoring in the scope of the project.

STEP 8: COMMUNICATE AND DISSEMINATE
To enhance the implementation of NbS projects in your country, you should disseminate project results and transfer knowledge to amplify the innovation in the scope of NbS projects. There are many projects implemented already, but the knowledge gap about the implementation is still substantial, therefore communicate and disseminate what you have learned.

IUCN NbS SELF-ASSESSMENT INTRODUCTION

In developing this Catalogue, we evaluated the green infrastructure techniques explained within the "Guidelines for Technical Design and Assessment of Socio-Economic Feasibility of Green Infrastructure Measures" (*the Guidelines)* against criteria established in the IUCN NbS self-assessment tool. Additional NbS that have potential for deployment in Croatia but not included in the *the Guidelines* were also reviewed e.g. dam removal, constructed wetlands, and floodplain forest restoration.

While assessing the projects, national legislation regarding water security (as explained in the chapter 4, Policy Overview) was considered, as well as the available information about restoration projects which have already been implemented in Croatia.

This exercise provides an assessment of how closely measures adhere to IUCN Global Standard on NbS. Green infrastructure techniques reviewed in *the Guidelines* that do not provide significant biodiversity benefits were not included within the scope of this Catalogue. For example, some engineering (e.g. building of groynes) measures do not fall within the scope of NbS while some green infrastructure measures have little positive impact on biodiversity (e.g. sedimentation pools).

Measures that achieve an average score of 25% or greater against the IUCN Global Standard on NbS are considered as an NbS. However if any individual of the NbS criterions is considered insufficient (less than 25%), the assessed technique cannot be considered an NbS.

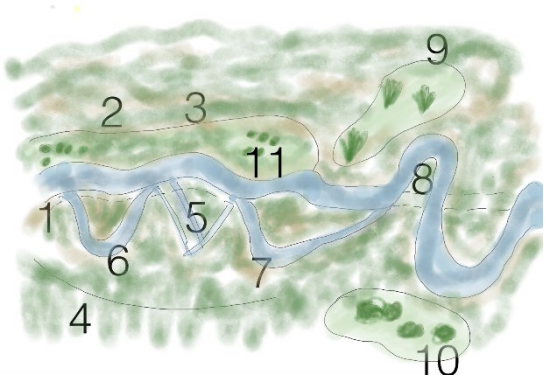
Table 1: Legend which showcases how an NbS intervention adheres to an IUCN Global Standard on NbS

Key		Output
	Strong	Intervention adheres to the IUCN Global Standard for NbS.
	Adequate	
	Partial	
	Insufficient	Intervention does not adhere to the IUCN Global Standard for NbS.

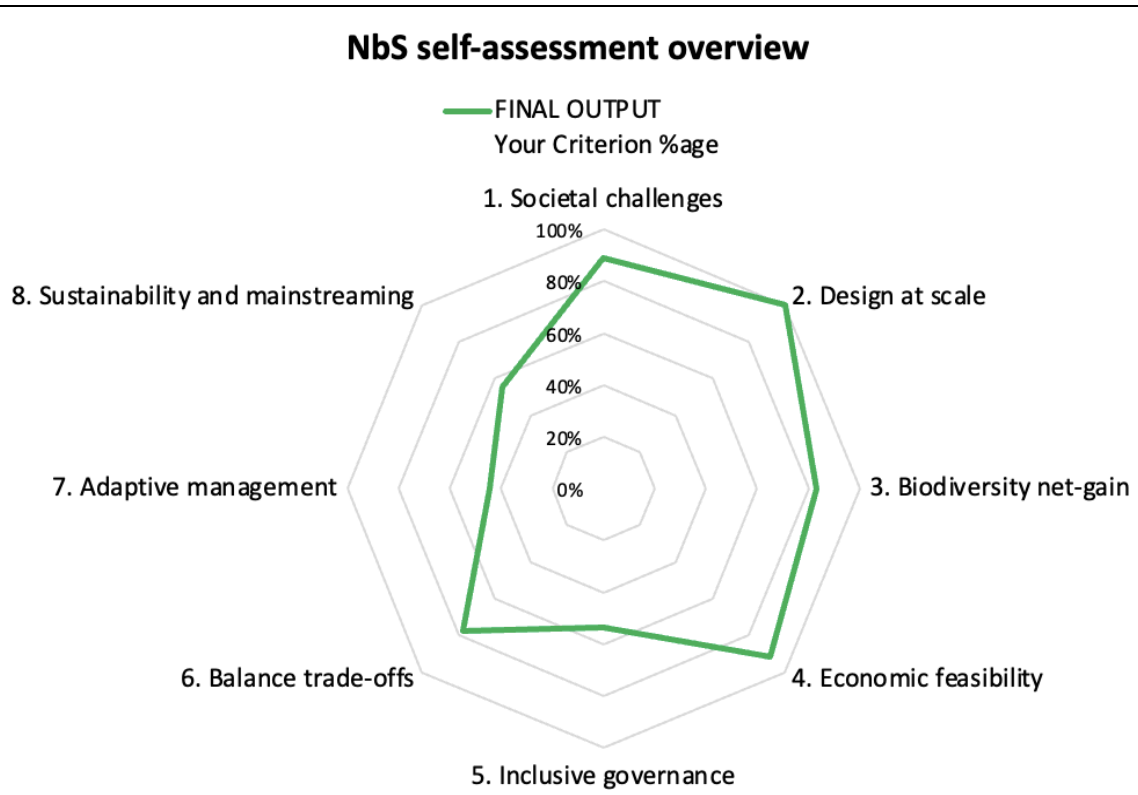
Table 2: Summary of proposed NbS measures and adherence with the IUCN Global standard of NbS (%)

NO	NbS MEASURE	LANDSCAPE TYPE	ADHERENCE WITH THE IUCN GS FOR NbS (%)
1	Floodplain restoration	lowland	74
2	Re-meandering	lowland	59
3	Side-branch and oxbow reconection	lowland	58
4	Wetland and peatland restoration	lowland	72
5	Floodplain forest restoration	lowland	72
6	River bank restoration	lowland	67
7	Coastal wetland restoration	Lowland/coastal	70
8	Dam/barriert removal	Lowland	70
9	Lake restoration	Lowland	36
10	Retention ponds	Lowland	37
11	Constructed wetlands	Lowland	55
12	Sinkholes	Karstic	42

1. NbS measure – Floodplain restoration

NbS MEASURE	FLOODPLAIN RESTORATION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
The floodplain restoration is not a single measure on its own but a very complex set of different restoration measures that could be implemented to result in restored lateral, and longitudinal connectivity of the main river course with its floodplain. Due to its complexity, it is extremely costly, however, it brings the biggest benefits to the local communities and biodiversity of the area. Multiple measures can be implemented in the scope of the floodplain restoration, among others, the measures that are listed in the scope of this Catalogue. To mention a few, the side-branch reconnection, re-meandering, dyke reallocation which provide more space for the river, as well as a possible repurposing of the channels previously used for removal of water from the floodplain which is now sometimes being used for the return of the water into e.g. floodplain forest to improve its function and increase the growth rate.	 1. dyke removal 2. opening of the dyke on multiple locations 3. lowering of the dyke 4. reallocation of the dyke 5. reconstruction of the existing channels 6. oxbow restoration 7. side-branch reconnection 8. re-meandering 9. wetland restoration 10. reforestation 11. wetland vegetation restoration 12. land-use change
	WATER SECURITY CHALLENGE PRIMARILY ADDRESSED: This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and improves water quality as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion** %age
1. Societal challenges	8	9	0.89	89%
2. Design at scale	9	9	1.00	100%
3. Biodiversity net-gain	10	12	0.83	83%
4. Economic feasibility	11	12	0.92	92%
5. Inclusive governance	8	15	0.53	53%
6. Balance trade-offs	7	9	0.78	78%
7. Adaptive management	4	9	0.44	44%
8. Sustainability and mainstreaming	5	9	0.56	56%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**74%**

MAIN ASPECTS OF THE MEASURE

Floodplain restoration is a challenging process that aims to enhance the benefits of the floodplain ecosystems within riverine landscapes. Large-scale floodplain restoration is highly complex and costly. It can take many decades until a floodplain is restored and again provides ecosystem services that were provided before the grey engineering practices began.

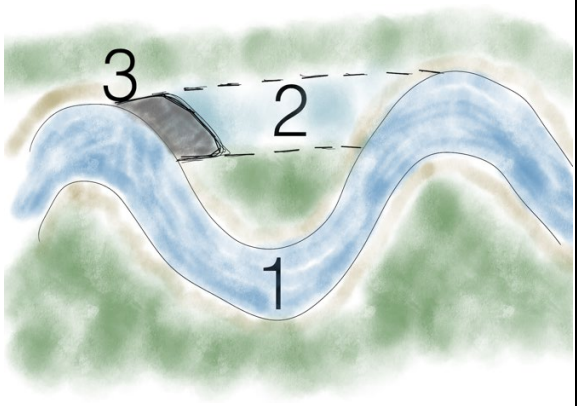
To achieve large-scale floodplain restoration many restoration projects should be implemented with each bringing positive outcomes (e.g. mitigating high water waves or increasing groundwater levels). That strategic approach to restoration is still possible in CEE and many SEE countries, including Croatia, however for the western European countries it is often highly difficult to implement since in many there is a loss of visible meanders in the landscape which were dried for the agricultural use or building of settlements or cities. Due to that and immensely high costs, in those countries, it is practically impossible to fully reconnect the river with its former floodplain.

Land use and ownership challenges further complicate floodplain restoration. The situation of land ownership in Croatia is very complex and quite often there are many landowners owning the same hectare of the land. Successful initiatives involve collaboration among various stakeholders, including governmental agencies, private landowners, and environmental organizations.

Effective communication, negotiation, and incentives that align both ecological and economic goals are crucial. Since this is a set of measures, the ones most relevant will be explained into more details in the text below.

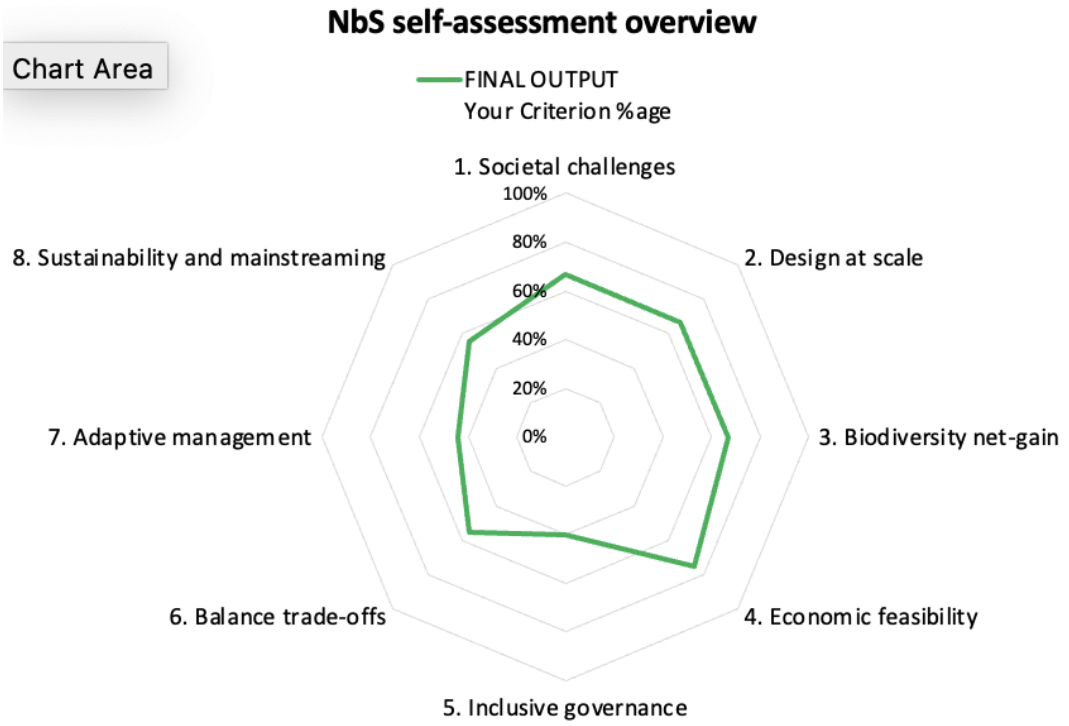
COSTS ASSUMPTION	Average of 260.000 €/ha (however it depends on the complexity and can be higher)
EXAMPLE AND SHORT DESCRIPTION	**PHOTO**
Danube4All (01/2023-12/2027, EU funded, Horizon Europe) The main outcome of the DANUBE4all project is the development of a strategic Danube Basin Restoration Action Plan (DBRAP). This plan will be scientifically based, practically orientated, and will be the result of a unique scientific, social, and economic based collaboration that aims to integrate the following objectives: • Ecological status and biodiversity improvement and ecosystem connectivity • Flood and drought risk reduction • Enhancement of sediment continuity • Economic interests • Inhabitants' interests and Citizen Science DANUBE4all seeks to integrate action on these environmental concerns with social and economic wellbeing; embracing a science-to-people approach that actively integrates public interests and empowers all Danube stakeholders. Source: https://www.danube4allproject.eu	Map which showcases pilot sites (Source: https://www.danube4allproject.eu/) 

2. NbS measure – Re-meandering

NbS MEASURE	RE-MEANDERING
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
Meanders are formed in the middle or lower part of the lowland rivers because of erosion and deposition processes, with the river eroding the outer bank of a bend and depositing sediment on the inner bank. Meanders showcase natural river dynamics in comparison to river channels created by cutting off meanders and shortening the river's course. Within the scope of the measure, the meandering river is again connected, while the previously regulated part of the river is cut off from the restored and reconnected main river course. With this measure, the river length and dynamics are again increased which positively impacts local hydrological conditions while creating a bigger water-retention capacity. It enables more sediment intake and is one of the floodplain restoration measures as well. Due to the slowing down of the river flow and the creation of new habitats, biodiversity also benefits from the implementation of this measure.	 1. *a former meandering river which is being restored* 2. *regulated river* 3. *barrier to stop the flow of regulated/channelized river* **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and improves water quality as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW

Criterion	Your Criterion Score	Maximum Criterion Score	Normalised criterion	FINAL OUTPUT Your Criterion %-age
1. Societal challenges	6	9	0.67	67%
2. Design at scale	6	9	0.67	67%
3. Biodiversity net-gain	8	12	0.67	67%
4. Economic feasibility	9	12	0.75	75%
5. Inclusive governance	6	15	0.40	40%
6. Balance trade-offs	5	9	0.56	56%
7. Adaptive management	4	9	0.44	44%
8. Sustainability and mainstreaming	5	9	0.56	56%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**59%**

MAIN ASPECTS OF THE MEASURE

Re-meandering again reconnects the cut-off meanders with the main river course while stopping the water flow through the previously main river channel. This approach reduces flood risks by extending the river length which increases water retention capacity, slowing down the water flow, and minimizing downstream peak flows. It also lowers the longitudinal fall and mitigates the erosion of the bottom of the river, while at the same time enabling sediment deposition on side banks.

The implementation of re-meandering mitigates flooding at the restoration site location, but also in downstream sections of the watercourse.

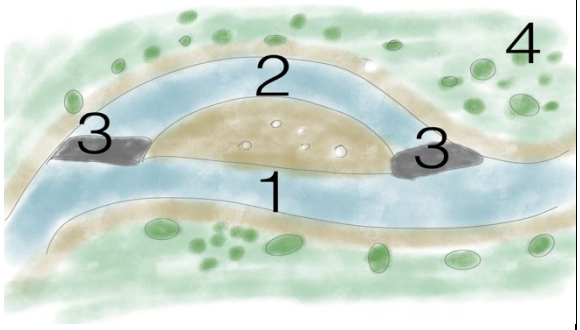
Old meanders are still visible in river floodplains of Croatia which enables the implementation of the floodplain restoration with many possible site-specific measures. Reconnecting these old meanders is often a more straightforward, and cost-effective approach compared to designing an entirely new channel. When old meanders are not visible, historical maps, photos, digital elevation models, and land boundaries can be used to determine the historic river location. However, that is a rather expensive restoration effort.

Meandering channels can be either actively meandering, exhibiting natural processes like erosion and deposition, **or passively meandering,** showing the form but not the active processes. While actively meandering channels work with natural processes, passively meandering channels may be chosen in cases where there's a lack of energy or urban constraints. In such situations, a passively meandering channel might be the most viable option.

COSTS ASSUMPTION	>500.000 euro per one re-meandering project

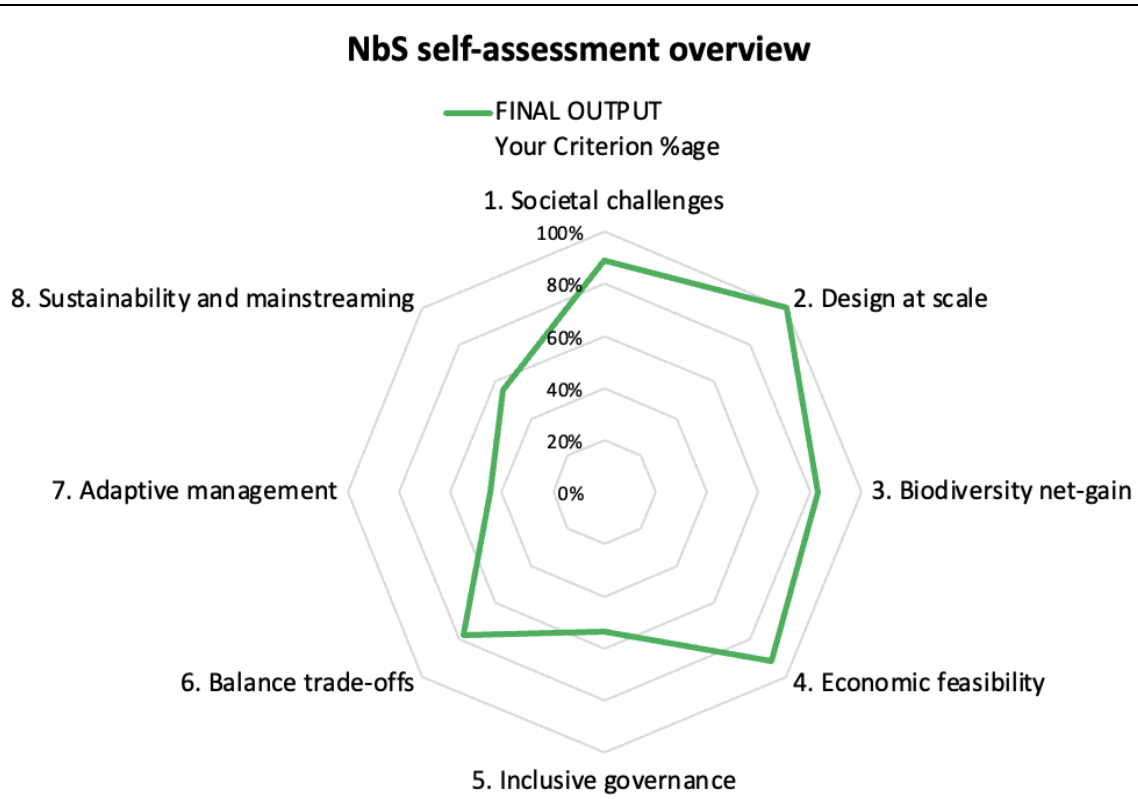
EXAMPLE AND SHORT DESCRIPTION	PHOTO
There is no Croatian example, therefore an example of the River Spree from Germany is showcased. The 380 km long River Spree flows into the rivers Havel and later Elbe. The lower Spree was heavily modified to facilitate flood protection, water mills, agricultural land use, and inland navigation. Cross-sections were widened and deepened, banks stabilized, and meanders cut off. Therefore, the river lost its natural flow regime. In the 1990s, the lower River Spree was characterized by eutrophic conditions (0.7-3.4 mg/L total nitrogen and 70-180 g/L total phosphorous), uniform channel form, almost lacking flow dynamics and the corresponding biota, phytoplankton, lipophilic and eurytopic invertebrates, and fish. Therefore, the water authorities in cooperation with numerous scientists developed a comprehensive management concept to improve the quality of a 35 km long river section, the so-called Müggelspree. The concept comprised reductions in nutrient loading, re-meandering, raising the riverbed, and removal of bank protections. Source: https://reformrivers.eu/news/245.html	Re-meandering – the former backwater has been reconnected at both sides and the former main channel blocked by a dam near the left, upstream opening (Source: Isabell Hiekel) 

3. NbS measure – Side-branch and oxbow reconnection

NbS MEASURE	SIDE-BRANCH AND OXBOW RECONNECTION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
This measure of reconnecting the old side branch is very similar to a previously mentioned measure of re-meandering. A side branch is a parallel watercourse that flows aside from the main river channel with a lower water capacity. For a meandering and dynamic lowland river, naturally, with time the side branches get accumulated with sediments, and when they completely lose the connection with the main river channel they form an oxbow, a former river meander no longer connected to a main river course during low and medium water levels. During floods they might get flooded, it depends on the water levels and if an oxbow is still a part of the floodplain or behind the dyke. In the scope of this measure, the side branch gets reconnected by removing the accumulated sediments or removing a barrier that previously stopped the water from flowing into the side branch. With this measure, the retention capacity increases which positively impacts local hydrological conditions as one of the possible measures within the floodplain restoration measures. The measure creates new habitats for gravel-breeder/steep-bank breeder birds and for fish spawning since the water flow is slower than in the main river course which provides more shelter for fish to spawn.	 1. main river 2. side-branch to be reconnected 3. barriers 4. vegetation **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and increases water quality as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW

Criterion	Your Criterion Score	Maximum Criterion Score	Normalised criterion	FINAL OUTPUT Your Criterion %age
1. Societal challenges	4	9	0.44	44%
2. Design at scale	8	9	0.89	89%
3. Biodiversity net-gain	8	12	0.67	67%
4. Economic feasibility	8	12	0.67	67%
5. Inclusive governance	6	15	0.40	40%
6. Balance trade-offs	5	9	0.56	56%
7. Adaptive management	4	9	0.44	44%
8. Sustainability and mainstreaming	5	9	0.56	56%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**58%**

MAIN ASPECTS OF THE MEASURE

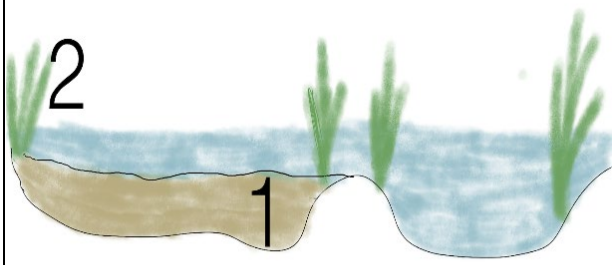
Natural hydro-morphological processes on terrains with gentle slopes and less resistant substrates lead to the meandering of riverbeds and the formation of secondary channels, known as backwaters, which flow back into the main riverbed downstream. **Meandering naturally occurs in lowland riverine landscapes**, and its changes unfold over several decades. The formation of a new channel can alter the erosion regime of the watercourse, leading to sediment deposition and the creation of sills that obstruct the entrance and exit of the meander. In such cases, a new oxbow may develop, dependent on water inflow from the main river course during high water levels or recharge from groundwater.

In the scope of this measure, **it is proposed to reconnect the river meander with the main river course in order to increase the water retention capacity** during higher water waves and mitigate floods, as well as mitigating droughts due to higher water level and more humidity in the summer period. Within the scope of this measure additional habitats are formed which benefits biodiversity as well.

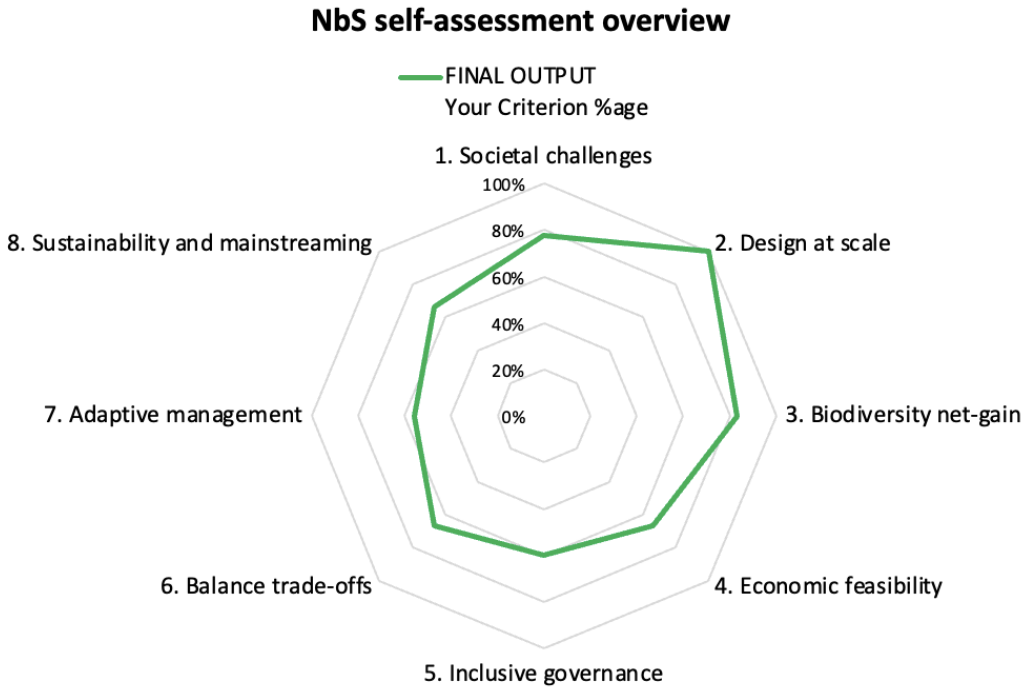
COSTS ASSUMPTION	>400.000 euro per one project site

EXAMPLE AND SHORT DESCRIPTION	PHOTO
DRAVA LIFE Integrated River Management (December 2015 – November 2024, EU funded-LIFE) The project area covers a length of 310 km, and includes 4 Natura 2000 sites in an area of 67.800 hectares. Within the project, key natural features of the riverine ecosystem will be restored through an intersectoral cooperation between Hrvatske vode, public institutions for nature protection and NGOs, who will showcase this innovative approach of river management. Planned six restoration actions encompass the opening and creation of new side-arms, the removal and modification of embankments and groynes, as well as the preservation of retention areas and natural steep river banks. This will benefit numerous types of endangered habitats and species within Natura 2000 sites and mitigate floods. The project will have a positive effect on groundwater supplies, as the restoration actions will improve the river water infiltration into the groundwater. Furthermore, the project increases the recreational value of the area for local people (e.g. fishing, swimming and relaxation). During the implementation, partners built up an educational centre, the Water School and educational paths along the Drava River. Moreover, several exhibitions and extensive awareness raising activities have been organized in cooperation with local citizens and schools. Source: https://www.drava-life.hr/en/home/	The first side branch reconnection in the vicinity of Legrad Municipality (Source: Branka Španiček)  

4. NbS measure – Wetland & peatland restoration

NbS MEASURE	WETLAND & PREATLAND RESTORATION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
The wetland and peatland restoration are also measures that can be implemented in the scope of the floodplain restoration. Wetlands are extremely complex ecosystems, as well as the habitats richest in biodiversity which provide carbon sequestration, water retention capacity, water purification, and multiple ecosystem services. Peatlands are a specific type of wetlands which due to organic matter decay form peat and they are very effective in carbon sequestration. Therefore, the rewetting of peatlands is one of the most effective climate change mitigation measures. Due to the complexity of wetlands, which often form a mosaic of habitats if they are in their natural state, it is needed to observe each potential case separately with the involvement of multiple sectors and local communities to implement the restoration measure.	 1. *accumulated sediment to be removed* 2. *wetland vegetation* **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** This measure creates bigger water-retention capacity therefore primarily floods and due to water purification. It locally mitigates the impact of droughts since it supports water inflow into aquifers and increases air humidity.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	7	9	0.78	78%
2. Design at scale	9	9	1.00	100%
3. Biodiversity net-gain	10	12	0.83	83%
4. Economic feasibility	8	12	0.67	67%
5. Inclusive governance	9	15	0.60	60%
6. Balance trade-offs	6	9	0.67	67%
7. Adaptive management	5	9	0.56	56%
8. Sustainability and mainstreaming	6	9	0.67	67%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**72%**

MAIN ASPECTS OF THE MEASURE

The **Ramsar Convention defines wetlands** as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Article 1.1). **Both wetlands and** percentage **peatlands** cover a small of the Earth's surface, however **are considered one of the most important** due to the variety of ecosystem services they provide (water purification, flood retention capacity, food, raw materials, recreational and spiritual services) and are the richest in biodiversity of all types of ecosystems. 40% of all species can be found in wetlands.

Restoration of peatlands includes rewetting and revegetation, however, the peatland systems are still being extensively researched since there are still unknowns about the restoration of those ecosystems.

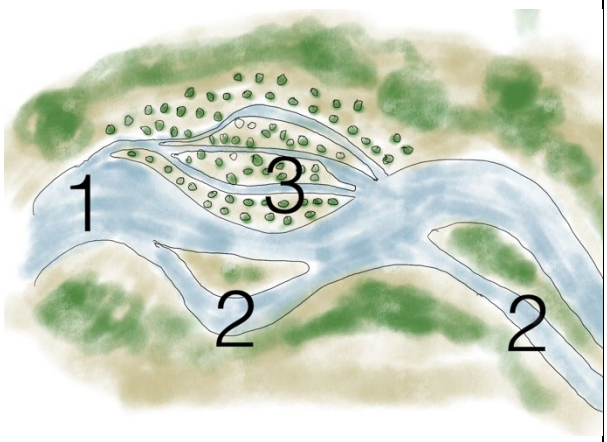
In regards to wetlands more is known from a scientific perspective. Each case of wetland or peatland restoration is unique. There is no universal strategy to restore wetlands or drained peatlands, as ecological and social conditions differ widely.

Restoring lost or degraded wetlands presents a valuable and cost-effective opportunity for society to recover and enhance benefits for human health and well-being. The value of benefits from a restored wetland is often several times higher than the cost of restoration. Maintaining and restoring wetlands also leads to cost savings when compared to manmade infrastructure solutions, in many cases. Restoration interventions are bringing back lost ecosystem services, increasing the spatial extent of wetlands, and increasing the heterogeneity of wetland functions and biodiversity.

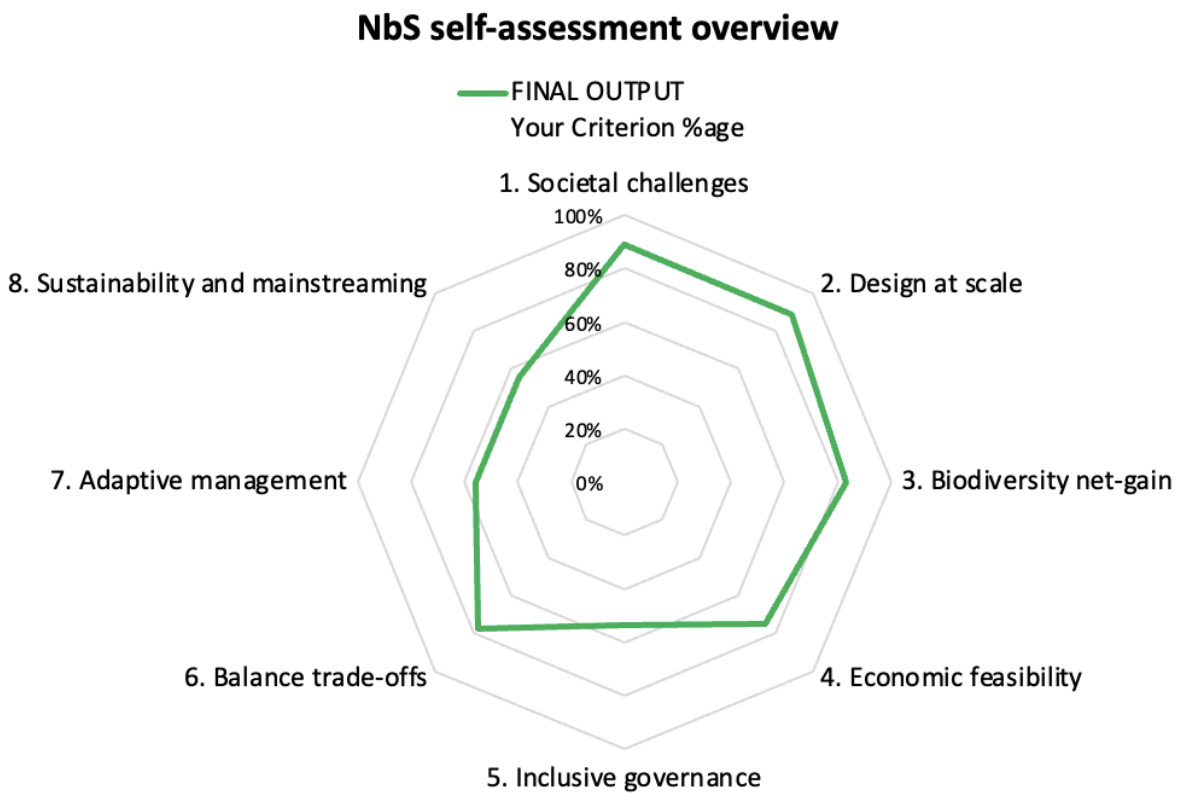
The restoration of a former wetland currently used for agriculture is not advised due to severe degradation, very high costs, and a duration of potentially a century which is needed for the wetland to return its state to one similar to before.

COSTS ASSUMPTION	Might be very high - for the whole wetland to be restored it is assumed that more than **50 mil euro** is needed, for e.g. Kopački Rit Nature Park restoration (2-nd largest Danube wetland). However also lower in case of establishment of traditional pasture like explained below (app. **100.000 euro**).
EXAMPLE AND SHORT DESCRIPTION	**PHOTO**
Restoration of feeding habitat near the Čigoč village (May-October 2017, funded by EURONATUR) This is a small but impactful measure of wetland restoration, which was implemented in the Kratecko Pasture within Lonjsko Polje Nature Park. The pasture is used as the feeding ground during floods. The project was implemented together with local stakeholders from the design stage. On this integrated level it was agreed to mulch the severely overgrown areas of the pasture. 30 ha out of 50 ha size pasture was mulched. The main activity – mulching of overgrown pasture has been conducted during the end of summer period. New electric fence around the traditional pasture was installed and the area is being used by the local farmers and the Nature Park. Source: Lonjsko Polje NP	Lonjsko Polje Nature Park (Source: Lonjsko Polje NP) 

5. NbS measure – Floodplain forest restoration

NbS MEASURE	FLOODPLAIN FOREST RESTORATION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
The floodplain forest restoration is a part of floodplain restoration in general. A third of Croatia is covered by forests where the alluvial forests are amongst the most threatened forest types and require a comprehensive and holistic restoration approach. Due to river incision, the floodplain forests are losing their connection to the main river course, therefore multiple actions need to be implemented to restore the forest and enable flooding again. The forest growth rate is mitigated due to the loss of lateral floodplain connectivity. It can be resolved with the opening of the side-branches within the forest so that the water can flow back into the forest on a more frequent basis since the tree species composition also requires regular flooding and it impacts the economic construction if the forest is being used for economic purposes.	 1. main river 2. river side-branch 3. opening of channels and/or side branches in the floodplain forest **WATER SECURITY CHALNGE PRIMARILY ADDRESSED:** This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and improves water quality as well due to water purification.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	8	9	0,89	89%
2. Design at scale	8	9	0,89	89%
3. Biodiversity net-gain	10	12	0,83	83%
4. Economic feasibility	9	12	0,75	75%
5. Inclusive governance	8	15	0,53	53%
6. Balance trade-offs	7	9	0,78	78%
7. Adaptive management	5	9	0,56	56%
8.Sustainability and mainstreaming	5	9	0,56	56%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**72%**

MAIN ASPECTS OF THE MEASURE

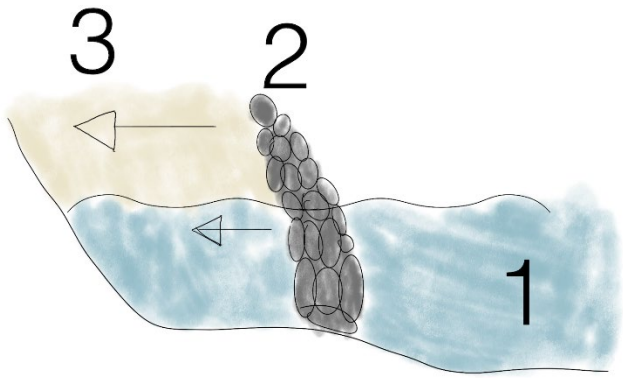
Restoring floodplain forests provides multiple benefits. **Floodplain forests mitigate flood risks** since they absorb the water during higher water waves as well as store it for a longer period during the dry periods of the year. They contribute to enhanced water quality by filtering pollutants and sediments.

Biodiversity thrives in restored floodplain forests, offering habitats for various plant and animal species. This biodiversity supports ecosystem resilience and contributes to overall environmental health in the changing climate. Additionally, these restored areas create recreational spaces, fostering community well-being and offering recreational opportunities. Moreover, **these restored ecosystems play a crucial role in climate change mitigation by sequestering carbon** and promoting sustainable land use practices. The floodplain forest can be restored in multiple ways, from changing the species composition to mimic the native forest, and to restore the hydrologic conditions. By restoring the lateral connectivity between the floodplain forest and the river, we are improving the ecosystem services the forest is providing us with. Many forests are used for economic purposes, therefore with opening of the side-branches or artificial channels we are letting the water back into the forest which supports its growth rate. In summary, the **benefits of restoring floodplain forests extend beyond flood control, encompassing ecological conservation, community well-being, and sustainable economic development.**

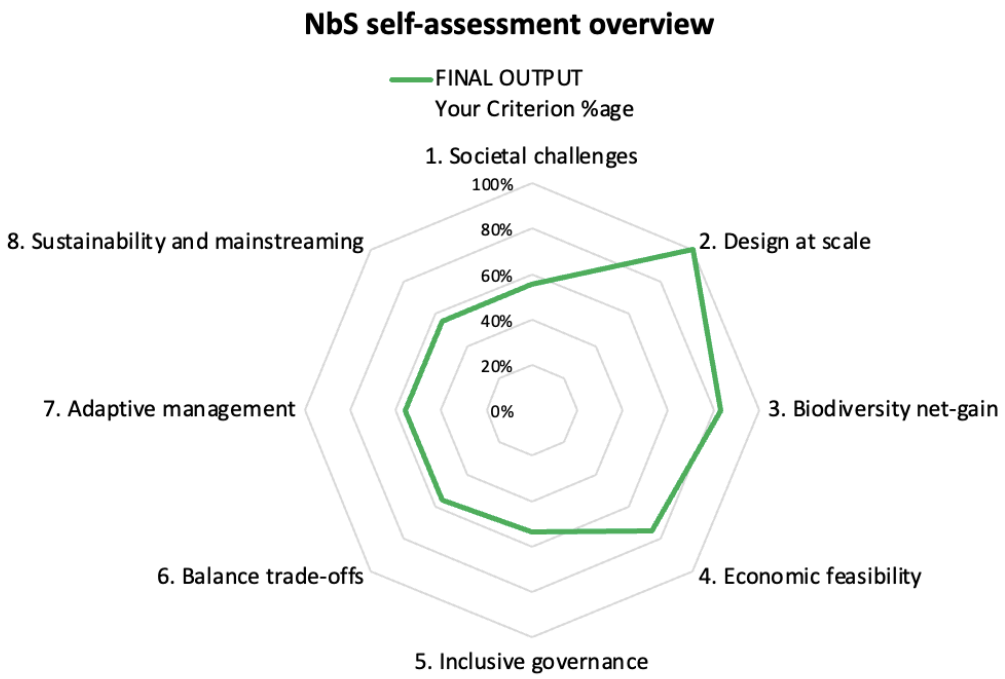
COSTS ASSUMPTION	Per one project site > 300.000 euro

EXAMPLE AND SHORT DESCRIPTION	PHOTO
LIFE RESTORE for MDD project (October 2023-September 2027, EU funded-LIFE) Preserving and restoring floodplain forest habitats along the Mura-Drava-Danube rivers focuses on the conservation and restoration of the largest contiguous floodplain forest habitat system in the Danube River Basin for improving its conservation status. During the project period the causes of degradation of the floodplain forests and the lack of connectivity between the individual habitats along the three transboundary river courses will be tackled in a coordinated and integrated conservation effort by 17 partners of the five involved countries Austria, Croatia, Hungary, Slovenia and Serbia. The focus of the planned measures is on the priority HT 91E0* Alluvial forests and HT 91F0 Riparian mixed forests of the Mura, Drava and Danube floodplains and their connectivity with the natural river dynamics, on which they depend. The project area with a total size of 2071,6 km2 is connecting 17 Natura 2000 Sites and one major Special Nature Reserve in Serbia (future Natura 2000 site). Source: LIFE RESTORE for MDD project proposal	Five-country UNESCO Biosphere Reserve Mura-Drava-Danube (Source: Ivana Korn Varga) 

6. NbS measure – Riverbank restoration

NbS MEASURE	RIVERBANK RESTORATION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
This is one of the measures that can be implemented in the scope of the strategic floodplain restoration approach. With the removal of the embankment, the side-erosion processes are again enabled allowing the water to erode the river bank while increasing the river dynamics and creating new habitats for steep-bank breeders (e.g. sand martin) as well as the gravel bar-breeders (e.g. little tern). This measure enables more additional intake of the sediments into the main river course. Due to the incision of the river courses, it is of the highest importance to bring back the sediments to improve the sediment balance. With the measure, we are returning the sediment to the river, which mitigates the river-bed incision and positively impacts the lateral connectivity.	 1. main river 2. stone embankments to be removed and allow lateral erosion 3. after removal of the stone embankment the river bank will erode **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** This measure creates bigger water-retention capacity therefore primarily floods however droughts as well due to groundwater recharge.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	5	9	0,56	56%
2. Design at scale	9	9	1,00	100%
3. Biodiversity net-gain	10	12	0,83	83%
4. Economic feasibility	9	12	0,75	75%
5. Inclusive governance	8	15	0,53	53%
6. Balance trade-offs	5	9	0,56	56%
7. Adaptive management	5	9	0,56	56%
8. Sustainability and mainstreaming	5	9	0,56	56%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**67%**

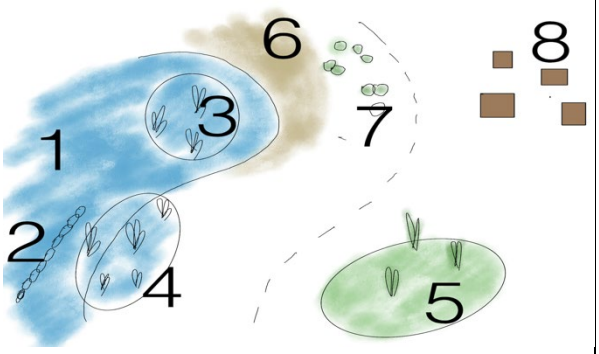
MAIN ASPECTS OF THE MEASURE

As mentioned more times already, floodplain restoration is extremely complex, and this is only one of the measures that can be implemented while approaching floodplain restoration strategically. To implement this measure, **it is important to have an agreement with the landowners of the land** which will be eroded as time passes. This measure can be joined with the dyke reallocation to enable more space for the river to meander freely. However, that additionally raises complexity and costs since the land in that case would need to be acquired from many different landowners. Due to complexity, the relocation of the dyke can take more than a decade. One important factor regarding this measure is that **it increases the sediment load back into the river**. Since the riverbed incision is increasing with time if there are no projects which are returning the sediment load to the riverbed again this is an important measure and is advised to be implemented while following all the needed procedures and legislation as well as aspect of community involvement. It is expected that there are benefits of explaining the project to the local people and involving them since also land will need to be acquired to implement the measure and it is beneficial to have their agreement as soon as the planning/designing of the project starts.

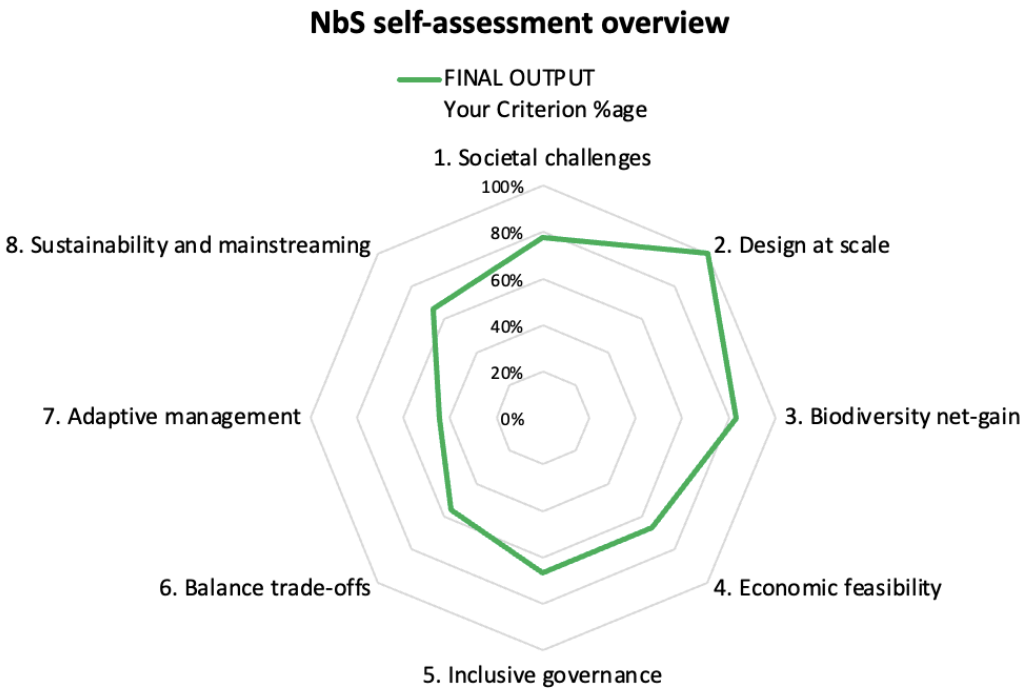
COSTS ASSUMPTION	It depends on the cost and maybe the land will need to be bought, but the cost of this measure if there is no reallocation of the dyke or buying of the land can be implemented for app. 100.000 euro per km of the river.

EXAMPLE AND SHORT DESCRIPTION	PHOTO
DRAVA LIFE Integrated River Management (December 2015 – November 2024, EU funded-LIFE) In the scope of the DRAVA LIFE project the conservation activity is being implemented due to the biggest nesting colony of sand martins, close to Đelekovec Municipality at the site called Libanovec. There was no removal of embankment, but big engagement of the project partners was needed to safeguard the steep-bank and to leave this part of the river to natural processes. The agreement with the local Municipality is under process since the land close to the river bank is being used for agricultural purposes. This is a joint conservation endeavour of the project and the Municipality to protect the biggest sand martin colony on Drava River.	Setting up of the info bord near Libanovec to inform about the steep bank and the sand martin colony (Source: Branka Španiček) 

7. NbS measure – Coastal wetlands restoration

NbS MEASURE	COASTAL WETLAND RESTORATION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
Coastal wetlands (tidal marshes, or salt marshes) are brackish and saltwater wetlands located in coastal areas. According to the Ramsar Convention, they include also areas of sea depth that do not exceed six meters. Shallow water ecosystems permanently or periodically inundated and intertidal habitats are also included. The restoration of coastal wetlands and see-meadows is extremely complex. Under this measure, we include coastal wetlands restoration, sea-meadows replanting/reallocating, and planting of native forests along the coast to protect human settlements from the high sea waves.	 1. coastal sea 2. stone embankment 3. sea-meadow replantation 4. sea-marsh 5. brackish wetland 6. beach 7. planted coastal vegetation 8. human settlements **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and improves water quality as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	7	9	0,78	78%
2. Design at scale	9	9	1,00	100%
3. Biodiversity net-gain	10	12	0,83	83%
4. Economic feasibility	8	12	0,67	67%
5. Inclusive governance	10	15	0,67	67%
6. Balance trade-offs	5	9	0,56	56%
7. Adaptive management	4	9	0,44	44%
8. Sustainability and mainstreaming	6	9	0,67	67%



Is this in adherance with the IUCN Global Standard for NbS?	Total percentage mach
Adequate	**70%**

MAIN ASPECTS OF THE MEASURE

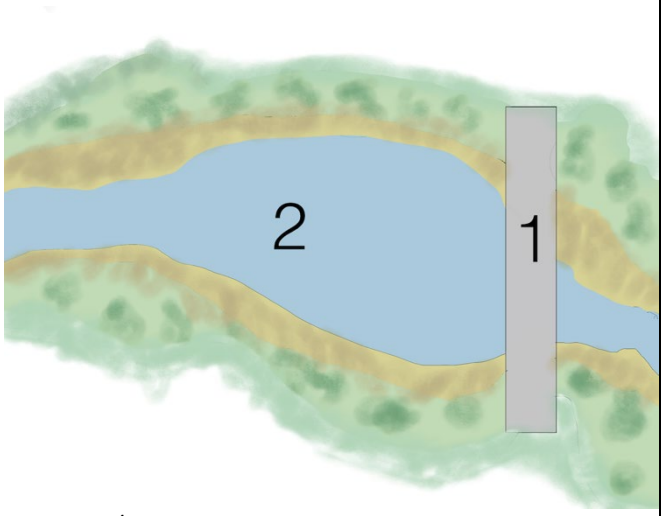
Coastal wetlands are very complex ecosystems, and the implementation of restoration measures is still in its initial stages in Croatia.

Ways to restore coastal wetlands include **restoration of geo-morphological structures by adding sediment to raise the land above the mean water level** and allow wetland plants to colonize, maintaining and rewetting coastal wetlands that had been drained in the past. Those measures aim at setting back the line of hard flood defenses to a new line, further inland and/or on rising ground to recreate intertidal habitats between the old and the new defense. The wetland will serve as a buffer zone where storm surges will be attenuated. Also, **small-scale measures aimed to reduce human pressures on wetlands and enhance habitat and landscape quality**. They can include clearing trees, changes in land use and in agricultural practices that enhance habitat and landscape quality.

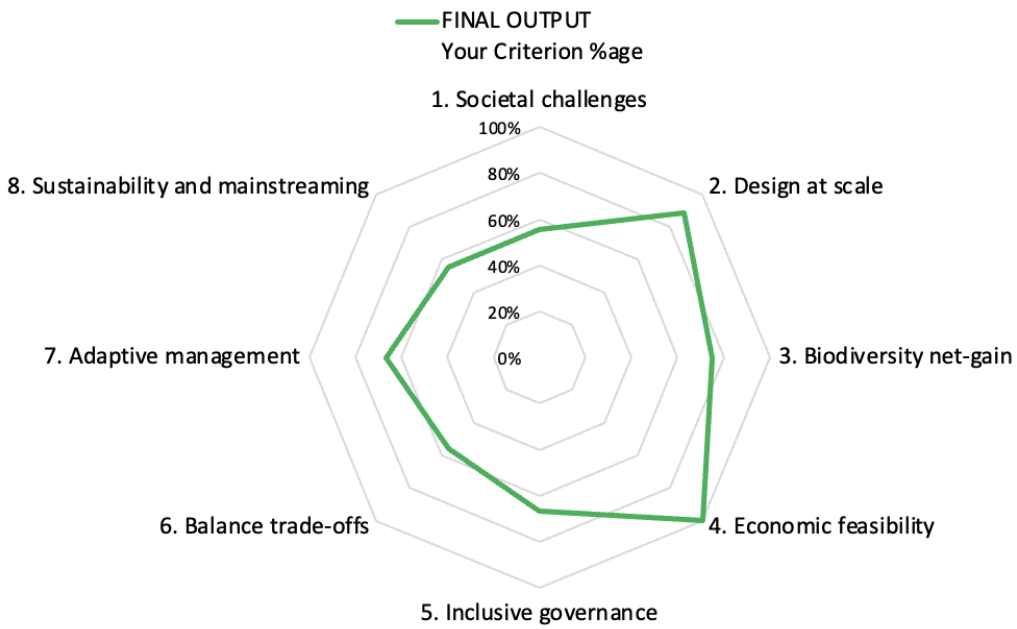
COSTS ASSUMPTION	It depends on the size of land, which is being restored, as well as on the activity and local circumstances. It can be from 50.000 euro to 20 million euro.

EXAMPLE AND SHORT DESCRIPTION	PHOTO
Hedwige-Prosper polder project in the Scheldt Estuary (Belgium/Netherlands) The Hedwige-Prosper polders project is part of the integrated plan of reinforcing dikes and quay walls and opening flood areas to protect land along the Scheldt Estuary and the upstream basin against floods. Depolderisation refers to returning reclaimed or drained land (a "polder" in Dutch) to the sea. Managed realignment can involve deliberate breaching or complete removal of a coastal defence such as a dike, or the relocation of defences further inland. For example, in the Hedwige-Prosper polder project in the Scheldt Estuary (Belgium and Netherlands), outer dikes are being removed to turn reclaimed land into wetlands, while inland dikes are being strengthened. Source: https://climate-adapt.eea.europa.eu	Source: Sigmaplan - Flanders regional government 

8. NbS measure – Dam/barrier removal

NbS MEASURE	DAM/BARRIER REMOVAL
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
Due to human development, the European rivers have been fragmented throughout the past. Negative impacts of this type of management have been realized and in the last decades, many river restoration activities were implemented on the European level. In Croatia, the restoration efforts started a decade ago. Importance of rivers, their biodiversity and ecosystem services are becoming more and more understood therefore many restoration efforts are now being implemented, Europe and world-wide. Dam removal being one of them, and really being kick-offed by many different organisations. The term dam is used to refer to any man-made barrier that has been constructed across a river to alter its flow and thus affect the transport of sediments or migration of species. Those could be dams, sluices, weirs, culverts, and fords.	 1. the dam/barrier planned to be removed 2. accumulated water **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** This measure aims to enable a free flow in a part of the river therefore locally and downstream it mitigates the impact of floods, droughts, and supports water quality as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	5	9	0,56	56%
2. Design at scale	8	9	0,89	89%
3. Biodiversity net-gain	9	12	0,75	75%
4. Economic feasibility	12	12	1,00	100%
5. Inclusive governance	10	15	0,67	67%
6. Balance trade-offs	5	9	0,56	56%
7. Adaptive management	6	9	0,67	67%
8. Sustainability and mainstreaming	5	9	0,56	56%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**70%**

MAIN ASPECTS OF THE MEASURE

Dam removal quite often refers to small dams, sluices, or any type of man-made barrier that impacts rivers' longitudinal connectivity. However, large dams can also be removed, especially if they are no longer serving the purposes for which they have previously been used, like electricity production or irrigation.

Many dams in operation still provide benefits to society. More on policy is explained within Chapter 4, however, it is important to state that **the WFD requires continuity for all EU river water bodies to support the achievement of good ecological status** – removal or adaptation of barriers is part of the measures necessary to fulfill the legal obligations under the WFD, the Habitats Directive, and the Biodiversity Strategy – primarily removal of obsolete barriers.

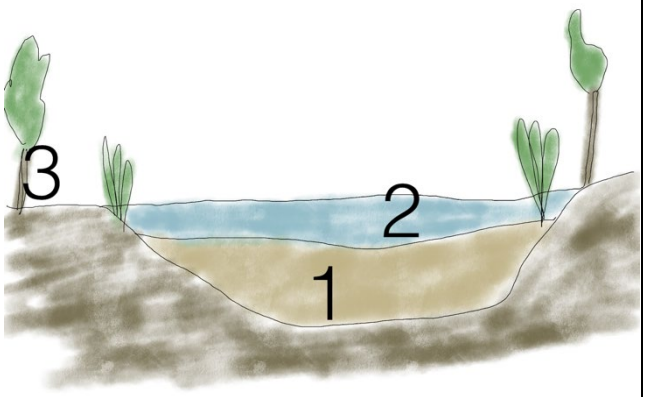
Nevertheless, **demand for hydropower increases, as well as water abstraction, due to climate change** and longer drought periods. It is important to observe the river system holistically while thinking of different climate change scenarios. Dam removal as a measure can be rather simple and it lasts less than many restoration measures that can be implemented.

Necessary permits need to be prepared and studies conducted to implement the dam removal. All this preparation process lasts approximately a year and the removal itself can be implemented quickly but an additional year is regularly planned for the direct implementation.

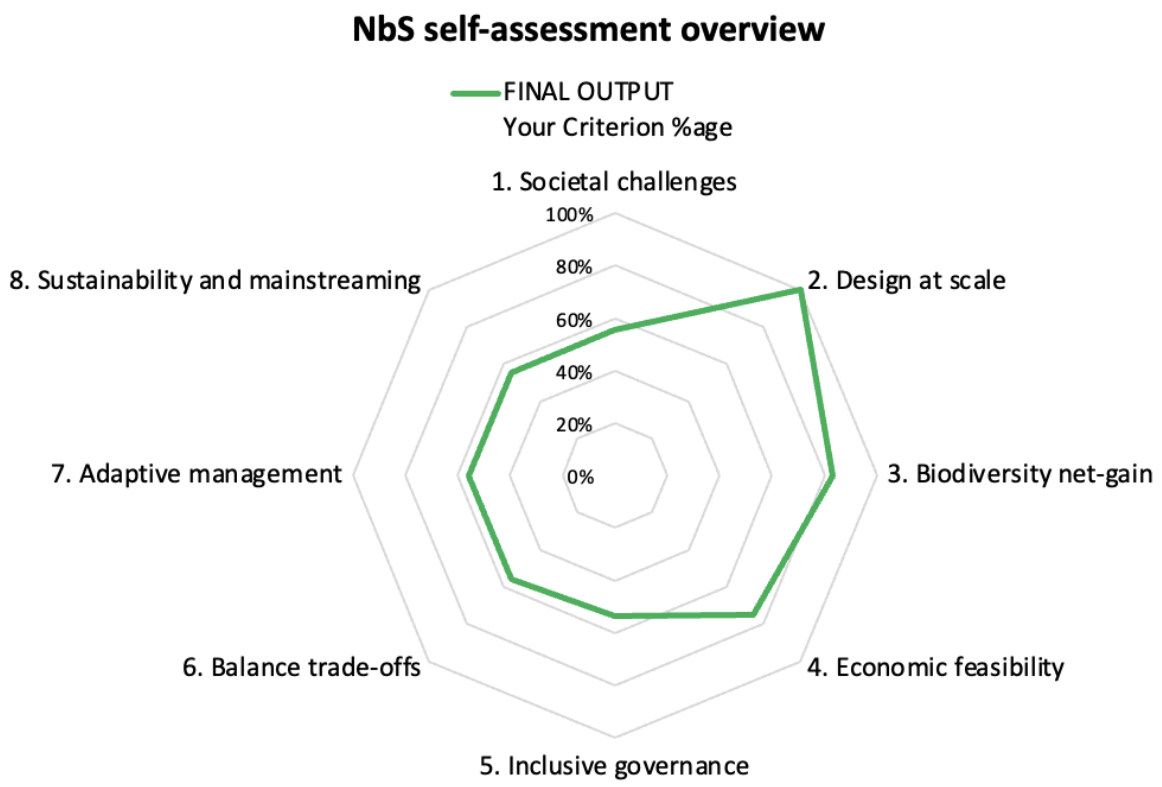
COSTS ASSUMPTION	App. 30.000 euro for one barrier removal

EXAMPLE AND SHORT DESCRIPTION	PHOTO
Dam Removal in Plitvice Lake National Park (Funded by Open Rivers Programme) **In Croatia by now we have only one dam removal project implemented.** During the project implementation the goal was to prepare all the permits, and all needed preparatory documentation while assessing eight barriers along the Bijela River to be removed. During the project it was clarified that from these eight barriers, all eight barriers will be removed, however on locations of four barriers additional small restoration works will need to be included. Those locations include the old mills and remains of older infrastructure that is of cultural value and part of the landscape. To retain the cultural value, restoration approach in the sense of redirecting the river back into its old natural riverbed and removal of smaller barriers will be applied in those locations.	Bijela River barrier (Source: Branka Španiček) 

9. NbS measure – Lake restoration

NbS MEASURE	LAKE RESTORATION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
One of the functions of lakes is that it serves as a water retention. Alongside that natural and even man-made lakes offer many ecosystem services like flood control, water purification, fish, and serve for recreational purposes. Additionally, lakes play a crucial role while serving the purpose of carbon sinks and providing essential habitats for a diverse range of plant and animal species. Unfortunately, historical practices have seen lakes drained for agricultural purposes or left unmaintained, resulting in silt accumulation. The process of restoring lakes involves improving their structure and functionality, especially in areas where they were previously drained. This restoration aims to restore the ecological balance of the lake, ensuring it continues to fulfil its ecosystem services, from flood control to supporting biodiversity and serving as a valuable resource for human activities.	 1. accumulated sediments 2. lake water 3. vegetation **WATER SECURITY CHALLENGE PRIMARILY ADDRESSED:** *This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and water quality as well.*

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	4	9	0,44	44%
2. Design at scale	3	9	0,33	33%
3. Biodiversity net-gain	4	12	0,33	33%
4. Economic feasibility	5	12	0,42	42%
5. Inclusive governance	5	15	0,33	33%
6. Balance trade-offs	3	9	0,33	33%
7. Adaptive management	3	9	0,33	33%
8. Sustainability and mainstreaming	3	9	0,33	33%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage mach
Partial	**36%**

MAIN ASPECTS OF THE MEASURE

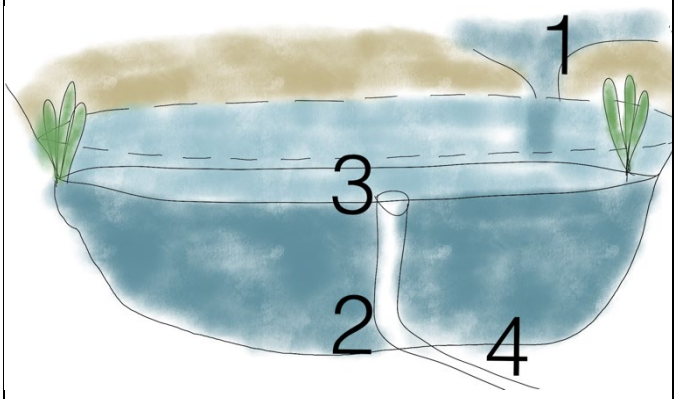
The lake restoration is also one of the very complex restoration activities that can be implemented and should result in an increased water retention capacity as well as offer better water quality which benefits biodiversity as well as local communities who might be using the lake for recreational purposes like fishing or swimming. The lake may or may not be connected to the groundwater. The restoration of lakes aims to improve the ecological health, water quality, and overall status of the freshwater ecosystem.

If agricultural surfaces are near, excessive nutrients, particularly phosphorus and nitrogen, can lead to algal blooms and oxygen depletion. Restoration efforts often involve measures to control nutrient inputs, such as upgrading wastewater treatment facilities, implementing agricultural best practices, or managing stormwater runoff. Sedimentation can degrade water quality as well by reducing light penetration and filling lake beds. The restoration activity is very complex since the main part is the removal of the sediment, silt, or other materials from the bottom of the lake. Sometimes it can be of chemical origin and therefore needs to be taken care with extreme caution not to endanger the biodiversity as well as water quality to a level that could be avoided. Before the removal of sediments, the fish and other species need to be taken out of the lake. The water is pumped out of the lake before the cleaning of the sediments and returned after. As for any of the restoration measures multiple experts should be involved within the implementation of this activity.

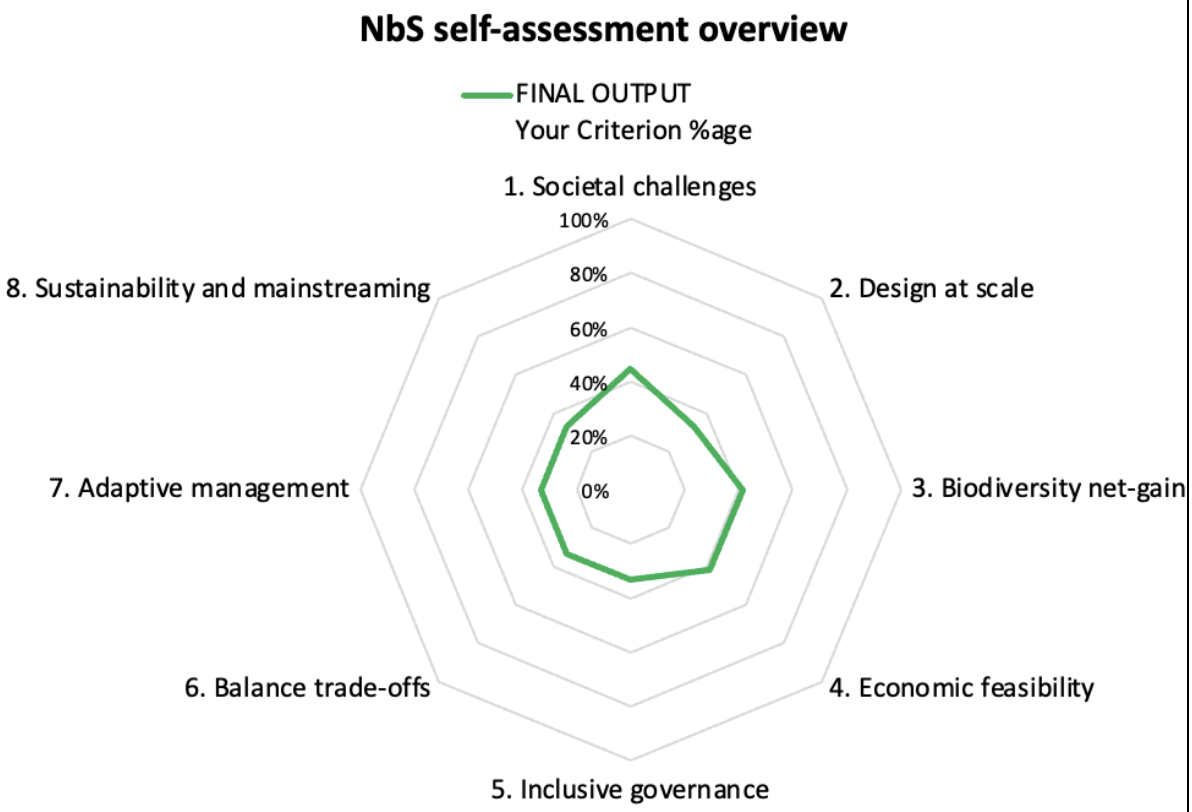
Lake shoreline restoration and planting natural vegetation along the lake shores helps prevent erosion, filter pollutants, and provide habitat for aquatic and terrestrial species.

COSTS ASSUMPTION	2 million euros
EXAMPLE AND SHORT DESCRIPTION	**PHOTO**
The Nagyszéksós-tó project in Hungary (2009) The project aimed to safeguard natural and recreational functions of the Nagyszéksós lake protected area through the improved retention of water from excess water periods of 1.2 million m^3 and the provision of surplus water from the nearby village's water treatment plant giving extra treatment through a newly developed wetland area. The other goals of the project are the improved infiltration to the groundwater and restored drainage capacity of the water system to prevent long lasting water logging periods on agricultural fields.The nearby village, Mórahalom also benefited from the development through improved recreation conditions and cultural, educational possibilities in the area. Source: http://nwrm.eu/case-study/water-supply-and-rehabilitation-nagyszeksos-southern-hungary	The Nagyszéksós lake (Source: https://www.morahalom.hu/hu/galeriak) 

10. NbS measure – Retention ponds

NbS MEASURE	POND WATER RETENTION
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
Retention ponds are used in agricultural or inhabited areas to increase the storage capacity of rainwater in cities or can be used as a small natural water retention in agricultural areas. They are designed to provide storage capacity to attenuate surface runoff during rainfall events. Aside from providing flood control benefits, they provide the service of water purification as well due to the planted plants and mitigate droughts.	 1. overflow 2. permanent storage capacity 3. additional storage capacity for rainwater 4. water disposal
	WATER SECURITY CHALLENGE PRIMARILY ADDRESSED: This measure creates bigger water-retention capacity therefore primarily floods, however, it locally mitigates the impact of droughts and improves water quality as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %age**
1. Societal challenges	4	9	0,44	44%
2. Design at scale	3	9	0,33	33%
3. Biodiversity net-gain	5	12	0,42	42%
4. Economic feasibility	5	12	0,42	42%
5. Inclusive governance	5	15	0,33	33%
6. Balance trade-offs	3	9	0,33	33%
7. Adaptive management	3	9	0,33	33%
8. Sustainability and mainstreaming	3	9	0,33	33%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Partial	**37%**

MAIN ASPECTS OF THE MEASURE

Retention ponds (e.g. flood storage reservoirs, shallow impoundments) are water bodies, store water to attenuate surface runoff during rainfall events. They provide storage as well as improving water quality. Retention ponds may also be used for irrigation of farmland and they can mitigate droughts during dry periods.

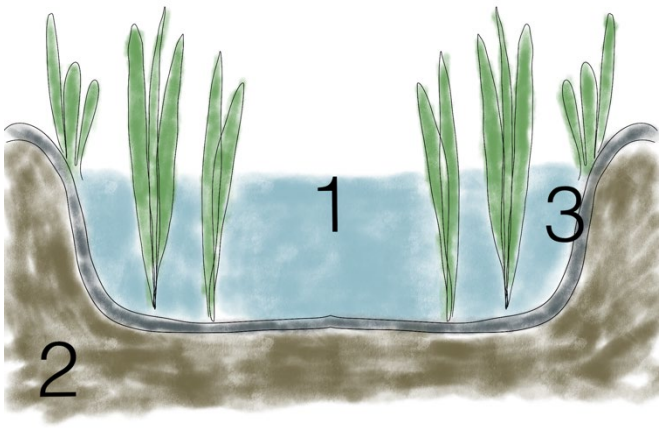
They are created either by using an existing natural depression, by excavating a new depression, or by constructing embankments. Existing natural water bodies should not be used, however, due to the risk that pollution events and poorer water quality might disturb/damage the natural ecology of the system. They facilitate pollutant removal through sedimentation, while aquatic vegetation and biological uptake mechanisms provide additional treatment. As a result, they have a significant role in removing urban/agricultural pollutants and enhancing the quality of surface runoff.

They can be built as **small ponds** (up to 2000 m^3, up to 4 m deep) and larger, more complex reservoirs (greater than 2000 m^3). Retention ponds achieve both stormwater attenuation and water quality treatment through supplementary storage capacity of runoff. Water is then released at a controlled rate once the risk of flooding has passed. A great benefit of retention ponds is that they hold water when there is an excess of it, which can be used later when water is not available (e.g. for irrigation). **Irrigation users are farmers,** so they see the advantage of using a retention system.

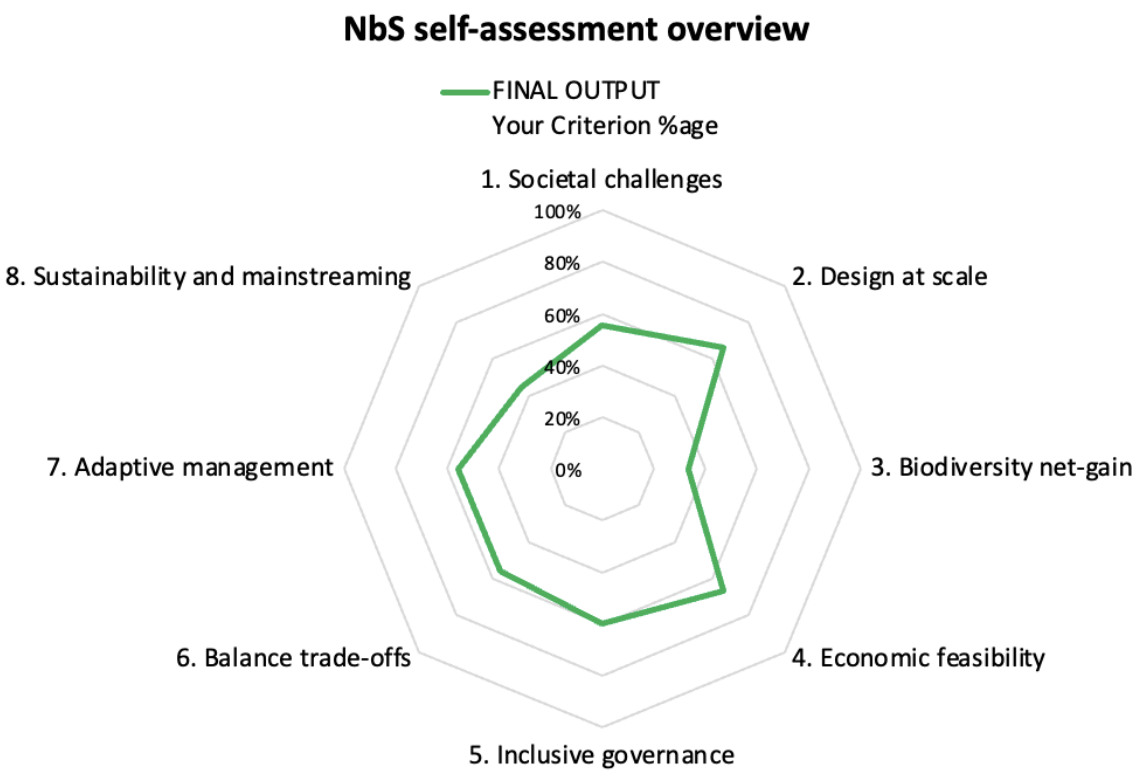
COSTS ASSUMPTION	The cost could largely differentiate due to difference in size of the lake, but minimum cost is 100.000 euro

EXAMPLE AND SHORT DESCRIPTION	PHOTO
OPTAIN - OPtimal strategies to retAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe (EU funded - Horizon, 2020-2025) **Case-study of a retention pond in Slovenia** Water retention pond – Potential storage volumes of 5,000 m^3 to 10,000 m^3 were considered. When placing a detention/retention pond, in the first phase it is necessary to produce a conceptual design of the intended construction of a pond, which must show the purpose and goals of the retaining wall, the size of the pond, the location, a list of plots, distances from neighbouring, anticipated activities in the impoundment area, impoundment volume, barrier size data, including stability assessment, and geotechnical data (Hočuršćak, 2017). When planning construction of the pond, attention should be paid to the impact it will have on surrounding area. Source: https://qcat.wocat.net/en/wocat/technologies/	Source: Gregor Kramberger (both photos)  

11. NbS measure – Constructed wetlands

NbS MEASURE	CONSTRUCTED WETLANDS
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
Constructed wetlands (CWs) are purposefully built systems that leverage the natural interactions among wetland vegetation, soils, and microbial communities to treat wastewater. These engineered wetlands are designed to imitate similar processes found in natural wetlands but operate within a controlled environment. Its primary purpose is to improve the water quality and quality of life for the people living in settlements for whom connecting with the waste-water treatment facility is not cost-effective.	 1. wastewater 2. soil 3. non-permeable layer
	WATER SECURITY CHALLENGE PRIMARILY ADDRESSED: This measure primarily improves water quality, however, it can have some available retention capacity and mitigate floods and droughts as well.

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	5	9	0,56	56%
2. Design at scale	6	9	0,67	67%
3. Biodiversity net-gain	4	12	0,33	33%
4. Economic feasibility	8	12	0,67	67%
5. Inclusive governance	9	15	0,60	60%
6. Balance trade-offs	5	9	0,56	56%
7. Adaptive management	5	9	0,56	56%
8. Sustainability and mainstreaming	4	9	0,44	44%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Adequate	**55%**

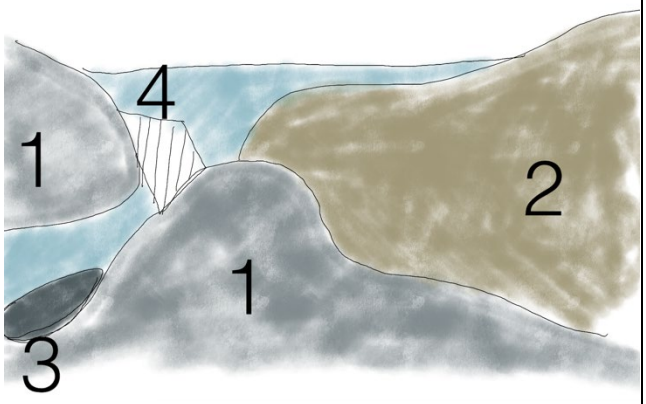
MAIN ASPECTS OF THE MEASURE

The constructed wetlands can, in general, be divided into surface-flow, horizontal subsurface flow, and vertical flow constructed wetlands. They come in various designs, such as horizontal surface, subsurface flow, vertical flow, and floating raft systems. Surface flow wetlands, resembling natural marshes, occupy shallow channels and basins where water flows at low velocities above and within the substrate. These basins typically feature a mix of gravel, clay, or peat-based soils and crushed rock, planted with macrophytes. In subsurface flow wetlands, wastewater moves horizontally or vertically through substrates like soil, sand, rock, or artificial media. Purification occurs as the wastewater contacts the surface of the media and plant rhizospheres. Subsurface flow systems prove more effective than surface flow systems in removing pollutants at high application rates. However, issues such as overloading, surface flooding, and media clogging can lead to reduced efficiency in subsurface systems.

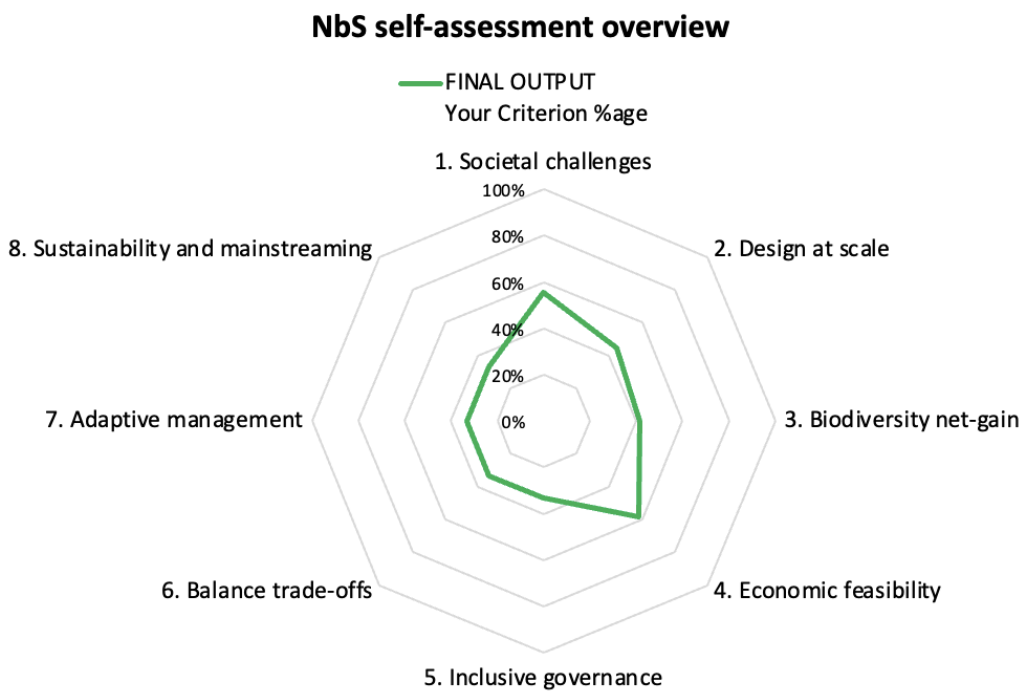
Constructed wetlands designed for organic waste treatment demonstrate a **lifespan of around 20 years.** Beyond their functional role, these wetlands can be aesthetically pleasing and incorporated into residential developments, providing a functional landscape. Moreover, they create valuable ecological habitats for wildlife. The literature shows that the waterbirds might use artificial wetlands only when natural wetlands are unavailable or of poor quality, especially during the winter time. **The performance of these wetland systems is influenced by factors such as area, length to width ratio, water depth, wastewater loading rate,** and the time it takes for wastewater to pass through the wetland. Typically, an efficiency above 90% is achieved for the removal of disease-causing microorganisms, while removal rates for organic material and suspended solids can reach 80%. However, nutrient removal efficiency is generally below 60%.

COSTS ASSUMPTION	It depends on the size of the wetland, but for small, constructed wetlands the cost can be 50.000 euro and more
EXAMPLE AND SHORT DESCRIPTION	**PHOTO**
Constructed wetland in Istria, Croatia Constructed wetland was built in the Kaštelir–Labinci municipality in Istria. It consists of 5 beds with total surface of 4.800 m². The specificity of this location is high fluctuation of population. Due to the tourist season the population during summer is more than doubled. Pumps are required for bringing the wastewater to the first two beds.	Costructed wetland, source: https://www.limnos.si/en/projekti/kastelir-croatia-2/ 

12. NbS measure – Sinkholes in karstic fields

NbS MEASURE	SINKHOLE IN KARSTIC FIELDS
SHORT DESCRIPTION OF THE MEASURE	**GRAPHICALLY PRESENTED**
Pits stand out as the predominant surface landform in karstic landscapes. The pits form when water infiltrates the limestone, causing the dissolution, and over time, continuous water flow widens those areas to result in the end of the pit. The measure itself is very simple to implement since a grid is placed to stop the debris from entering and filling out the pit. If maintained and cleaned it provides the capacity to retain water to mitigate the impact of floods.	 1. permeable surface 2. impermeable surface 3. accumulated sediments and debris 4. grid to stop entering of debris
WATER SECURITY CHALLENGE PRIMARILY ADDRESSED: This measure creates bigger water-retention capacity therefore primarily floods.	

IUCN NbS SELF-ASSESSMENT OVERVIEW				
Criterion	**Your Criterion Score**	**Maximum Criterion Score**	**Normalised criterion**	**FINAL OUTPUT Your Criterion %-age**
1. Societal challenges	5	9	0,56	56%
2. Design at scale	4	9	0,44	44%
3. Biodiversity net-gain	5	12	0,42	42%
4. Economic feasibility	7	12	0,58	58%
5. Inclusive governance	5	15	0,33	33%
6. Balance trade-offs	3	9	0,33	33%
7. Adaptive management	3	9	0,33	33%
8. Sustainability and mainstreaming	3	9	0,33	33%



Is this in adherence with the IUCN Global Standard for NbS?	Total percentage match
Partial	**42%**

MAIN ASPECTS OF THE MEASURE

The karstic systems are rather complex regarding water since the limestone is soluble over the long period which forms multiple karstic forms in the landscape. Carbon dioxide-enriched water enters through fissures of the limestone, dissolving the rock and creating **various karstic forms** (such as funnels, depressions, karst fields, towers, columns, and more) and subsurface (caves and pits).

As speleological objects caves and pits are specific and sensitive habitats at the contact of surface and underground ecological conditions and may include different aquatic and terrestrial organisms. The cave ecosystems to which pits belong can include diverse and protected cave fauna.

Cleaning and regular maintenance of the pit restores the natural hydrological function of the speleological system, which contributes to the maintenance of natural ecological conditions in the karst aquifer and the surface habitats that are hydrologically connected to it (springs and watercourses in the slopes of karst fields located at lower altitudes).

COSTS ASSUMPTION	Due to high difficulty of entering the pit and a large quantity of wooden debris for the last cleaning the cost was almost **300.000 euro.** Source: https://www.voda.hr/hr/novost/ciscenje-dulinog-ponora

EXAMPLE AND SHORT DESCRIPTION	PHOTO
Cleaning of Đula's pit (Hrvatske vode, 2017) The cleaning of Đula's pit as a preventive action to mitigate the risk of floods, following two recorded floods in Ogulin in 2017. With the removal of the debris, the retention capacity increases. The Croatian Mountain Rescue Service and 20 workers from the contracted company were involved, with the possibility of hiring speleologists in later stages for deeper exploration into the cave system. This is particularly important as part of the debris may have been dragged deeper into the cave system.	Source: https://www.voda.hr/hr/novost/ciscenje-dulinog-ponora 

Annex 2

Methodology and a process of NbS study preparation

In the scope of preparation of this document, "Harnessing the Power of Nature-based Solutions Concerning Water Security Challenges in Croatia" there were multiple stages of preparation to make it useful for Croatian stakeholders as well as for potential investors of NbS projects in Croatia. The main objective of the collaboration between the TNC and EIB was to define the most suitable NbS measures for Croatian circumstances, open a dialogue with stakeholders and decision-makers, and jointly define potential locations where NbS projects could be implemented.

In the beginning, it was needed to define the relevance of specific water security challenges (floods, drought, water quality) for the currently ongoing work of TNC in Croatia. Since the protection of freshwater ecosystems is one of the strategic objectives, in the scope of this study, we focused on potential NbS projects related to floods, water quality, and droughts, however, primarily hydrological droughts since that type of drought is directly connected with reduced streamflow and groundwater levels. Hydrological drought occurs when deficits in surface and sub-surface water supplies (including streams and lakes) are below a defined threshold.[79] Although all types of drought are connected to precipitation, the impact on hydrological drought is last observed when compared with agricultural (impact on crop production due to insufficient water), socio-economic (when the water demand exceeds the supply, affecting goods and services), ecological (prolonged and widespread deficit in naturally available water supplies, including changes in natural and managed hydrology, that create multiple stresses across ecosystems) or meteorological drought (lack of precipitation over an extended period).[80]

Since the hydrological drought is also mitigated (aquifer water levels rise) by implementing NbS measures that provide retention capacity during high water waves and target floods, in the scope of this study we provided (within Annex 1) an overview of measures that mitigate floods, while mitigating hydrological droughts at the same time.

Regarding water quality, we proposed constructed wetlands (within Annex 1) to treat/purify localized sources of wastewater. Over the past decade, connection to wastewater treatment plants (WWTP) in settlements <2000 PE has increased from 9% to 19% of the total population living in small settlements along the CEE, however for Croatia the percentage is still very low (1%), although 39% of the population lives in settlements below 2000 inhabitants.[81] Wetlands are among the crucial nature-based solutions for river water purification.[82] Constructed wetlands, in contrast to natural wetlands, are human-made systems that are designed, built, and operated to emulate wetlands or functions of natural wetlands for human desires or needs. Constructed wetlands have recently received considerable attention as low-cost, efficient means to clean up not only municipal wastewaters but also point and non-point wastewaters, such as acid mine drainage, agricultural effluents, landfill leachates, petrochemicals, as well as industrial effluents.[83]

---

79 Wilhite, D.A. (2002) 'Combating Drought through Preparedness', Drought Mitigation Center Faculty Publications, Available at: http://digitalcommons.unl.edu/droughtfacpub.

80 Reichhuber, A., Svoboda, M., King-Okumu, C., Mirzabaev, A., Vicente-Serrano, S.M., Srinivasan, R., Ehlert, K., Jia, X., Karnib, A., Lal, R., Mislimshoeva, B., Ravindranath, N.H., López Santos, A., Schipper, L., Stefanski, R., Vuković, A. and Zhang, H., 2022. Multiscale Approaches for the Assessment and Monitoring of Social and Ecological Resilience to Drought. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

81 Istenič, D., Bodík, I., Merisaar, M., Gajewska, M., Šereš, M. and Griessler Bulc, T., 2023. Challenges and Perspectives of Nature-Based Wastewater Treatment and Reuse in Rural Areas of Central and Eastern Europe. Sustainability, 15(10), p.8145. Available at: https://doi.org/10.3390/su15108145

82 Sileshi, A., Awoke, A., Beyene, A., Stiers, I. and Triest, L. (Date of Publication) 'Water Purifying Capacity of Natural Riverine Wetlands in Relation to Their Ecological Quality', Department of Biology, Vrije Universiteit Brussel (VUB), Brussels, Belgium; Department of Environmental Health Sciences, Haramaya University, Harar, Ethiopia; Department of Environmental Health Sciences and Technology, Jimma University, Jimma, Ethiopia.

83 Dordio, A., Palace Carvalho, A.J., and Pinto, A.P. 'Wetlands: Water "living filters"?'. Department of Chemistry, University of Évora, Centro de Química de Évora, ICAM – Instituto de Ciências Agrárias e Mediterrâneas, University of Évora, Évora, Portugal.

Nature-based Solutions (NbS) offer the world a real chance to meaningfully address multiple sustainability crises, including climate change, food and water security, land degradation, and biodiversity loss.[84]

Since water security is one of the most relevant societal challenges of today, we should start building resilience to climate change impacts as well as raising awareness about the negative impacts of human pressures. To tackle this challenge in a nature-positive way it is imperative to increase deployment of NbS projects. Due to greater recognition of NbS, on global and EU levels, as explained in more detail in the part about policy, we have legislation that supports and creates possibilities for the implementation of NbS projects as well as other ecosystem-based approaches, although in Croatian legislation the term NbS is not adequately recognized or transposed from EU level.

There are already multiple NbS approaches available on the global level, among the most relevant and widely used is the IUCN Global Standard of NbS[85] which sets the basis for the design and implementation of NbS projects while tackling one or several societal challenges. The IUCN Global Standard of NbS with all accompanying supporting publications was used as the basis in the preparation of this study since it is by far the most comprehensive, reviewed, and consulted than any other NbS concepts available worldwide. The IUCN Global Standard for NbS Self-assessment Tool[86] was used to assess potential NbS measures and their adherence with the IUCN Global Standard of NbS. Since December 2023 it has been available in an online version[87], however since in the scope of this study a Catalogue of NbS measures was prepared before (Annex 1 to this study), we used the self-assessment spreadsheet available at the time. Since this study has been prepared for Croatia, which is an EU country we also used the available knowledge and experiences from multiple Horizon projects[88] being implemented under the European Green Deal[89] "umbrella". The third major source of available knowledge that was used to prepare this study and is recommended to be used if designing or implementing the NbS project is the University of Oxford Nature-based Solutions Initiative[90]. It also provides knowledge and experiences from the implementation of multiple NbS projects worldwide.

As explained the process of this study started with the preparation of the Catalogue of NbS measures (Annex 1) that correspond to the Croatian context. As the basis for the proposed NbS measures also the "Guidelines for Technical Design and Assessment of Socio-Economic Feasibility of Green Infrastructure Measures"[91] was used. These Guidelines include recommendations for 18 types of green infrastructure measures, specifically focused on flood protection, erosion, and sediment control as well as flash flood management. The listed measures were assessed according to the IUCN Global Standard of NbS and it was defined how much they adhere to the mentioned IUCN Standard while including Croatian circumstances and legislation as the basis. Additional measures were also proposed and explained in short within the Catalogue of proposed NbS measures in Croatia (Annex 1 to this study).

After defining the most suitable NbS measures and assessing their adherence to the IUCN Global Standard of NbS we used the TNC Europe Freshwater Outcomes Prioritization Tool92 (TEFOP) to have a clear and scientifically based overview of possible locations for NbS deployment In Croatia. TEFOP supports the identification of priority areas for freshwater ecosystems and the services they provide as well as biodiversity. Given this prioritization, it aims to guide the selection of areas where conservation interventions are best suited to make a positive impact. We used the TEFOP to overlay the flood risk and the drought risk data to Natura 2000 and protected areas maps to define where the biggest threats from floods and droughts occur as well as where we could have positive impacts on protected freshwater biodiversity. Since the TEFOP is most relevant at the European level, we also used the flood maps from the River Basin Management Plan 2022-2027[93] to define potential locations for

---

84 IUCN (2020) Guidance for using the IUCN Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of Nature-based Solutions. First edition. Gland, Switzerland: IUCN.

85 IUCN (2020) Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN.

86 Available at: https://www.surveygizmo.com/s3/5785977/IUCN-Global-Standard-for-NbS-Sharing-Results

87 Available at: https://nbs-sat.iucn.org/

88 European Commission & European Research Executive Agency (2022) Nature-based solutions – EU-funded NBS research projects tackle the climate and biodiversity crisis. Publications Office of the European Union. Available at: https://data.europa.eu/doi/10.2848/42098

89 Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

90 Available at: https://www.naturebasedsolutionsinitiative.org/what-are-nature-based-solutions/

91 VITA projekt (2021) Smjernice za tehničko projektiranje i procjenu socioekonomske izvedivosti mjera zelene infrastrukture u smanjenju rizika od poplava. RN/2021/002. Zagreb: Hrvatske vode.

92 Available at: https://tnc-app-dd8a4.web.app/

93 River Basin Management Plan, 2022-2027. Available at: https://mingor.gov.hr/UserDocsImages/Uprava_vodnoga_gospodarstva_i_zast_mora/PLAN%20UPRAVLJANJA%20VODNIM%20PODRUČJIMA%20DO%202027..pdf.

implementation of measures proposed in the scope of the NbS Catalogue (Annex 1). Therefore, the Catalogue proposes measures targeting floods and hydrological droughts. However to target the water quality it proposes a measure of constructed wetlands to assure sustainable sanitation for people living in small settlements where it is too costly to build a regular wastewater treatment network.

To ensure that proposed NbS measures and proposed potential locations for their deployment correspond to Croatian circumstances, as well as views of relevant Croatian stakeholders at the end of January the TNC, in collaboration with the EIB, organized a workshop with Advisory Board members (Croatian Waters, JJ Strossmayer Water Institute, Ministry of Environment and Green Transition – Directorate for Water Management and Sea Protection, the State Institute for Nature Conservation representing the same Ministry, and WWF Adria). During the workshop participants were very engaged and provided valuable input about potential locations where NbS projects could be deployed.

As a follow-up to a workshop, we defined priority NbS projects and checked local interests for NbS implementation, for more details check Chapter 8 (Identification of Potential NbS Measures and Suitable Locations for NbS deployment in the Croatian context).

Annex 3

Identification of suitable locations for NbS deployment in Croatian context

9.1 Table 4. Potential locations for NbS projects in Croatia

Potential NbS site	Water security challenge primarely addressed	Main investors	Description of potential NbS site	Priority for NbS project implementation	Explanation of the reason for the given priority
Lonjsko Polje Nature Park	**Floods, water quality, droughts**	Lonjsko Polje Nature Park, Hrvatske vode	Lonjsko Polje is the biggest wetland along the Sava River which is still free-flowing in its middle and lower courses, and a Ramsar site. It serves as a natural retention area during high waters. Over 67% of the Park is covered by alluvial forest, representing the most integral complexes of oak and ash, as well as valuable communities of alder floodplain forests. Togather with wet meadows and pastures they make a mosaic of the most integral floodplain ecosystem in the whole biogeographic region (European Continental region). Due to the fact that local people live there in a rather traditional way, using extensive pastures for cattle, horses and pigs (including several indigenous breeds) and conserving the unique traditional architecture of wooden houses, this area	**Priority 1**	Whole Sava River in Croatia is under Priority 1 for NbS deployment, however in the Sava River basin there are multiple sites, with different management authorities and therefore it is not observed as one case, although it could become a priority basin with multiple NbS projects implemented jointly with different management authorities. Sava River Basin is already observed by nature conservation sector as one of the most important to be restored. Therefor studies researching restoration potential have been prepared already (e.g. Sava restoration from Brežice to Rugvica[99]) and the TNC could build on already implemented projects and high interest for implementation of NbS from the side of conservation sector.

[99] EuroNatur - Stiftung Europäisches Naturerbe(2021) Sava River restoration from Brežice to Rugvica - feasibility study: River restoration concept based on calculations of optimal river width. Available at: https://www.balkanrivers.net/uploads/files/5/sava-river-restoration-feasibility-study-full.pdf.

			also represents a unique feature of the natural, landscape with cultural heritage.[94] Since parts of the floodplains are used for agriculture from previously uncultivated areas and flood dykes where built, mostly in the 20th century, it had negative impact to the river system.[95] Many projects are implemented or under implementation including SavaTies[96], DanubeParks[97], Protection of Sava River/EuroNatur[98] in order to retein previouslly fully functional ecosystem services.		
Finalisation of Odransko Polje flood defense sstem	**Floods**	Public Institution responsible for protected areas of Sisak-Moslavina County and of Zagrebačka County, Hrvatske vode	Odransko polje and Turopolje are located in Posavina - an alluvial plain along the Sava river at an altitude of 95 to 110 m. This floodplain, which receives water from the surrounding higher ground, is characterized by micro-relief forms that condition the emergence of different aluvial habitats of wet meadows and forests that depend on the flooding regime, as well as levels of underground water.[100] Odransko Polje is a protected area under the category of significant landscape.[101] The Sava River shaped the main characteristics of the	**Priority 1**	The project is already in plans, but with very slow implementation process, therefore is advised to be further researched with the responsible stakeholders. The TNC could collaborate with the Public Institutions (Pis) responsible for protected areas and Hrvatske vode to propose, design and implemenet the NbS project.

[94] RSIS (2020) Lonjsko Polje Nature Park, Information Sheet on Ramsar Wetlands (RIS), Update version, previously published on 1 January 2012, Site number 584. Available at: https://rsis.ramsar.org/RISapp/files/RISrep/HR584RIS_2002_en.pdf

[95] Schwarz, U. (2016) The River Sava: Threats and Restoration Potential. Sava White Book. Radolfzell/Wien: EuroNatur/Riverwatch. Available at: https://pp-lonjsko-polje.hr/wp-content/uploads/2019/04/euronatur_SavaWhite-Book-Study.pdf.

[96] Available at: https://www.interreg-danube.eu/approved-projects/sava-ties

[97] Available at: https://danubeparks.org/projects/danubeparks-step-20-2012-2014

[98] Available at: https://www.euronatur.org/en/what-we-do/news/launch-for-transnational-programme-to-protect-the-sava-river

[100] Available at: https://zastita-prirode-smz.hr/zastcena-podrucja/odransko-polje/

[101] Available at: https://savaparks.eu/znacajni-krajobraz-odransko-polje-585

			lowland relief by deepening its bed and raising the banks on which the settlements were located, and then the relief gradually descends towards the flooded pastures and forests that surround the banks of the Odra River.[102] Some of the implemented projects are: SavaParks I and II.[103] SavaParks is the international network of protected areas that advocates for the restoration of Sava River.[104] Water management authorities are already working on establishing the flood protection within the scope of Odransko Polje[105] [106]and creating conceptual solution. [107] and the EIA was already conducted.[108]		
Revitalization of Sava floodplain upstream Zagreb	**Floods, droughts, water quality**	Public Institution responsible for protected areas of Zagrebačka County, Hrvatske vode and City of Zagreb	City of Zagreb is using drinking water from Zagreb acquifers and with restoration activities on Sava River upstream from Zagreb we would improve current issues with groundwater recharge of Zagreb acquifers. Due to Sava rivebed incision and high water demand the waterlevels are getting lower and a solution	**Priority 1**	This is a priority 1 since it is very important for ground water recharge to implement a project in line with nature and it should be the most sustainable solution. There where more initiatives already active to manage this issue, like "Zagreb on Sava".[109] International organisation Euronatur was advocating restoration measures, but

[102] Chamberlain, L. (2018) Eco-Masterplan for the "Save the Blue Heart of Europe" campaign. Available at: https://balkanrivers.net/sites/default/files/Eco-Masterplan%20for%20Balkan%20Rivers-PRESS-REVISION%201-2018%20November%2026-WEB.pdf

[103] Available at: https://www.savaparks.eu/sava-parks-4282

[104] SavaParks Guiding Principles on Nature Conservation, River Rehabilitation and Flood Prevention and Sustainable Regional Development (2015). Available at: https://savaparks.eu/guiding-principles-on-nature-conservation-river-rehabilitation-flood-prevention-and-sustainable-regional-development-7172

[105] Hrvatske vode (2015) Flood Protection Implementation plan. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_10_-_provedbeni_plan_obrane_od_poplava.pdf

[106] Available at: https://hrcak.srce.hr/file/58805

[107] Available at: https://www.vpb.hr/2017/06/30/koncepcijsko-rjesenje-zastite-od-poplava-odranskog-polja/

[108] Available at: https://mingor.gov.hr/UserDocsImages/UPRAVA-ZA-PROCJENU-UTJECAJA-NA-OKOLIS-ODRZIVO-GOSPODARENJE-OTPADOM/Puo/17_02_2020_Sazetak_Sisacko_podrucje.pdf

[109] Available at: http://www.casopis-gradjevinar.hr/assets/Uploads/JCE_65_2013_12_5_Reagiranje.pdf

			should be found to mitigate the problem.		both initiatives are no longer active mainly due to lack of interest from local stakeholders.
Mirna River	**Floods, droughts**	Public Institution responsible for protected areas of Istrian County, Hrvatske vode	Mirna is the largest river in Istrian County, which results not only from the size of its catchment area, which is about 725 km2 (influential, i.e. hydrogeological catchment, of which approximately 380 km2 is the immediate surface basin), but also from its water balance which makes up about 30% of the total water balance of the Istrian area. About 7% of the basin (45 km2) is located in Slovenia.[110] A large part of the water balance is provided by karstic springs, of which Bulaţ and Mlini partly supplement from the territory of Slovenia.[111] River Mirna is embanked troughout almost all of its length, and groundwater of this watershead is being iilegally used (wells) for drinking water, which is highly above sustainable capacities during summer and tourism season.	**Priority 1**	This is a priority 1 since in Istria this is a main watercourse, and the water from acquifer is being used heaveliy during tourism season. Some more sustainable solution should be found, as well as for management of the river to be more nature-positive. There is a high potential for NbS project development due to interest of Public Institution responsible for protected area management. Collaboration between nature and water management sector already started and this case should be more researched with relevant local stakeholders. For the beginning the meeting and site visit is planned with the Public Instituion responsible for protected areas (Natura Histrica).
Spačva floodplain forest basin	**Floods, droughts, water quality**	Hrvatske vode, Public Institution responsible for protected areas of Vukovar-	Spačva is an oak forest and part of Natura 2000 network covering 40 000 ha in Croatia, however also a part in Serbia.[112] The dominant tree species is pedunculate oak (*Quercus robur L.*) with a significant share of	**Priority 1**	This is a very important potential NbS case since in 2014 there where severe floods. The biggest issue regarding that flood came from BiH but still, it could be used as water retention for the flood protection in parts of the year which would improve the oak

[110] Popijač, A. (2013) Definiranje ekološki prihvatljivog protoka Mirne. Stručna studija. Ugovor broj: 23-125/10 (Oikon 683-10). Zagreb: HRVATSKE VODE. Available at: https://www.voda.hr/sites/default/files/dokumenti/prateca-dokumentacija/definiranje_ekoloski_prihvatljivog_protoka_mirne.pdf.

[111] Available at: https://www.istrapedia.hr/en/natuknice/291/mirna.

[112] Croatian Waters & Public Water Management Company ''Vode Vojvodine'' (2017) Integrated Cross-Border Monitoring and Management Systems for Flood Risks, Environmental and Biodiversity Protection and Forestry Through Transboundary Forest Retentions and Other Measures. Croatian Waters & Vode Vojvodine.

		Srijem County, Croatian Forests	common hornbeam (Carpinus betulus L.), and narrowleaved ash (*Fraxinus angustifolia Vahl.*). Black alder (*Alnus glutinosa* (L.) Geartn.).[113]		production as well, since they grow in slower rate or drying when groundwater levels are to low.
Karlovac-Sisak flood defense system	**Floods, droughts, water quality**	Hrvatske vode, Public Institution responsible for protected areas of Sisak-Moslavina County, Public Institution responsible for protected areas of Karlovac County	Karlovac and Sisak region, where four rivers (Kupa, Korana, Mrežnica, and Dobra) meet near Karlovac, and three rivers (Sava, Kupa, and Odra) near Sisak, faces complex flood risks. This area struggles with flood defense due to the challenging and sometimes impossible task of completing the protection system. Climate change has increased extreme flooding in these areas. From 2014 to 2018, Karlovac and Sisak experienced ten significant high-water events, requiring extraordinary flood protection measures. Record-breaking water levels were observed on Kupa and Korana rivers during this period. [114] The flood defense system of the city of Karlovac is the only one in the area whose construction was started but due to its incompleteness and slow expansion, only the narrow part of the city center is protected. The rest	**Priority 1**	Although Sisak and Karlovac where at the beginning observed as separate potential NbS cases, since they are connected, and their flood management as well we merged it under one, however very sizeble case. Sisak-Karlovac flood defense is merged. This could also be connected to Odransko Polje which tor the time being is it separate case to also have options for smaller NbS cases. The interest to work on this exist since the project is still not fully funded and open for potential implementation of NbS solution to already planned gray flood defense solutions.

[113] Ostrogović Sever, M.Z., Paladinić, E., Barcza, Z., Hidy, D., Kern, A., Anić, M., & Marjanović, H. (2017). Biogeochemical modelling vs. tree-ring measurements - Comparison of growth dynamic estimates at two distinct oak forests in Croatia. South-east European Forestry, 8(2), 71-84.

[114] Hrvatske vode. (2019) Dokument Studija o utjecaju na okoliš – ne-tehnički sažetak: Projekt Sustav zaštite od poplava karlovačko-sisačkog područja II. faza – sisačko područje. Izrađivač: Geateh d.o.o. Available at: https://mingor.gov.hr/UserDocsImages/UPRAVA-ZA-PROCJENU-UTJECAJA-NA-OKOLIS-ODRZIVO-GOSPODARENJE-OTPADOM/Puo/09_12_2019_Sazetak_Sisacko_podrucje.pdf.

			of the area is still unprotected.[115]		
Bregana River	**Floods, droughts, water quality**	Hrvatske vode, Public Institution responsible for protected areas of Zagrebačka County	Bregana River is a transboundary river between the Republic of Croatia and Republic of Slovenia. It is a small river, 26 km long with a catchment area of 92 km2 most of which is located in Croatia. According to flood maps, 0,84 km2 of the basin is threatened by high probability floods (10 year return period), while 2,22 km2 is threatened by floods of low probability of occurrence (500 year return period). The flood events that occurred in 2005., 2014. and 2015. show the distinctive torrential character of Bregana River, with specific flood sites.[116] Hydrographically, this area belongs to the Sava river basin. The watershed is mostly covered by forest and steep slopes that give a relatively large base flow of Bregana with an average flow of 1.36 m3/s and consequently result in pronounced erosion processes. A smaller part of the area is under agriculture or inhibited.[117]	**Priority 1**	Bregana is a collaborator case in an NbS project, RECONECT already therefore upscaling of current efforts could be implemented. Many retention areas where previously planned and there are current chellanges due to unrisolved border issues with Slovenia.
Orljava River	**Floods, droughts, water quality**	Hrvatske vode, Public Institution responsible for protected areas of Požega-	Orljava-Londža river basin in Požega-Slavonia County, covers 1,815 km² is a key area in central Slavonia between the Sava and Drava rivers. This region, with Orljava and Londža rivers being Sava's tributaries include two	**Priority 1**	Currently the gray solution is under development therefore it might be highly benificial to work on this case, although it is more local level. There is a potential to include NbS measure into the current project.

[115] Hrvatske vode (2014). Provedbeni plan obrane od poplava branjenog područja sektor D – Srednja i Donja Sava, branjeno područje 11: Područje maloga sliva Kupa. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_11_-_provedbeni_plan_obrane_od_poplava.pdf.

[116] Available at: http://www.reconect.eu/network-of-cases/.

[117] Available at: https://frisco-project.eu/hr/slivna-podrucja-rijeka/bregana/

		Slavonia County	main catchment areas: "Orljava-Londža" (70% of the county) and part of the "Ilova-Pakra" watershed (30%). The "Orljava-Londža" catchment area is notable for its natural surroundings, bordered by several mountains and three cities as well as 203 settlements. Flood defense currently includes 69,622 km of embankments. [118]		
Kopački Rit Nature Park	**Floods, water quality, droughts**	Kopački Rit Nature Park, Hrvatske vode	Kopački Rit Nature Park is the 2nd biggest wetland along the Danube River and a Ramsar site.[119] Due to the Danube riverbed incission it is under increased sucession. In general, the area alternates with mosaic-arranged parts of land and water surfaces, which change size and shape depending on the amount of flood waters, therefore the appearance of the entire area depends on flooding dynamics. Certain areas, or lakes are permanently filled with water where Kopačko lake is the largest, and Sakadaško lake is the deepest. A network of canals and seals connects water surfaces with each other, and with the Drava and the Danube, whose canals serve to fill the area with water. Bogger part of the area is mostly flooded with water from the Danube, while they receive water from the	**Priority 2**	Kopački Rit Nature Park is the biggest Croatian wetland and one of the most important locations in need of restoration and NbS deployment. Due to the status of the nature park and its importance it is already managed, as well as under restoration process trough multiple projects. The urgency to improve status of biodiversity and ecosystem services is already recognised and dealt with by multiple international organisations. That is the reason why it is considered Priority 2.

[118] Hrvatske vode (2014) Provedbeni plan obrane od poplava branjenog područja sektor D – Srednja i Donja Sava, branjeno područje 3: Područje maloga sliva Orljava-Londža. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_3_-_provedbeni_plan_obrane_od_poplava.pdf.

[119] Ramsar Convention Secretariat (2006-2008) Information Sheet on Ramsar Wetlands (RIS) – 2006-2008 version. Available at: https://rsis.ramsar.org/RISapp/files/RISrep/HR583RISformer_170612.pdf

			Drava to a much lower extent.[120] Multiple projects are implemented already or under implementation: NATURAVITA[121], Restoring the Amazon of Europe[122], LIFE RESTORE for MDD[123], DanubeParks[124] implemented trough more projects, Restoration of Aljmaški RIt[125], etc.		
Crna Mlaka fishpond	**Droughts**	Public Institution responsible for protected areas of Zagrebačka County, Hrvatske vode and City of Jastrebarsko	Crna Mlaka is very small open water area but there, especially during the winter, you can see all the richness of the bird life that comes during cold season or lives there permanently. The area is protected as a special ornithological reserve.[126] The area is also designated as Natura 2000 site for the protection of non-bird species and important habitats as well as Ramsar site.[127] It is an area of natural depression, used for fish production[128] It is already planned to become t is research and visitor center (birdwatching), and is	**Priority 2**	This is a priority 2 since the impact of the NbS project would be very local. It is still reccomended to be implemented in the future, however there are potential sites with higher priority then this.

[120] Management plan for the Kopački rit Nature Park (2024-2033) and the associated protected area and areas of the ecological network (PU 008). Available at: https://mingor.gov.hr/UserDocsImages/UPRAVA%20ZA%20ZA%C5%A0TITU%20PRIRODE/NATURA%202000/PU%20008%20Kopa%C4%8Dki%20rit.pdf#page=3.09

[121] Available at: https://naturavita-project.eu/o-projektu/

[122] Available at: https://www.ekovjesnik.hr/clanak/7001/wwf-priprema-ciscenje-kanala-u-kopackom-ritu

[123] Available at: https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE22-NAT-AT-LIFE-RESTORE-for-MDD-101113557/preserving-and-restoring-floodplain-forest-habitats-along-the-mura-drava-danube-rivers

[124] Available at: https://danubeparks.org/

[125] Available at: https://vukovisadunava.com/archive2.php?topic=16945.0

[126] Available at: https://mingor.gov.hr/djelokrug/uprava-za-zastitu-prirode-1180/zasticena-podrucja/medjunarodno-proglasena-zasticena-podrucja/ribnjaci-crna-mlaka/5326

[127] RSIS (2020) Ramsar Information Sheet: Crna Mlaka Fishponds. Update version, originally published on 1 January 2012, site number 582. Croatia. Available at: https://rsis.ramsar.org/ris/582

[128] Available at: https://prirodahrvatske.com/2018/12/13/crna-mlaka-skladan-suzivot-covjeka-i-prirode/#google_vignette

			used for an extensive fish production.[129] [130]		
Zagreb Constructed Wetland	**Water Purification**	City of Zagreb and Zagreb Wastewater Company	Building of constructed wetland [131]for the 3rd level of water purrification.[132]	**Priority 2**	This is a priority 2 due to very local impact. It is still reccomended to be implemented in the future, however there are potential sites with higher priority then this.
Town Obrovac Constructed Wetland	**Water Purification**	City of Obrovac	Construction of the plant and constricted wetland. No treatment today. Investor: Town Obrovac[133]	**Priority 2**	Here we could have potentially water quality combined with flood protection involving NbS with Zrmanja. It is currently Priority 2 due to its high complexities with local stakeholders.
Neretva River Delta	**Floods**	Public Institution responsible for protected areas of Dubrovnik County, Hrvatske vode	The Neretva, spanning 225 kilometers, flows mainly through Bosnia and Herzegovina, with its last 20 kilometers crossing into Croatia.[134] Its delta, near Ploče in southern Dalmatia, is Croatia's only true delta and a key Mediterranean wetland, notable for its fertility and as a crucial agricultural and transportation hub in Dalmatia. Recognized internationally for its ecological significance, particularly the Ramsar list of wetlands[135], the Neretva Delta is home to 310 bird species and about 150 fish species, showcasing a diverse mix of marine and freshwater	**Priority 2**	Neretva River Delta is Priority 2 due to again high complexities with the local stakeholders, additionaly upscaled with the complexities of transboundary collaboration with Bosnia and Herzegovina where the biggest part of the river flows.

[129] Available at: https://zeleni-prsten.hr/portal/zasticena-podrucja/crna-mlaka/
[130] Available at: https://crna-mlaka.geog.pmf.hr/index.php/zastita-prirode/
[131] Zalaznik, A.M., Brodnik, U. & Pugelj, A. (2023) 'Nature-based Solutions for Integrated Local Water Management', Review. DOI: 10.15255/KUI.2022.062. Available at: https://hrcak.srce.hr/file/443936
[132] Available at: https://www.zagreb.hr/procistac-otpadnih-voda/160486
[133] Zeleni servis d.o.o. (Year) Zahtjev za ocjenu o potrebi procjene utjecaja zahvata na okoliš: "Uređaj za pročišćavanje otpadnih voda Grada Obrovca".
[134] Available at: https://www.voda.hr/hr/novost/neretva-od-granice-do-usca.
[135] RSIS (2020) Ramsar Information Sheet: Neretva River Delta. Update version, originally published on 11 February 2020, site number 585. Croatia. Available at: https://rsis.ramsar.org/RISapp/files/RISrep/HR585RIS_2002_en.pdf

			life. Downstream, the Neretva expands into a valley, displaying numerous springs and remnants of its deltaic past, including old meanders and backwaters. The construction of hydroelectric power plants and water management projects upstream has altered the river's flow and sediment deposition patterns, impacting natural retention and the water regime in the Neretva's lower reaches.[136]		
Bosut River	**Floods, droughts**	Public Institution responsible for protected areas of Vukovar-Srijem County , Public Institution responsible for protected areas of Osijek-Baranja County and Hrvatske vode	The Bid-Bosut area is mainly in Eastern Slavonia, with a small part in Western Srijem, sitting on the left side of the Sava River.[137] It's named after two rivers, Bida and Bosut, that flow through it. This area covers about 343,200 hectares, with most of it, 307,600 hectares, in Croatia and the rest, 35,600 hectares, in Vojvodina, Serbia. The area is part of two counties in Croatia: Vukovar-Srijem and Osijek-Baranja.[138]	**Priority 2**	This is a priority 2 since the impact of the NbS project would be very local. It is still reccomended to be implemented in the future, however there are potential sites with higher priority then this.
Rivers around Požega	**Floods**	Public Institution responsible for protected	The small watershed "Subocka-Strug" is located in the extreme eastern part of Sisak-Moslavina County which makes up	**Priority 2**	This is a priority 2 since the impact of the NbS project would be very local. It is still reccomended to be

[136] Hrvatske vode (2014) Provedbeni plan obrane od poplava branjenog područja sektor F – Južni Jadran, branjeno područje 32: Područja malih slivova Neretva - Korčula i Dubrovačko primorje i otoci. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_32_-_provedbeni_plan_obrane_od_poplava.pdf.

[137] Hrvatske vode. (2015) Studija za Glavnu ocjenu prihvatljivosti zahvata za ekološku mrežu: Zahvat Dovodni melioracijski kanal za navodnjavanje Bid-bosutskog polja – 7. faza – dionica spoja s rijekom Savom. Available at: https://mingor.gov.hr/UserDocsImages/NASLOVNE%20FOTOGRAFIJE%20I%20KORI%C5%A0TENI%20LOGOTIPOVI/doc/studija_za_glavnu_ocjenu_prihvatljivosti.pdf

[138] Hrvatske vode (2014) Provedbeni plan obrane od poplava branjenog područja sektor D – Srednja i Donja Sava, branjeno područje 1: Područje maloga sliva Bid-Bosut. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_1_-_provedbeni_plan_obrane_od_poplava.pdf

		areas of Požega-Slavonia County, Public Institution responsible for protected areas of Sisak-Moslavina County	the area of western Slavonia. In the southern part, the area is bordered by the river Sava mouth of the river Veliki Strug and part of the river Una, which at the same time form the border with B and H, East via the Zelenik retention embankment, then upstream again along the Sava River to the confluence of Stari Trebež in Sava, further north along the Stari Trebež river, the Nova Ilova canal, the Ilova river. [139]With the northern and eastern sides of the border of the defended area coincide with the border of the Sisak-Moslavina county. The total area of the basin is 58,480 ha. The defended area includes the City of Novska with 27 settlements, the Municipality of Jasenovac with 10 settlements and the Municipality Lipovljani with 4 settlements. According to the 2011 census, the total number of inhabitants is 18,970.[140]		implemented in the future, however there are potential sites with higher priority then this. However it could also be merged with Orljava case and tackeled on the higer level.
Papuk streams	**Floods**	Papuk Nature Park and Hrvatske vode	Flood defense system Streams within Nature Park Papuk which is also UNESCO GEOPARK are causing underground floods due to their chanellisation.[141]	**Priority 2**	This is a priority 2 since the impact of the NbS project would be very local. It is still reccomended to be implemented in the future, however there are potential sites with higher priority then this. However it could also be merged with Orljava case and tackeled on the higer level.

[139] Available at: https://www.pozega.hr/images/dokumenti/2023/nabava/JN-056/JN-56%20usluga%20izrade%20okvirnog%20programa%20aktivnosti%20PROJEKTNI%20ZADATAK.pdf.

[140] Hrvatske vode (2014). Provedbeni plan obrane od poplava branjenog područja sektor D – Srednja i Donja Sava, branjeno područje 5: Područje maloga sliva Subocka-Strug.

[141] Available at: https://mpgi.gov.hr/UserDocsImages/dokumenti/Prostorno/Planovi/PPPPPapuk/PPPPapuk-JR/Odredbe_PP.pdf.

Krka/Cetina (small scale NbS)	**Floods**	National Park Krka, Public Institution responsible for protected areas of Split-Dalmatia County	National Park Krka and the Šibenik coast belong to the Cetina river basin. This area deals with specific flood defense challenges due to significant fluctuations in water flow and rapid flood wave movements. Main features include the Krka River, a permanent body of water, and the Čikola River, as well as various smaller streams and drainage channels across the region.[142] Flood defense strategies for larger rivers include constructing regulated beds and embankments, while smaller streams are managed with structures to control water flow, particularly in urban areas or near vital infrastructure. In agricultural fields, maintaining drainage canals is crucial for preventing floods by ensuring water is efficiently evacuated. The Krka River, starting at an altitude of 222 meters, flows through a scenic canyon with multiple waterfalls and lakes, ultimately reaching Prokljan Lake and the sea via Šibenik Bay. The river's hydroelectric potential is tapped by five power plants. [143]Butišnica, Krka's major tributary, features steep sections and collects water from several smaller streams, contributing significantly to the river's flow.[144]	**Priority 2**	This is a priority 2 since the impact of the NbS project would be very local. It is still reccomended to be implemented in the future, however there are potential sites with higher priority then this.

[142] Hrvatske vode (2014) Provedbeni plan obrane od poplava branjenog područja sektor F – Južni Jadran, branjeno područje 27: Područje malog sliva Krka - Šibensko primorje. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_27_-_provedbeni_plan_obrane_od_poplava.pdf.

[143] Tomić, F. et al. (1981) Vodni režim i mogućnost daljnjih melioracija u Dalmaciji. Available at: https://hrcak.srce.hr/file/222954.

[144] Hrvatske vode (2014) Provedbeni plan obrane od poplava branjenog područja sektor F – Južni Jadran, branjeno područje 28: Područje malog sliva Cetina. Available at: https://voda.hr/sites/default/files/dokumenti/novosti/2022-07/bp_28_-_provedbeni_plan_obrane_od_poplava.pdf

Harnessing the Power of Nature-based Solutions Concerning Water Security Challenges in Croatia

The Nature Conservancy

2024-0223