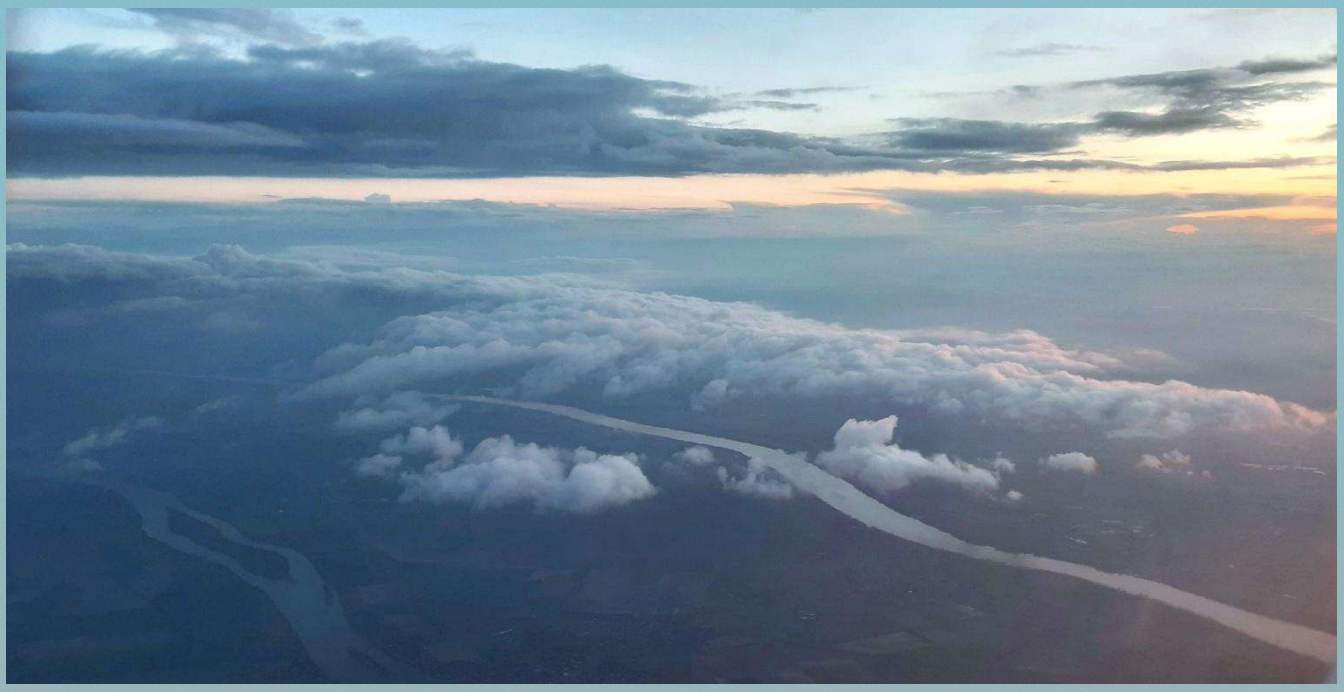
MERLIN



Scaling Up – From Vision to Large-Scale Change: The future's Danube

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MERLIN

Imprint

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1 For the reader

Large floodplain rivers are among the most dynamic and ecologically diverse ecosystems on Earth. They support a wide array of plant and animal species and provide essential ecosystem services. Throughout history, these rivers, along with their associated floodplains, have been vital to human societies. However, human activities such as dam construction, river regulations from flood risk management, land use alteration or navigation purposes, urbanization and agriculture use of floodplains have significantly altered and degraded many of these rivers. This has led to a loss of biodiversity, declines in water quality and increased vulnerability to flooding.

In response to these challenges, designing restoration plans for large floodplain rivers, like the Danube, has become increasingly important. These plans aim to restore the natural functioning of river systems, enhance habitat diversity and improve overall ecosystem health. By implementing well-designed strategic restoration actions, we can mitigate the negative impacts of human activities and promote the resilience of these vital ecosystems. Restoration plans for large floodplain rivers offer significant benefits for various stakeholders, including local communities, businesses and governments.

The purpose of this document is to outline a Regional Scalability Plan (RSP) for the lower Hungarian portion of the River Danube (MERLIN pilot site case study 7b, Middle-Danube, Hungary) to promote sustainable water management. Firstly, we explain why this region is particularly important for developing large-scale restoration plans on the Danube. Secondly, we detail the roles of different stakeholder groups, without which the RSP cannot be effectively conducted. Thirdly, we introduce the Green Deal goals essential to be addressed by the RSP in this region. Finally, we identify specific actions necessary for the sustainable water and landscape management of the target area. While there are good examples of small- scale restoration actions in this lower Hungarian Danube portion, we believe that strategic large-scale planning involving various stakeholder groups is necessary for the sustainable use of river resources. This approach promises a harmonious balance between ecological integrity and socio-economic advancement. The RSP also outlines the required policy frameworks and interventions essential for realizing the objectives, aligning with the overarching goals of the EU Green Deal.

The content of the document was developed as part of the MERLIN project, funded under the H2020 program of the European Commission. Most of the groundwork was conducted in close cooperation between WWF Hungary as implementation and the HUN-REN Balaton Limnological Research Institute as scientific partners in the MERLIN project. The RSP also benefited from several workshops where researchers, local and national policy makers and a variety of stakeholders discussed possibilities of restoration actions in the Hungarian portion of the Danube. It is our intention that these interdisciplinary groups, consisting of ecologists, environmental scientists, conservationists, water engineers, legal experts, financial administrators, on-site implementers and sector representatives continue to collaborate to realize the vision of large scale restoration actions in the investigated section of the Middle-Danube, Hungary.

2 Focus of the RSP

2.1 Regional characteristics

The Danube has a drainage area of approximately 800,000 km2 and a mean discharge of 6,500 m^3 s^{-1} at its mouth. From source to mouth the Danube drains 19 countries, which makes the Danube basin the most international catchment in the world (http://www.icpdr.org/main/danube-basin). Large-scale river regulations starting from the second half of the nineteenth century and paralleled by massive agricultural and industrial activities in the twentieth century have substantially changed the natural Danubian riverscape. The extent of floodplains has been reduced by nearly 70%, and the integrity of the remaining floodplain habitats is further threatened by disconnection due to river engineering works that provide flood control, navigation and hydropower generation.

The studied Danubian floodplain is situated in the Middle-Danube, Southern Hungary, between river km 1,499 and 1,433 (Fig. 1). In this reach, the Danube has a mean annual discharge of 2,400 m^3 s^{-1}. The average slope is about 5 cm km^{-1}, with 0.8–1.2 m s^{-1} flow velocity at mean water level. The floodplain is still the largest functioning floodplain in the Middle-Danube together with its transboundary Croatian counterpart. A major part of the floodplain belongs to Danube-Dráva National Park, which was established in 1996.

The whole historical floodplain (Fig. 1) was considered for the study area within the studied 66 km Danube segment, which covered 1,125 km^2 and was determined based on the SRTM Digital Elevation Model (http://srtm.csi.cgiar.org), historical sources and the Copernicus database (https://land.copernicus.eu/local/riparian-zones).

In the Danube Floodplain Interreg project (2018-2021), water management directorate already designated expansion opportunities with parts of historical floodplain an area of 400 hectares (http://earth.geo.u-szeged.hu/dfgis/).

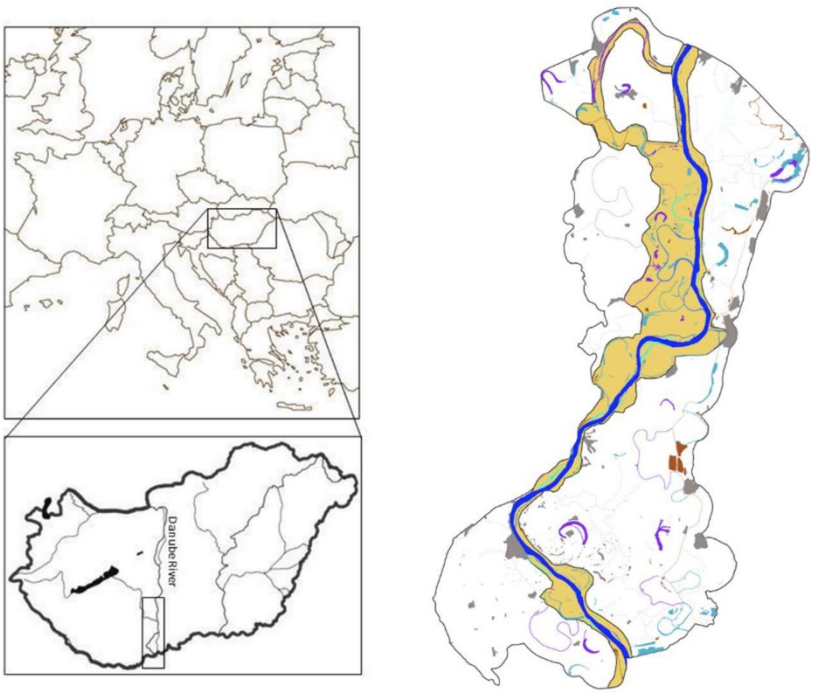


Figure 1 Location and border of the studied Danubian floodplain system in Central-Europe, Hungary. The active floodplain is indicated with light brown around the main channel of the Danube (dark blue line).

Data on land use indicate consistent and dramatic transformation of the landscape across centuries in this region (Fig. 2). The most apparent change was the increase in agriculture (from 9.7% to 63.7%) congruent with a decrease of wetlands (from 29.7% to 1.4%). The ratio of forests also decreased substantially (from 35.9% to 22.7%), although a slight increase could be observed from 1941 (17.1%) to 2018 (22.7%). The ratio of settlements (e.g., urban areas, villages) just slightly increased in the area (from 1.0% to 4.1%).

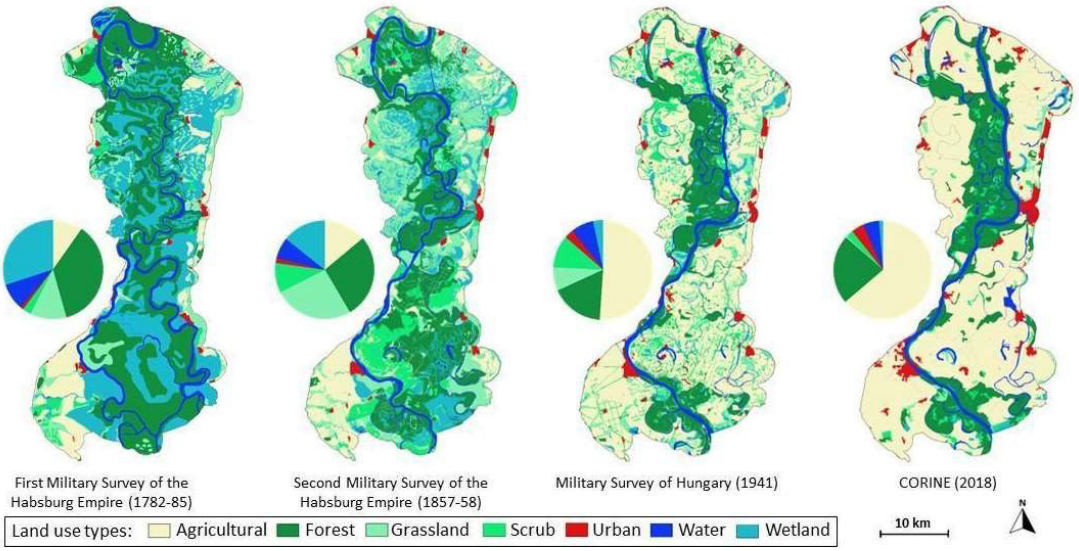


Figure 2 The reconstructed changes in the area and proportion of land use categories over four centuries in the studied Danubian floodplain

Historical and remote sensing-based maps revealed that the most substantial changes in the area and configuration of aquatic habitats happened between the nineteenth and the twentieth centuries (Fig. 3).

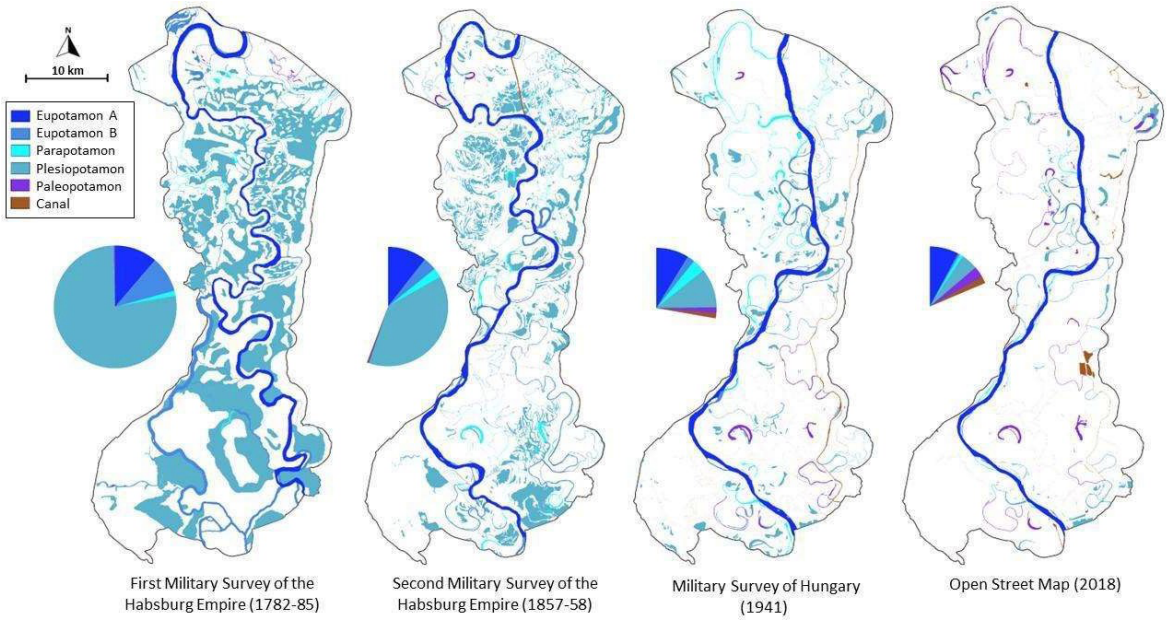


Figure 3 The reconstructed changes in the area and proportion of aquatic habitat types over four centuries of the studied Danubian floodplain in Central-Europe, Hungary

Due to large scale hydromorphological modifications riverbed incision processes accelerated in the main channel of the Danube. Siltation of side arms induce successional processes, which threaten the diversity and integrity of floodplain habitats. River regulation works induced substantial changes in the structure of specific floodplain habitat types (Fig. 3).

2.2 Justification for the region

The segment of the Danube under study stands apart from its upstream counterpart due to distinct hydromorphological characteristics. Here, sand dominates as the primary substrate, while expansive meandering arms and floodplains emerge along the river's right bank. The study area's downstream limit is demarcated by the borders of Hungary, Croatia, and Serbia. Restoring the study area and safeguarding its most valued water bodies stand as crucial objectives for ensuring the sustainability of Danubian floodplain habitats, and they are prioritized tasks within the scope of the Danube-Dráva National Park Directorate's efforts. The area's diverse habitats and the intricate interplay of natural and human-induced alterations render the region

an ecologically vulnerable area. While its natural values remain significant, activities such as agricultural utilization, inland navigation, and riverbed incision pose threats to its ecological integrity. Consequently, the area serves as an ideal model system for study, and its long-term sustainability is pivotal for advancing a variety of Green Deal objectives in the Middle-Danubian region.

More specifically, the area still contains a diverse array of river-floodplain habitats, rich in ecological diversity. However, the landscape's hydromorphological alterations pose a significant threat to its ecological integrity. An immediate imperative emerges: identifying and prioritizing the restoration of key aquatic habitats, while devising a comprehensive plan for large- scale restoration efforts within the area.

The primary river channel experiences a diminishing connection with its floodplain due to river incision, attributed to extensive regulation and prolonged periods of low water periods (i.e., droughts). As the river's course becomes increasingly uniform, habitat loss escalates, species populations decline, and the ecosystem's vital functions diminish. Such degradation poses risks not only to biodiversity, but drinking water sources, recreational activities like ecotourism, floodplain water retention, and climate adaptation mechanisms. Riverbed incisions also impact groundwater levels, precipitating degradation in floodplain vegetation. Rising water demands, spanning human, industrial, and agricultural sectors, strain the capacity of a channelized river unable to sustain adequate water supply or manage flood runoff effectively. Compounding these challenges is the disparate perception of issues across sectors, underscoring the imperative for robust intra- and inter-sectoral dialogue among stakeholders to forge compromised and optimized solutions. Foremost among the urgent objectives, already bearing numerous ancillary benefits, are enhancing biodiversity, bolstering flood and drought resilience, regulating climate impacts, promoting health and well-being, and fostering inclusivity.

2.3 Linkages and synergies with other initiatives

Despite the significance of the target area for large scale restoration, there lacks a comprehensive concept or strategy endorsed by authorities, decision-makers, and responsible ministries. Although various sectors engage with the Danube and its floodplains through separate programs and strategies—such as river basin management plans of the EU Water Framework Directive, flood risk management plans of the Floodplain Directive, Natura 2000 management plans of the Birds and Habitats Directives, and transportation/inland navigation programs—harmonization among them remains elusive. These sectors encompass agricultural land use (including irrigation), drinking water supply, general water management of the riverbed and floodplains, among others.

Internationally, there are cross-border initiatives which vision aligns with the proposal of the RSP. Notably, the Danube Region Strategy prioritizes areas such as water quality, biodiversity and landscapes, waterways, environmental risk management, culture, and tourism.

The target area is a part of the world's first 5-country biosphere reserve, Mura-Dráva-Danube, and shares functional connections with territories along the Danube in Croatia and Serbia. The proposed restoration efforts align with the goals outlined in river basin management plans and are not at odds with flood risk management; in fact, they may enhance flood protection by increasing the water retention capacity of reactivated floodplains.

The RSP aim to enhance cooperation among the aforementioned sectors, facilitate expert discussions, garner political support, and increase public engagement. Additionally, it serves as a platform to openly communicate that preserving the current ecological status and improving morphological conditions are priorities.

2.4 Relevant materials

Erős, T., Petrovszki, J., Mórocz, A. (2023) Planning for sustainability: Historical data and remote sensing-based analyses aid landscape design in one of the largest remnant European floodplains. Landscape and Urban Planning, 238, 104837, ISSN 0169-2046.

Erős, T., & Bányai, Z. (2020). Sparing and sharing land for maintaining the multifunctionality of large floodplain rivers. Science of The Total Environment, 138441

3 Stakeholders of the RSP

3.1 Main stakeholders

To create a common vision and understanding, a broad range of water managers, users and policymakers need to be involved.

Water management directorates are responsible for the main river course, river regulation structures, and flood protection management. They also provide water for other uses like agriculture. They also manage a large part of the active floodplain (between the dykes), though some parts of the active floodplain are managed by other entities. For example, forestry departments are responsible for the state-owned property within the broader floodplain areas and engage in intensive forest management. There are only a few isolated areas, such as some small islands, which are managed by the national park directorate.

Key stakeholders also include waterworks and sewage treatment companies - since in Hungary ~40 % of its inhabitants drink filtered Danube water.

Other main users of the Danube include the navigation sector, agriculture, industry, angling associations, rowing associations and inhabitants who engage in various recreational activities along the river.

We have begun to build a “stakeholder-union” step by step. Key issues related to the Hungarian section of the Danube and possible next steps were discussed in 2 workshops.

Invited experts were from:

1. national parks: Fertő-Hanság, Duna-Ipoly, Duna-Dráva National Parks, conservation managers, rangers, foresters, district leaders
2. research institutes: HUN-REN Balaton Limnological Research Institute, Institute of Aquatic Ecology of the HUN-REN Centre for Ecological Research, Budapest University of Technology and Economics
3. nature conservation department of the Agricultural Ministry
4. navigation experts (1 captain, 1 former coworker of department of ministry responsible for navigation)
5. water management directorates
6. forestries

Key findings of these discussions were as follows:

1. A reference state, present state, future state goal should be clearly defined. The goal is to keep the diversity of natural floodplain habitats, and their biodiversity. Achieving this will require preserving the floodplain as natural as possible.

This is aimed by the actions of Biodiversity and Climate GD goals.

2. A primary condition for implementing NBS measures is to show that restoration of the ecosystems is of a very important public interest.

This is aimed by the actions of Inclusivity GD goals.

3. Managing the prolonged low water periods in the Danube is urgent. Sidearms are not being flushed, water level decreases quickly, and there is no delay preventing the floodplains to absorb sufficient water. Environmental flow standards should be established for water regime dynamics.

This is aimed by the actions of Flood & Drought, Climate and Biodiversity GD goals.

4. Sediment balance is disrupted which is a core problem also in restoration works. There is a significant accumulation and recharge from suspended sediment which results in reforested reefs, increasing flood levels, etc.

This is aimed by the actions of Biodiversity and Inclusivity GD goals.

5. Fairway regulation structures should be optimised and adjusted to reflect the current state of the river. This revision should be conducted with a multi-sectoral perspective. A solid foundation for this could be a fairway development study (conducted by the responsible ministry for fairway conditions'

development, funded by Connecting EU facility sources), but it should be completed and adjusted to incorporate multisectoral goals and views.

This is aimed by the actions of Inclusivity, Sustainable Transport and Biodiversity GD goals.

6. At this stage of the RSP the roles and responsibilities of stakeholders have not been clearly identified. While we have an ideal vision of which stakeholders should assume specific roles, this vision is strictly theoretical and has not been shared with the stakeholders. One of the main weaknesses at this stage is the varying levels of engagement among stakeholders, and there is not a core stakeholder group willing to take on the responsibility.

Next steps are currently being planned. The National Days workshop in MERLIN is yet to be organised and decision need to be made regarding what would best serve the formulation of a commonly agreed-upon strategy. Also, the remaining sectors of management and water use should be involved more actively.

Further stakeholders to be involved:

1. Institutions which are responsible for international harmonisation of river management (Ministry of Interior)
2. Water supplier companies (DMRV Zrt., Érdi Vízművek, Fővárosi Vízművek, Baranya Víz Zrt.)
3. Local municipalities (Érd, Tolna, Metropolitan Government of Budapest):

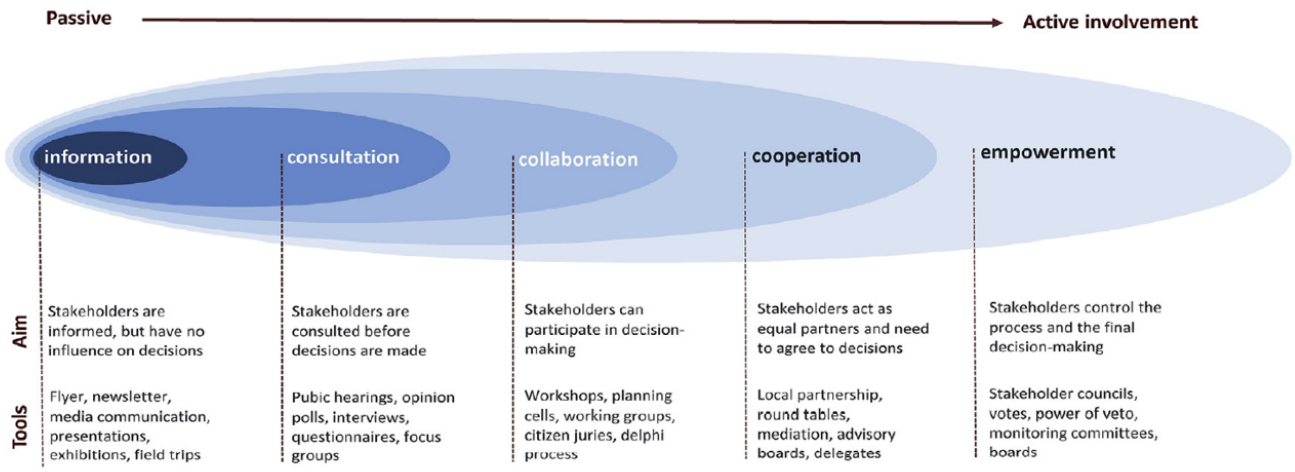


Figure 4 Different intensities of stakeholder engagement, taken from Grygoruk and Rannow (2017)[1]

[1] Grygoruk, M. & Rannow S. (2017). Mind the gap! Lessons from science-based stakeholder dialogue in climate-adapted management of wetlands. Journal of Environmental Management. https://doi.org/10.1016/j.jenvman.2016.10.066

Table 1 Overview of stakeholders. EMP = empowerment; COL = collaboration; COO = cooperation; CON = consultation

Acronym	Sector	Involvement status*		Scale (level)	Ownership	Description: Expectations, interests, responsibilities	WebLink	Role: implementer, funder, monitorer
WWF HU	Environment, climate and disaster	Already involved	EMP	National	NGO	MERLIN Case Study project manager	https://wwf.hu/en/home/	Coordinator, Monitorer
	Other	To be invited	COL	Municipal	NGO	I, R: organization of environmental protection actions E: strong involvment of inhabitants, increasing responsibility for the environment	https://www.facebook.com/aztakeservit/	monitorer
	Other	To be invited	COL	Municipal	Community group	I, R: kayak-canoe teaching	http://www.bajaivizisport.hu/	monitorer
	Other	To be invited	COL	Regional	NGO	I, R: organization of kayak-canoe trips E: a lot of guests involved, good water quality	http://dunatura.hupont.hu/	monitorer
	Other	Already involved	COL	Local	Community group	I, R: kayak-canoe teaching		monitorer
	Forestry	Already involved	COO	Municipal	Private (commercial, investor, etc)	R: management of the Gemenc forest area and wild animals I: a lot of trees for profit E: ?	http://gemenczrt.hu/	implementer
	Forestry	To be invited	COO	Regional	Public	R: management of the Gemenc forest area and wild animals I: a lot of trees for profit E: ?	https://parkerdo.hu/	implementer
	Water resources	To be invited	COO	Regional	Public	R: provision of drinking water	https://www.baranyaviz.hu/	implementer
DRV	Water resources	To be invited	COO	Regional	Public	R: provision of drinking water	https://www.drv.hu/drv	implementer
KH Bács-Kiskun	Cross Sector (governance, regulation, etc.)	Already involved	COO	Municipal	Public	R: Legal and regulatory tasks	http://bkmkh.hu/kecskemeti_jarasi_hivatal/_kornyezetvedelmi_es_termeszetvedelmi/	monitorer

KH Baranya	Cross Sector (governance, regulation, etc.)	Already involved	COO	Municipal	Public	R: Legal and regulatory tasks	https://www.kormanyhivatal.hu/hu/baranya/szervezeti-egysegek-menu/kornyezetvedelmi-termeszetvedelmi-es-hulladekgazdalkodasi-foosztaly	monitorer
ADUVIZIG	Water resources	Already involved	COO	Regional	Public	R: Operation of state- owned water facilities	http://www.aduvizig.hu/	implementer
DDVIZIG	Water resources	Already involved	COO	Regional	Public	R: Operation of state- owned water facilities	https://www.ddvizig.hu/	implementer
OVF	Water resources	Already involved	COO	National	Public	Central authority for water management	https://www.ovf.hu/	coordinator, implementer
KDVVIZIG	Water resources	Already involved	COO	Regional	Public	R: Operation of state- owned water facilities	https://www.kdvvizig.hu/	implementer
DDNPI	Environment, climate and disaster	Already involved	COO	Regional	Public	R: nature conservation management, ecotourism, environmental education	https://www.ddnp.hu/	implementer
DINPI	Environment, climate and disaster	Already involved	COO	Regional	Public	R: nature conservation management, ecotourism, environmental education	www.dinpi.hu	implementer
HAKI	Other	To be invited	COL	National	Other	R: fish research	https://haki.naik.hu/	monitorer
MHT	Other	To be invited	CON	National	Other	R: exchange of knowledge and experience between professionals in the field of water sciences and technology	http://www.hidrologia.hu/mht	monitorer
BME	Other	To be invited	CON	National	Other	R: Education, research, innovation in the field of technology, natural science, and economics	https://www.bme.hu/	monitorer
IAE	Other	To be invited	CON	National	Other	R: research in water- related sciences	https://www.voi.ecolres.hu/	monitorer
	Cross Sector (governance, regulation, etc.)	Already involved	COL	Local	Public	R: provision of public services to the local inhabitants	https://mohacs.hu	monitorer

	Cross Sector (governance, regulation, etc.)	To be invited	COL	Local	Public	R: provision of public services to the local inhabitants	phszeremle@t-online.hu	monitorer
	Cross Sector (governance, regulation, etc.)	To be invited	COL	Local	Public	R: provision of public services to the local inhabitants	polgarmester@hercegszanto.h u	monitorer
	Cross Sector (governance, regulation, etc.)	To be invited	COL	Local	Public	R: provision of public services to the local inhabitants	hivatal@bogyiszlo.hu	monitorer
VÖI	Other	Already involved	CON	National	Public	R: Education, research, innovation in the field of technology, natural science, and economics	https://ecolres.hun-ren.hu/en/intezetek/institute-of-aquatic-ecology/	monitorer
BLKI	Other	Already involved	CON	National	Public	R: Education, research, innovation in the field of technology, natural science, and economics	https://www.blki.hun-ren.hu/en	monitorer
AM	Agriculture	Already involved	COL	National	Public	Responsible for agricultural subsidies, regulation	tvhat@am.gov.hu	coordinator
BM	Water resources	To be invited	COL	National	Public	Highest level authority of water management	https://kormany.hu/belugyminiszterium	coordinator
	Water resources	To be invited	EMP	National	Public	Government-owned water planning company that designed the Bereg landscape's water management system, will support technical implementation	https://environ.hu/	monitorer
	Other	To be invited	CON	National	Public	R: Education, research, innovation in the field of technology, natural science, and economics	https://en.uni-nke.hu/faculties/faculty-of-water-sciences/about	monitorer
MOHOSZ	Fishery	To be invited	CON	National	Public	R: provision of public services to the local inhabitants	https://horgaszjegy.hu/ht/horgaszoknak/fooldal	implementer

4 Green deal goals

Our long-term goal is to establish a biodiverse, healthy, and functional Danubian floodplain system that preserves all floodplain habitats, mitigates river incision processes, improves lateral hydrological connectivity between floodplain habitats and the main channel, and halts succession dynamics. Achieving such a sustainable river-floodplain management system also entails water retention to counteract increasing drought periods. Realizing this vision in the region requires harmonizing ecological principles with navigation, forestry, agriculture, and recreation activities such as fishing and water- related tourism.

The most urgent and significant goals, which encompass numerous advantages, include enhancing biodiversity net gain, bolstering flood/drought resilience, regulating climate, promoting health and well-being, and fostering inclusivity. The deterioration of species and ecosystems poses the most significant threat in today's world, leading to the loss of ecosystem functioning and vital ecosystem services. Therefore, focusing on biodiversity improvement yields substantial benefits, including regulating ecosystem services crucial for controlling climatic processes. Climate change, a consequence of various human activities, exacerbates hydrological processes. Mitigating these impacts entails restoring riverine ecosystems, which can be measured by indicators of resilience and climate regulation.

Regulative ecosystem services, despite their critical importance, often receive insufficient attention, and many fail to recognize their direct link with natural ecosystems. Physical and mental well-being form the foundation of a prosperous life, and heightened awareness is essential for understanding that healthy ecosystems offer one of the best opportunities to achieve this goal. However, realizing this vision requires committed individuals, making inclusivity, education, and involvement of all possible interest groups imperative.

The goals outlined align with the objectives of the EU Green Deal, which aids in defining and achieving restoration targets for biodiversity improvement and ecosystem services enhancement. The RSP initiative distinguishes primary and secondary goals. Primary goals represent the main objectives pursued by the RSP, while secondary goals offer additional areas where the RSP can contribute. This chapter provides a summary of the primary and secondary Green Deal goals crucial for restoring the region.

4.1 SMART Green Deals relevant for the region: primary goals

Our analyses in the framework of MERLIN suggest that protected areas in this Southern Hungarian portion of the Danube have higher potential for the maintenance of aquatic biodiversity than unprotected ones. This is because these areas cover the active floodplain where all floodplain habitat types are still present, while unprotected areas cover mainly agricultural and urbanized areas where (semi) artificial channels are predominant. The evaluations also highlighted which are the most valuable water bodies for conservation purpose, i.e., the ones that have the highest biodiversity potential and lowest human utilization. Most of these waterbodies are situated in the Gemenc area (e.g., Nyéki-Holt-Duna, Decsi-Kis-Holt-Duna, Káposztás Duna, Forgó-tó, Grébeci-Holt-Duna), which is one of the widest active floodplains of the Middle-Danube and contains waterbodies that are good representatives of the full array of lateral hydrological connectivity. Nevertheless, we identified many waterbodies that still have relatively high biodiversity potential, yet where human utilisation is also relatively high (e.g., Szeremlei Sugovica, Kiskoppányi side arm, Bátai oxbow). Their utilisation contains mainly recreational angling, but, in fact, fishing pressure and disturbance of the habitat and the biota by transformation of invasive fishes, the riparian zone and the bank for fishing stations, fish bait feeding etc. can be high in some of these waterbodies. Decreasing human pressure in protected areas and the maintenance of natural ecological processes should thus be an important management need for more effectively conserving biodiversity in the region. Intensity of recreation service utilisation varied widely among the waterbodies, especially in protected areas. In some protected parts of the floodplain (Gemenc area), hiking, cycling and canoeing routes provide recreational services for the visitors (https://visithungary.com/articles/gemenc- forest). The pressure by tourists is relatively low because the area is remote from the capital and population density of resident inhabitants is low in the region. Providing such recreational facilities that also call attention to the importance of floodplain conservation is important for raising society’s awareness of conserving biodiversity.

Unprotected areas do not contain aquatic habitats with exceptionally high biodiversity. Rather, these habitats are mainly used for fishing/angling activities or to drain water from agricultural areas. In this regard the present land use practice is advantageous since protected areas serve mainly for biodiversity conservation while nonprotected areas are under more intense human utilisation. It is still a question, however, whether this land sparing strategy will be effective for saving biodiversity in the long run with intensification of human needs and climate change effects. Therefore, conservation and restoration activities should be increased in the future in the area.

4.1.1 Climate regulation

Since forests and wetlands play a crucial role in carbon dynamics and climate change mitigation, the most important climate related goal is to maintain forested areas in the landscape. Natural forest dynamics should be maintained at least in the strictly protected areas of the floodplain, but forest plantations should be encouraged in other parts of the landscape, too. Another goal is to preserve aquatic habitats from desiccation processes in the long run. This can be only achieved if the floodplain receives enough water according to environmental flow requirements. Estimations are necessary to estimate the required dynamics and amount of water on the long run.

Indicators

- Carbon sinks increased
- Preserve or increase the area of native forests (ha)
- Increase the area of inundated areas (ha)

4.1.2 Biodiversity net gain

Considering the huge decrease in the area of floodplain habitats over centuries, it is clear that management must preserve the remaining, still actively functioning floodplain to reach biodiversity goals. Wetlands are the most threatened habitat types in the world, although they play an outstanding role in biodiversity conservation and freshwater purification. Thus, purchasing land (to become state owned instead of private property) and revitalization of aquatic floodplain habitats and wetlands would be important in biodiversity conservation. These sites could be important targets of eco-friendly tourisms and related cultural ecosystem services (e.g., functioning as demonstration sites of the use of former floodplain ecosystem services. This could decrease the load of tourism in protected areas.

Overall, careful spatial planning, which would retain sites for biodiversity conservation (land sparing) while others provide a variety of ecosystem services for society (land sharing), could ensure the maintenance of floodplain multifunctionality for biodiversity conservation and the use of a variety of ecosystem services. We believe there is still some space for natural water retention to provide both biodiversity benefits and human well-being in this formerly large river–floodplain system.

Indicators

- Preserve or improve the conservation status of HD Annex I listed habitats including wetland and freshwater habitats, focusing on selected indicator species
- Preserve or improve the conservation status of HD Annex II and Annex IV listed species including wetland and freshwater species, focusing on selected indicator species
- Preserve or improve conservation status of Annex I listed species in the Birds Directive, focusing on selected indicator species
- Preserve or increase the area of hydrologically functioning floodplain water bodies (ha)
- Increase the area of wave protected shorelines (ha)

4.1.3 Inclusivity

Inclusivity in restoration and land use design ensures that diverse perspectives, needs and values are considered, leading to more equitable and sustainable outcomes. Engaging a wide range of stakeholders fosters community ownership, increases the likelihood of successful implementation, and promotes resilience by incorporating varied expertise and experiences. Ultimately, inclusivity not only enhances the effectiveness of restoration efforts but also strengthens social cohesion and environmental stewardship.

Indicators

- NBS concept is approved by core (professional) stakeholders. The concept is discussed and updated by core (professional) stakeholders in 3-year periods and adjustments are made by using lessons learnt

- At least one citizen involvement or awareness raising action is organized per year at selected pilot sites (NBS implementation sites)
- Number of stakeholder workshops organized for core and wider group of stakeholders
- Number of participants in stakeholder workshops

4.2 SMART Green Deals relevant for the region: secondary goals

4.2.1 Sustainable transport

Since navigation plays a crucial role in the Middle Danube, sustainable transport should be a key goal (refer to sectoral briefings in WP4, Merlin). Ensuring compliance with international fairway conditions on the Danube should not compromise the hydromorphological conditions of the main course or the lateral connectivity with the floodplains. During periods of critical low water conditions, prioritizing the preservation of the most valuable habitats and species, as well as maintaining drinking water supply services, is of utmost importance. Neither fairway maintenance nor the use of the fairway by tourist or cargo ships should cause significant harm. Additionally, maximizing the fairway capacity of the Danube to meet the goals of the transport sector must account for climate change scenarios and the projected increase in the length of low water level periods. This consideration is crucial as limitations in fairway depth expectations may arise during these periods.

Indicators

- Increase the area of wave protected shorelines (ha)
- Implementation of environmental flow standards in harmony with navigation

4.2.2 Flood and drought resilience

Restoring sidearms helps sustain clean water supplies by enhancing water infiltration and storage capacity in wetlands and soils, as well as facilitating the recharge of aquifers. Natural storage features such as soil, groundwater, surface water, and aquifers have a crucial role in mitigating drought. Additionally, they contribute to regulating water quality and mitigating the impacts of catastrophic flood events. Moreover, during droughts, restored sidearms can act as cooling agents, providing further resilience to ecosystems and communities.

Indicators

- Increase the area of restored and functioning side-arms and adjacent floodplains (ha)
- Increase the storage capacity of functioning aquifers (ha)

4.2.3 Health and wellbeing

Restoration of sidearms not only enhances habitat and biodiversity by creating diverse aquatic and riparian environments but also provides richer angling opportunities and fosters various forms of tourism or research. These restored areas attract a multitude of fish species, creating ideal conditions for angling enthusiasts and promoting recreational activities centered around water-based tourism. Additionally, the revitalization of sidearms offers a unique opportunity to showcase the natural beauty and ecological significance of the landscape, making it a prime destination for ecotourism. Visitors can engage in activities such as birdwatching, nature walks, and boating, all while appreciating the restored ecosystems and their inherent value to the environment and local communities. The primary business opportunity lies in preserving and enhancing ecosystem services through river and habitat restoration efforts, coupled with raising public awareness about the value of living rivers and fostering a sense of ownership over key symbolic spots along the river. While exploiting these business opportunities, it is important to recognize that certain core zones undergoing restoration may need to be restricted from visitor access, either by closure to the public or by permitting visits only with guides. Alternatively, these areas could be opened exclusively for scientific monitoring purposes. This strategic approach ensures that restoration efforts can proceed effectively while balancing the need for conservation with the desire for tourism and recreation.

Indicators

- Number of visitors in restored areas (individual)
- Income from ecotourism (HUF)

4.2.4 Sustainable food systems (F2F)

Given the anticipated drought periods in the Carpathian Basin, Hungary, it's imperative to prioritize mitigating the effects of climate change on agriculture. Looking to traditional models of animal husbandry in floodplain forests can offer valuable insights into developing more sustainable agricultural practices. Transitioning away from large-scale monoculture crop production towards more diversified farming methods presents an opportunity for local farmers to diversify their food resources and boost their income through the sale of locally produced goods. By adopting agroecological principles such as crop rotation, agroforestry, and integrated pest management, farmers can enhance soil health, increase resilience to climate variability, and contribute to the conservation of biodiversity.

An important goal is also to change the land use, especially on deep floodplains, converting arable land back into meadows or pastures. It should be kept in mind that if Danube will loose its discharge from glaciers, it will depend solely on precipitation, which is becoming increasingly erratic with long summer droughts. This poses a significant threat to agriculture. Therefore, we should restore the floodplains' ability to slow the water cycle and mitigate climate change.

Indicators

- Improvement of soil organic matter content and soil structure due to improved water supply
- Improvement in plant and animal diversity within agricultural systems
- Improvement in the number of farming practices
- Improvement in food security, employment opportunities and social cohesion due to changing farming practices

5 From general goals to actions

Stakeholder workshops highlight the pressing need for restoration actions, yet achieving large-scale restoration across the entire area requires a consensus and strategic cooperation among stakeholders. However, each stakeholder currently faces their own administrative and bureaucratic burdens, impeding cohesive thinking and the development of a comprehensive restoration strategy. National-level action plans aimed at mitigating drought effects may prioritize other regions, limiting support for large-scale restoration in the target area. Without robust top-down support, grassroots restoration efforts may falter. This robust top-down approach has been missing and there is no institution, ministerial body, or interministerial agency which would take over this task. Bringing the topic in the political arena is not a proper solution since Danube related questions are still politically sensitive issues, since the Gabcikovo-Nagymaros dam project which was rejected in Hungary. Therefore, the following approach is suggested on mid and long-term:

1. Facilitating intensified cooperation among stakeholders to formulate a sustainable landscape and water management plan for the region.
2. Prioritizing local-scale restoration actions within this framework.
3. Implementing pilot projects focused on floodplain restoration, mitigating shipping impacts, and promoting sustainable forestry management and agriculture.
4. Demonstrating the effectiveness of restoration actions to stakeholders and society at large.
5. Advocating at governmental level for strategic large-scale restoration of the river-floodplain system (resulting environmental resilience and socio-economic well-being) .

Climate Goal

Action 1:

Climate adaptation program to be developed including priority on floodplain and river restoration Action 2:

Preserve or improve the area of native forests. Protect the forest riparian zones and increase their area (gallery forests) along the margin of selected channels, side-branches and oxbows.

Action 3:

Increase the area of constantly/regularly flooded or inundated areas.

Biodiversity Goal

Action 1:

Develop and implement a monitoring program of NATURA 2000 habitats and species. Propose and implement conservation actions in case of decline.

Action 2:

Preserve or increase the area of hydrologically dynamic, functioning floodplain water bodies, especially in the Gemenc floodplain. Keep riparian forests along these water bodies.

Action 3:

Explore the biodiversity values of non-protected, not N2000 sites and channelized sections, too. Facilitate the protection of protected species by enhancing habitat conditions.

Action 4:

Increase the area of wave protected shorelines in the main channel of the Danube.

Inclusivity goal

Action 1:

Organize stakeholder meetings to initiate and facilitate the stakeholders' strategic collaboration to develop a sustainable landscape and water management plan for the region.

Action 2:

Propagate the importance of sustainable water management via education, off-line and online awareness raising activities.

Action 3:

Cooperation of key stakeholders to develop a sustainable landscape and water management plan for the region. It will be a landscape planning, which consists of plans for smaller sections.

Sustainable transport

Action 1:

Together with navigation stakeholders identify measures which can improve both fairway conditions and river hydromorphology on selected river stretches

Action 2:

Increase the area of wave protected shorelines in the main channel of the Danube. Improve awareness of waterway users to wave effects on biota.

Flood and drought resilience

Action 1:

Increase the area of restored side arms and wetlands.

Action 2:

Increase the storage capacity of functioning aquifers.

Action 3:

Design water government plans which ensure the permeability between floodplain and flood-protected areas of the former floodplain to increase water retention potential.

Health and well being

Action 1:

Promote recreational opportunities of floodplains and ecosystem services which healthy rivers and floodplains provide.

Sustainable food systems (F2F) goal

Action 1:

Analyse the cost of land transformation from monoculture to more diverse agriculture options. Conduct cost-benefit analysis, and social attitude research to support sustainable land use practices.

Other primary/secondary goal

Restoration actions: Restoration actions which will happen in the region during implementation of upcoming projects are: Danube Parks - Korpádi strait, groynes, R4MDD - Bátai oxbow water retention structure

Monitoring actions: Need for biomonitoring is already emphasized at the biodiversity goals and actions, as the status of species and habitats is a key to identify the necessary conservation activities. Monitoring the results of the restoration works and their impact on the society and ecosystem services is necessary to evaluate the effectiveness of the restoration.

Funding actions: see also chapter 7 (Budget) of this document for more details. While it is not relevant to specify funding actions at the moment, it is important to define them during the preparation of concrete implementation projects. Public funds are the primary sources available, with company sources serving as additional options.

Research and knowledge building actions: As already mentioned in the monitoring and biodiversity goals, there is a significant need for further research (hydromorphology, habitats, species) because much data is missing to properly define restoration activities. There is also a knowledge gap in ecosystem service related research, with ongoing expert debates on how to monetize value that the rivers and floodplains provide to society. Formulation of concrete research questions needs to be part of the proposed workshops and bilateral meetings.

Our vision on an infographic:

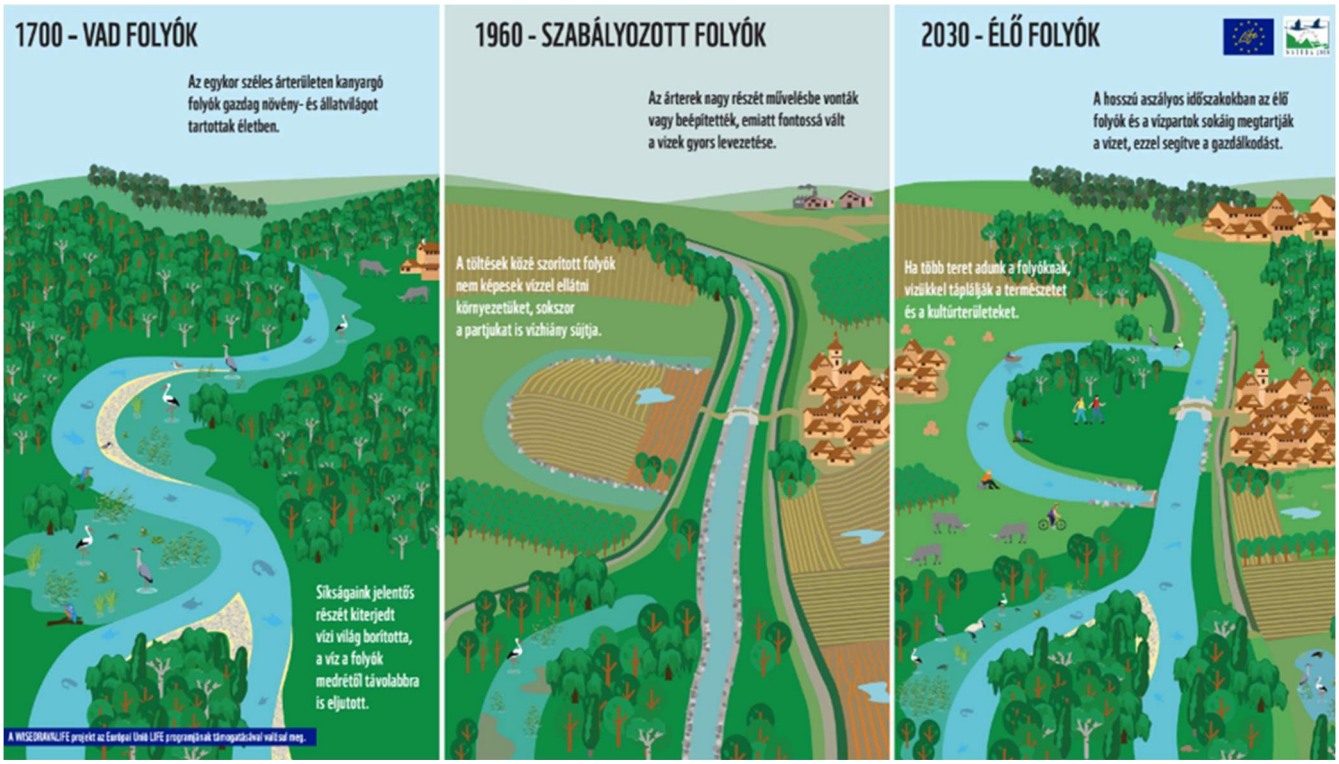


Figure 5 Various states of rivers from past century until future vision

This infographic represents our vision of a functional consensus of nowadays on use of rivers and floodplains. The first part of the infographics symbolizes the historical state of the river, the pre-regulation conditions. The middle picture shows the post-regulation state of riverine habitats with various negative consequences of regulations.

The third picture shows the realistic state which could be achieved with common effort. This state is already able to mitigate climate change effects.

6 Timeline

The timeline is developed separately for the actions in the short term, within a 2-year period, and in the long term, within an 8-10 year timeline. The short-term actions are supported by further sub-actions.

Table 2 Short-term actions

Key actions within a 2-year period	2026/1st half	2026/ 2nd half	2027 / 1st half	2027/ 2nd half
Key activity 1 Organize stakeholder meetings (action under inclusivity goal)	X	X	X	X
sub-action: 1 workshop per year	X		X	
sub-action: bilateral meetings with key stakeholders	X	X	X	X
Key activity 2 Propagate the importance of sustainable water management (action under inclusivity goal)	X	X	X	X
sub-action: develop and produce products and materials for dissemination	X	X		
sub-action: off-line and online awareness raising activities,		X	X	X
Key activity 3 develop and implement monitoring program		X	X	X
sub-action: develop joint monitoring projects and harmonize them with restoration activities, scan funding opportunities		X	X	X

Table 3 Long-term actions

Key actions in the long run	2028-2029	2030-2031	2032-2033	2034-2035	2036-2037
activity 4 (long run) Increase the area of constantly/regularly flooded or inundated areas			X	X	X
activity 5 (long run) Design water government plans which ensure the permeability between floodplain and flood-protected areas of the former floodplain to increase water retention potential	X	X			
activity 6 (long run) Develop and Implement an ecotourism plan for the region, which shows the multifunctional role of the floodplain	X	X			

7 Budget

The key activities within 2 years from 2026 require a relatively moderate budget. The regular meetings and workshops are identified as key ones which will support the implementation of the mid and long run activities.

Budget of short-term actions:

- Key activity 1 - Organize stakeholder meetings (action under inclusivity goal): €2000/year, maximum €4000/year if the workshop is co-organized with a field visit;
- Key activity 2 - Propagate the importance of sustainable water management (action under inclusivity goal): offline events: €15000 - €20000 depending on the equipment to be developed and number of events; online tools: €15000
    - €25000, the costs depend on what online tools are selected and how intensively disseminated;
- Key activity 3 - develop and implement a comprehensive monitoring program: The costs are highly dependent on complexity of the program and territory to be monitored. Estimated costs € 20000-€30000 / year.

These 3 key activities are to be financed from public funds, from calls for proposals. Involvement of the private sector is an opportunity if a strong partnership is established or there is a high potential in disseminating the results.

Budget of long-term actions:

- activity 4 (long run), “Increase the area of constantly/regularly flooded or inundated areas”: the restoration costs can only be preliminary estimated: €600 000 - €1 000 000 per year.
- activity 5 (long run), “Design water government plans which ensure the permeability between floodplain and flood- protected areas of the former floodplain to increase water retention potential”; If the plans cover technical and governance components, their costs can be €80 000 - € 400 000.
- activity 6 (long run), “Develop and implement an ecotourism plan for the region, which shows the multifunctional role of the floodplain”; The costs without implementation of the plan can be estimated to €200 000.

8 Uncertainties and assumptions/ boundary conditions

8.1 Uncertainties

- missing political will to open intersectoral discussion on what is the vision of Hungary for the Danube;
- traditional sectoral behaviour doesn't or very slowly change;
- missing coordinator (coordination body) for developing joint, cross-sectoral programs and supporting the implementation of actions which are to be (should be) identified by the programs.
- increasing water demands to be satisfied especially irrigation, cooling water of power plants;
- increasing demand to invest in grey infrastructure (easy to implement, quick and controllable results); the biggest grey infra investments (dams on the river) usually depends on political will, while expectation of the society, experts' inputs or economic arguments are neglected;
- traditionally low interest/capacity of stakeholders and community in mid-, long-term strategic planning processes

8.2 Assumptions and boundary conditions

The opportunistic scenario for the scalability plan that the MERLIN partners envision relies on several critical factors and conditions. Here's a detailed breakdown of these conditions and their implications:

1. Willingness to Cooperate Among Core Stakeholders:**
    - Current Situation: For any scalability plan to succeed, it is essential that the core stakeholders, including government bodies, local communities, environmental NGOs, and businesses, are willing to cooperate.
    - Future Needs: This cooperation must not only be maintained but also improved over time. Strong relationships and a shared vision among stakeholders will facilitate smoother implementation of nature-based solutions (NBS) and other initiatives.
    - Impact: Improved cooperation can lead to more integrated and comprehensive approaches to river management, ensuring that efforts are synergistic rather than fragmented.
2. Openness of Impactful Sectors:
    - Current Situation: Sectors that have significant impacts on the Danube, such as agriculture, industry, and urban development, need to recognize the importance of sustainable practices.
    - Future Needs: There should be a growing recognition of the benefits of NBS over technocratic, grey infrastructure solutions. This implies a cultural and perceptual shift towards valuing natural and ecological methods for managing water resources and river ecosystems.
    - Impact: As these sectors become more open to NBS, there will likely be increased adoption of practices that enhance the river's health and resilience, contributing to the overall sustainability of the Danube.
3. No New Hydropower Plants on the Danube (Slovakian-Hungarian and Hungarian Stretches):
    - Threats of hydropower plants at any time: The construction of new hydropower plants can significantly alter river ecosystems, impacting biodiversity, sediment transport, and water quality.
    - Future Needs: A moratorium or prohibition on new hydropower projects in these key stretches is crucial. This would help preserve the natural flow regime and the ecological integrity of the river.
    - Impact: Without new hydropower plants, existing ecological conditions can be maintained, providing a stable foundation for NBS and other restoration efforts.
4. Controllable Levels of Recreational Use Pressure:
    - Current Situation: Recreational activities, while beneficial for local economies and communities, can exert pressure on river ecosystems through pollution, habitat disturbance, and increased human traffic.
    - Future Needs: The level of recreational use needs to be carefully managed to prevent degradation of intact river stretches. This means implementing regulations, providing education on sustainable

practices, and potentially limiting access to sensitive areas. Impact: By keeping recreational pressure at a moderate level, the natural habitats and biodiversity of the river can be protected, ensuring that the ecosystem services provided by these areas remain or increase.

5. No New Heavy Infrastructure Developments on Intact River Stretches:
    - Current Situation: Large-scale infrastructure projects (which are not concrete risks now, but can't be excluded) can lead to habitat destruction, altered hydrology, and pollution, adversely affecting river health.
    - Future Needs: It is vital to prevent the initiation of new developments that require significant infrastructure works on pristine river stretches. This can be achieved through stringent land-use policies and robust environmental impact assessments.
    - Impact: Preserving intact river stretches allows for the continued provision of ecological functions and services, supporting biodiversity and resilience against environmental changes.

8.3 Conclusion

For the opportunistic scenario to be feasible within the scalability plan, the conditions outlined must be met. This involves fostering a cooperative environment among stakeholders, increasing openness to NBS, managing recreational use, and avoiding new heavy infrastructure developments on untouched river stretches. These measures will help maintain and enhance the ecological health and resilience of the Danube, facilitating sustainable development and conservation efforts.