WP4 Recommendations

Deliverable D 4.4.3

Summary of general recommendations for a successful realization process, communicated to local, national, and international stakeholders in workshop activities and publications as input for D 5.2.1 and D 5.2.2.

Work Package (WP)	WP4: Flood prevention pilots
Activity	Activity 4.4
Deliverable	D 4.4.3 Summary of general recommendations for a successful realization process, communicated to local, national, and international stakeholder in workshop activities and publications as input for D 5.2.1 and D 5.2.2.
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Involved partners	All partners from countries with pre-selected pilot areas (NARW, NIHWM,), CUEI, TUM, WWF HU
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1. Summary

Deliverable D 4.4.3 summarizes the main recommendations and lessons learned from Work Package 4 (WP4) of the Danube Floodplain Project. Comments and ideas were collected from the project and associated strategic partners, to transfer knowledge to future projects that will deal with floodplain restoration measures.

In terms of planning and design, we suggest that the measures are not planned by a singular institution, but the development should be built on the collaboration of different authorities and institutions, as well as stakeholders. Enough time should be considered for this task when determining the operating schedule. The floodplain restoration measures should focus on reducing flood risk and improving the water status, i.e. fulfilling the European Union's Water Framework Directive (WFD) and Floods Directive (FD). In this deliverable, we describe some examples that can potentially fulfill the requirements of both directives.

Using two-dimensional hydrodynamic models is an appropriate way to analyze the impacts of possible restoration scenarios on the flood hazard and the corresponding risk. The restoration measures are very different according to each pilot area and the results' discussion should consider the models' limitations (e.g., uncertainty), as well as the potential effects of tributary rivers.

Not only hydrological and hydraulic parameters but also habitat modeling and ecosystem services (ESS) can be used to evaluate the measures more holistically. In terms of biodiversity and habitat assessment, fuzzy logic-based models are a promising option, which allows combining different kinds of input data and knowledge. In general, a meso-scale habitat modeling approach, used in the Danube Floodplain Project, can provide an overview of the ecological effect of restoration measures, but habitat modeling on the micro-scale gives more detailed insights and evaluates specific target species. At the same time, such modeling is data demanding and labor-intensive.

The concept of ESS is still poorly integrated into decision-making in countries of the Danube River Basin (DRB). Within the project's framework, we chose a mixed approach of stakeholder engagement, land use/land cover analysis, and the Toolkit for Ecosystem Service Site-Based Assessment (TESSA) to estimate benefits of floodplain restoration in terms of monetized ecosystem services. We encourage the utilization of TESSA for the further evaluation of other kinds of nature-based solutions (NBS). However, we see the need for TESSA to add more ESS within the tool, specifically concerning habitat services, noise regulation, or local climate regulation. Moreover, the results are affected by uncertainties and more modeling could be implemented for some ESS (e.g., water quality).

We recommend extending the cost-benefit analysis with additional benefits (monetized ecosystem services) in decision-making for flood risk purposes, as done within the Danube Floodplain project. Nevertheless, we underline that the CBA is only one part of a bigger picture that should be considered when meeting decisions in terms of flood risk management and nature-based solutions. Engineers, experts, and researchers should only provide the tools and results to allow decisions to be taken by politicians.

We finally recommend continuing to use stakeholder engagement in future projects. Stakeholder workshops proved to be a constructive way of communicating our ideas to the stakeholders. Personal communication should be supported by presentations of the actual situation and possible solutions during meetings in the local areas. The widest possible professional range and knowledge should participate, from experts to the local population. Regarding the content of the workshops, the concept of ESS must be presented and explained understandably to the stakeholders. Finally, stakeholders should be kept updated about the developments of the restoration projects, to maintain the cooperation between them and the project partners.

A general evaluation tool combining results from the hydraulic analysis, habitat modeling, ecosystem services, cost-benefit, and stakeholder analysis would simplify and standardize the assessment of floodplain restoration projects. Within WP4 and WP6, such a general evaluation tool for restoration projects called FEM Tool was developed (see Danube Floodplain, 2021c).

2. Introduction

Adapted from Danube Floodplain (2020a), Danube Floodplain (2020b), Danube Floodplain (2021b), and Perosa et al. (2021b)

European rivers are under enormous pressure. Nutrient inputs from agriculture, water abstraction, energy production from hydropower plants, and climate change have changed the river ecosystem dramatically in recent decades. They all have a direct or indirect impact on the ecological status of surface waters and groundwater. Within the Danube River Basin (DRB), only 25% of rivers have good ecological status or good ecological potential (ICPDR, 2015b). Around 77% have good chemical status (without considering the influence of mercury on biota). The high pressure on the Danube River and its heavy use also affect its floodplains. Today, only 32% of the former floodplains still exist (Hein et al., 2016). European floodplains are rarely undisturbed by human activities, with the result that only 17% of the floodplain habitats and species listed in the Habitats Directive are at good conservation status (European Environment Agency, 2020). At the same time, flood risk management became an increasingly relevant issue. Recognizing that Europe's rivers and their floodplains are under great pressure and have undergone major changes, the EU has drawn up several directives to protect and maintain their ecological status on the one hand, and to strengthen the flood-regulating function of floodplains on the other hand.

In October 2000 the EU established the Water Framework Directive (WFD) to protect and enhance the ecological status of water bodies and to ensure sustainable water use (European Parliament, 2000). It is a new water management approach in which river basins act as management units and not national or political boundaries. The WFD aimed to achieve the good ecological and chemical status of rivers and groundwater throughout Europe by 2015. For achieving these goals, transboundary management of rivers is considered to be crucial. To this end, the ecological and chemical status of surface waters and groundwater was recorded and assessed based on a five-tier scale and, where necessary, measures were taken to improve the ecological status. Since good status could not be achieved for all waters by 2015, monitoring and implementation of restoration measures will be repeated every six years. So far, the implementation of the WFD has slowed the deterioration of water status and reduced chemical pollution (mainly from point sources). However, due to the delayed implementation of the Directive, less than half of the EU's water bodies are in good status, although the deadline for achieving this objective, except in duly justified cases, ended in 2015 (European Commission, 2019).

A further consequence of the diverse use or partial overuse of floodplains is the reduction of natural flood areas along rivers. This is accompanied by flood damage in agriculture and urban areas. The EU, therefore, adopted the Flood Risk Directive (FD) in 2007 (European Parliament, 2007). The EU Member States are required to prepare flood hazard maps, flood risk maps, and flood risk management plans for areas with potentially significant flood risk, to review them every six years and update them where necessary, as done in the Danube River Basin (ICPDR, 2015a). The aim of the European Flood Risk Management Directive (FRMD) is to reduce the damage caused by floods to human health and human life, environment, cultural heritage, and economic activities and infrastructure (European Parliament, 2007). Potential measures for flood risk management can be hazard zone planning, dedication, local development, building regulations, maintenance, etc. In addition to flood retention areas, more drastic measures such as resettlement from risk areas are also an effective measure, although these are rarely implemented due to a lack of legal regulations and low acceptance by affected people. Since floods do not stop at borders, the management units are the river basins, as for the WFD.

This Danube Floodplain Project's deliverable (D 4.4.3) contains recommendations for restoration measures aimed at improving the ecological and chemical status of rivers and floodplains and reducing flood damage. The main objective is to suggest measures that simultaneously improve the ecological status and prevent flood-related damages and costs. Figure 1 shows the framework, in which this deliverable is included, namely work package 4 (WP4) of the Danube Floodplain Project. In deliverable D 4.1.1 (flood prevention measures tested in pilot areas) (Danube Floodplain, 2020a), the effect of floodplain restoration measures in different flood events was assessed. The national partners applied hydrodynamic two-dimensional models in five pre-selected pilot areas to investigate the hydraulic efficiency of restoration measures. Spatial results of the applied hydrodynamic models in raster format of the maximum water depth and flow velocity of each scenario are available for each pilot area showing different effects depending on the restoration measures and maximum discharge of the simulated flood event. These results are an important input for biodiversity, ecosystem services, and flood risk assessments. The planned measures in the pre-selected pilot areas affect a wide range of stakeholders including landowners and residents. Therefore, stakeholders were informed from the beginning about the intentions of the project and were partly involved in the development of the measures. This process, which included stakeholder workshops in the pilot areas, is described in deliverable D 4.2.1 (Danube Floodplain, 2019), where the fundamental knowledge of the stakeholders is recorded and was later used to evaluate the ecological, economic, and cultural values of the pilot areas with the aid of the ecosystem services approach. The ecosystem services were mapped for deliverable D 4.2.2 (Danube Floodplain, 2020b), which provided information about nature's regulatory services like nutrient retention, the supply of natural products like water, and the cultural uses within an area, including the stakeholders' point of view. Both reports about the stakeholder analysis, their interests, and their benefits from the floodplains (Danube Transnational Programme, 2020) and the report about the ecosystem services mapping (Danube Floodplain, 2020b) created the basis for further analyses of ecosystem services and provided useful input data for a more specific and monetary-based assessment of the floodplain restoration measures in Activity 4.3. This lead to deliverable D 4.3.1 (Danube Floodplain, 2021a), which includes the results in an extended cost-benefit-analysis (CBA), estimated following the methodology described in D 4.3.2 (Danube Floodplain, 2021b). An additional deliverable of Activity 4.3 is the D 4.3.4, which aims at summarizing the whole methodology of WP4. As a final step, the current deliverable (D 4.4.3) should collect all recommendations and lessons learned from this work package on pilot areas, to potentially improve the implementation of similar floodplain restoration measures in the future.

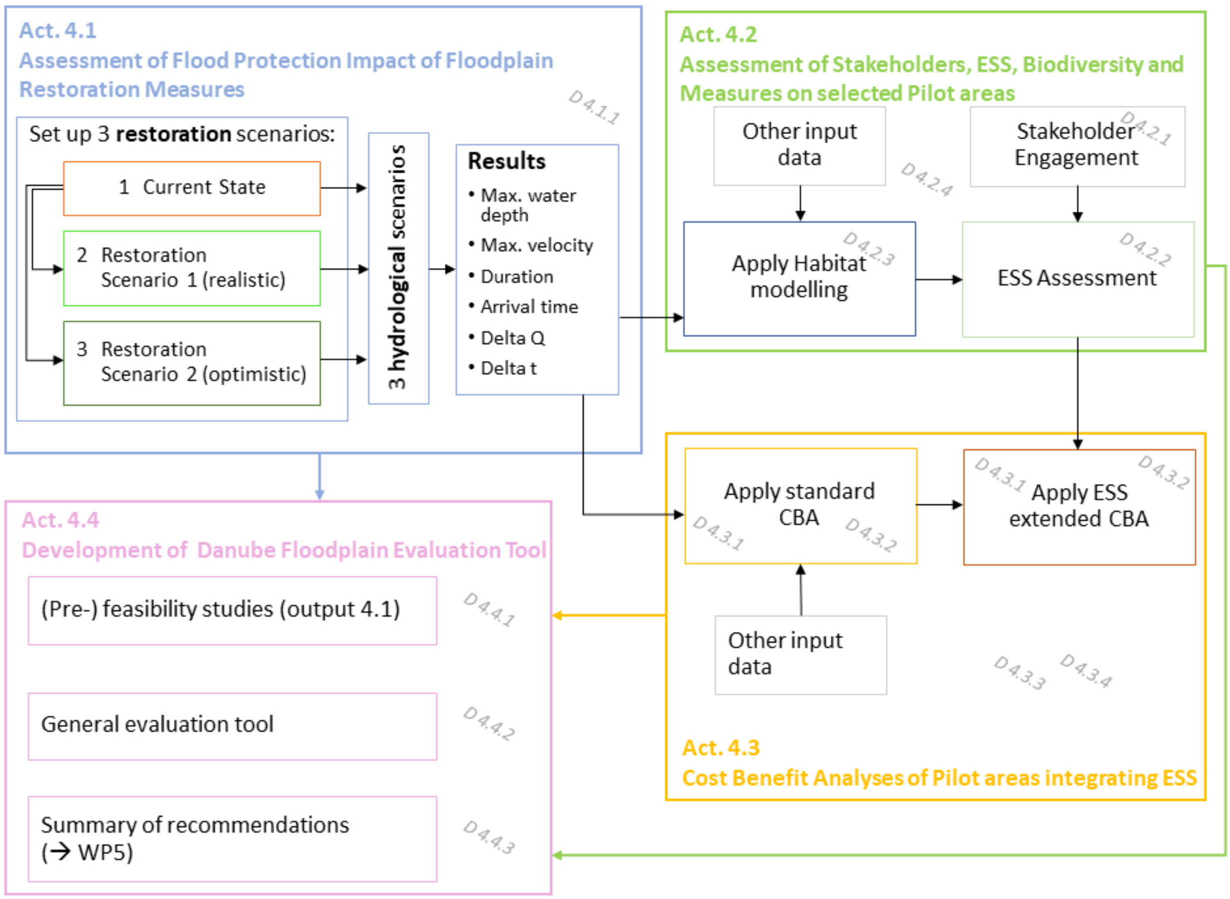

Figure 1. Flow chart of the tasks in WP4 in the pilot areas including activities and deliverables

For more information on location, characteristics, or hydrological and restoration scenarios of the pilot areas, please refer to the "Pilot Areas" Chapter of deliverables D 4.1.1 (Danube Floodplain, 2020a), D 4.2.2 (Danube Floodplain, 2020b), or D 4.3.1 (Danube Floodplain, 2021a). These include the descriptions of the five pilot areas (Begecka Jama, Bistret, Krka, Middle Tisza, and Morava), and the realistic (RS1) and optimistic (RS2) restoration scenarios, which were tested for three potential hydrologic scenarios (HQ_{2-5}, HQ_{10-30}, and HQ_{100}).

3. Recommendations in terms of Floodplain Restoration Planning

3.1 Recommendations for Organizational Aspects of Planning

Within this section, we give recommendations on the planning of floodplain restoration measures, by involving the area responsible PPs, to answer the following questions:

- Who should plan the restoration scenarios?
- How can stakeholders be involved in the design/planning process?
- How much time do the procedures require?

During the Danube Floodplain Project, the planning of the restoration measures was conducted mainly by local water authorities (Morava and Middle Tisza) and national authorities (Morava, Krka, Begecka Jama, and Bistret), with the help of external associates (Krka) and other governmental institutions (Institute for Nature Conservation for Begecka Jama). However, as suggested by PPs, the restoration measures should not be planned by a singular institution, but they should be built on the collaboration of local and national water authorities, other governmental institutions, NGOs, stakeholders, and managers of the protected areas or nature conservation institutions.

To increase the involvement of stakeholders in the design and planning of floodplain restoration scenarios, different recommendations were collected. Stakeholders should be contacted already in the phase of preparation (diagnostic of the situation), and evaluation of the possible solutions. They can provide information according to their knowledge and experiences about the past and present situation in the area, and with good practices known among the local population. A way to do so is to involve the stakeholders personally, via meetings or questionnaires. The project, its goals, benefits, and potential negative consequences should be presented clearly to achieve understanding, support, and active participation of the stakeholders. Therefore, the stakeholders must have an adequate understanding of the problems, as well as of the potential benefits and downsides of any proposed measures. This would require additional time for the education of the stakeholders, e.g., about the ecosystem services concept. Some local stakeholders are not experts on environmental issues. Informed decisions or suggestions are a key point in this case.

Moreover, consulting stakeholders about the real world and everyday issues they face will lead to a more integrated approach to the creation and proposal of mitigation measures. Stakeholder participation should be conceived in a way that the stakeholders can give useful input and that they feel they are part of the project. Therefore, one-on-one discussions during the breaks, as well as informal meetings on the field after the workshop, are helpful tools for sharing information and creating a more relaxed atmosphere. Nevertheless, careful preparation of meetings and questionnaires is a prerequisite for successful understanding and quality feedback.

Finally, the temporal aspect should not be forgotten. The planning time for these measures oscillated within the project between one and more than two years when water authorities are only involved in the process. The inclusion of more points of view will most likely increase the planning and organizational time, which should be considered in the general project schedule.

3.2 Recommendations for Restoration Measures

Recommendations on floodplain restoration measures could be derived from the project deliverables D 4.2.2 (Danube Floodplain, 2020b) and D 4.2.3 (Danube Floodplain, 2020c), others are taken from the LAWA-Blano catalog of measures (Bund/Länder-Arbeitsgemeinschaft Wasser, 2020).

Some restorations measures are implemented in the river itself, others in the adjacent floodplains. While some measures focus either on reducing flood risk or on improving water status, some measures address these two aspects simultaneously. The following Section (0) recommends measures that contribute to achieving good ecological and chemical status, i.e. to fulfill the EU Water Framework Directive (WFD) of the European Parliament (2000). Restoration measures to fulfill the Floods Directive (FD) of the European Parliament (2007) are listed in Section 3.4. Table 1 brings together the two chapters and gives an overview of the specific priorities of the different suggested restoration measures.

Table 1: Restoration measures in rivers and floodplains to fulfill WFD and/or FD.

Restoration measure	**WFD**	**FD**
Dike relocation, dike slitting	x	x
Creation of near-natural riparian zones	x	
Land-use changing to an extensively land use in the active floodplain	x	x[1]
Removal of impediments (bank stabilization, weirs, dams, culverts, and bridges)	x	x
Reconnection of floodplain waters (oxbow lakes, flood channels)	x	x
Creation of new floodplain waters (side-arms, oxbow lakes, flood channels)	x	x
Desilting and weeding of oxbow lakes	x	x
Widening the river bed	x	x
Input of deadwood or gravel	x	
Flood-adapted foreland management (removal of herbs and shrubs, mowing)		x

3.3 Recommendations for Restoration Measures to fulfill WFD

There are many potential restoration measures to improve the ecological and chemical status of rivers. Some measures need space, such as dike relocation. Other measures can be done in smaller areas, which makes them easier to implement, especially where settlements are close to rivers. Most measures have a positive impact on both the ecological and chemical status of rivers.

Very effective restoration measures are those that improve natural water retention. These measures, such as dike relocation or dike slitting, lead to more active floodplain areas with manifold ecosystem functions and services, such as nutrient retention and provision of floodplain-typical habitats. As a result, more nutrients can be absorbed by soils and plants during flood events, thereby purifying

[1] If it is grassland and not forest

river water (see also Danube Floodplain, 2020b). In addition, improving the channel-floodplain connectivity favors floodplain-typical biodiversity (see Danube Floodplain, 2020b, and Danube Floodplain, 2020c). These two effects, filtering nutrients and providing floodplain-typical habitats, can also be achieved, even though to a lesser extent, by creating riparian zones between agricultural land and rivers. Especially near-natural forestry, which prevents deterioration in the chemical status of adjacent water bodies by also reducing soil acidification, is a good foreland management option.

Land use also has a significant impact on the status of water bodies. By changing from intensive agricultural use to extensive use, such as converting arable land into grassland, nutrient inputs to the river are reduced. Land-use changes make sense above all when regular flooding makes profitable agriculture difficult. Thus, the relocation of a dike should be coming along with a change in land use to near-natural land use such as extensive grassland or riparian forest.

Other effective restoration measures to fulfill the WFD are measures to improve the structure of water bodies, such as the removal of bank stabilizations, weirs, dams, and culverts or input of deadwood and gravel. These measures improve the hydro-morphology and dynamics of rivers, allowing a proprietary development of the river course and the forming of different habitats (Danube Floodplain, 2020c).

In addition to dyke relocation, there are other measures to increase the lateral connectivity between river and adjacent floodplain, thereby also improving the ecological status of the water bodies and their floodplains and increasing biodiversity. Such measures include the creation of new watercourses such as sidearms, oxbow lakes, temporary flood channels, lowering the bank of the river, or the desilting or reconnection of existing oxbow lakes and other floodplain waters. They also lead to a well-developed moisture gradient in the floodplain and therefore increase biodiversity, by creating habitats for colonies of species with different habitat requirements, from dry to humid/wet habitats.

Where dams inhibit longitudinal connectivity, by-pass waters with natural habitats allow the migration of aquatic species, while providing new habitats such as spawning or juvenile fish habitats. Such semi-natural by-pass waters have a greater impact on the condition of rivers than technical fish migration aids which only aim to allow fish to migrate but do not provide any habitats.

3.4 Recommendations for Restoration Measures to fulfill FD

In contrast to the restoration measures required to comply with the WFD, there are much less effective floodplain restoration measures that also reduce the probability of flooding. Measures to reduce flood risk can have a direct local impact or a further downstream impact. In principle, measures can be differentiated according to their mode of action. First, some measures mainly aim at increasing water retention in the area. Above all, these require a lot of space to be effective. Second, some measures are aimed at modifying the runoff behavior of the river. These measures can be applied in smaller areas.

A promising restoration measure to fulfill both FD and WFD is the activation of the adjacent floodplains, e.g. by dike relocation or dike slitting (Danube Floodplain, 2020b; Danube Floodplain, 2020c). The creation of near-natural riparian zones or the widening of the river bed, as well as the reconnection of separated floodplain waters, can also increase water retention and can thus reduce the risk of flooding of downstream areas. However, a near-natural riparian zone with a forest rich in structures can increase the flood risk in nearby surrounding areas through a dense shrub layer and thick tree trunks. Thus, great attention should be put on avoiding local/upstream flooding of the floodplain, when trying to reduce flood risk downstream of it.

Even minor measures in the river or its tributaries, such as the removal of culverts, weirs, or bridges, will increase runoff and thus reduce local flood risk. This is also achieved by desilting and weeding of connected oxbow lakes and by creating flood channels.

Finally, some measures have the purpose to increase the river runoff in the floodplain, to prevent local flooding. These include measures of flood-adapted foreland management, such as the removal of herbs and shrubs or mowing in the floodplain. In addition, land-use change from forestry to grassland enables the flood wave to pass or drain quickly. Also in this case, attention should be put on planning the restoration measures, so that the avoidance of flood risk in one area does not enhance it in another.

4. Recommendations in terms of Flood Hazard Reduction Measures and Hydrodynamic Modeling

Using two-dimensional (2D) hydrodynamic models is an appropriate way to analyze the impacts of possible restoration scenarios on the flood hazard and the corresponding risk. Yet, it is crucial to consider that restoration measures can be manifold in their way, and thus, their impacts can differ remarkably. Restoration measures implemented in the five pilot areas of the Danube Floodplain Project comprise modifications on the river channel geometry, morphology, the floodplains, lateral branches, land use, etc. Conclusions of the effects should thus not be made on an equal basis but only under consideration of causal explanations, which measure has effects on which hydraulic parameter and which feedbacks between measures are possible. For example, comparing the pilot areas Bistret and Begecka Jama in terms of the flooded area in the floodplain, one could conclude that the restoration in Begečka Jama was not successful. However, the restoration measures themselves were different. While measures in Bistret fostered the activation of the floodplain, measures in Begečka Jama aimed for relief of the main channel by its widening and deepening and the activation of old oxbows. The discharge was still transported in the river channel (not in the floodplain) but the flow velocity was decreased resulting in less erosion potential. This example emphasizes the importance that, before a restoration project is implemented, its exact goals should be determined (i.e. is an increase in flooded area in the floodplain or the reduction of flow velocity in the channel desired or both) which serves as a basis of the selection of the measures and of course the evaluation of scenario simulation results. Nevertheless, it is reasonable to look at a rather broad spectrum of parameters to evaluate possible effects as done in the Danube Floodplain Project. This allows to obtain a more holistic picture of the flood situation and avoids that decisions are met on a unilateral foundation.

Furthermore, it is recommended to assess different combinations of restoration measures to obtain the best possible effects. In the optimistic restoration scenario of the Morava pilot area, measures for the river channel and the floodplain were implemented, leading to the highest peak discharge reduction simulated within this project. Yet, it should be considered that more measures do not necessarily bring larger effects. Interactions of different measures have to be considered and strategies thoroughly identified.

Besides possible interactions of restoration measures, interactions with local conditions shall be considered. Major tributaries discharging to the investigated river just before or after the restored area might diminish the effects. Here it also has to be considered that, when comparing different scenarios, the tributary conditions can vary, i.e. even if the hydrological scenario (i.e. the discharge and its corresponding return period) of the main river channel increases (concerning the one compared to), the hydrological scenario of the tributary does not necessarily increase as well in realistic conditions. If no information on the complete hydrological conditions is available, wrong conclusions on the effectiveness of measures can be drawn. It is recommended to run many different hydrological scenarios to get a better picture of possible flood retention effects. Other local conditions, which should always be considered during an analysis of restoration impacts on the flood hazard, are for example existing flood protection structures (e.g. polders or dikes) and their activation levels.

While evaluating restoration measures with hydraulic simulations, it has to be kept in mind that models are generally a representation of reality but with assumptions and simplifications of real-world processes included (Beven, 2012). Therefore, it is crucial to know the strengths but also the limitations of the applied models to adequately interpret the results. Within a modeling process, many parameters have to be estimated, as a direct measurement in the field would be unfeasible. One of the parameters required as input to hydraulic models is an estimation of the surface roughness within the simulated area. Roughness values like Manning's roughness coefficient shall be close to the physical reality. Therefore, land-use and land-cover maps can be used to determine distributed roughness coefficients per land use from previous studies (Liu et al., 2019). Estimates of roughness coefficients from literature are not always an optimal representation of a specific study site and measurements of exactly one specific study site are usually not available. Thus, roughness parameters are very often a calibration parameter within the modeling process. During the calibration, it should be considered that different parameter sets can produce equally good model results following the principle of equifinality (Beven, 2012; Pappenberger et al., 2005). Yet, uncertainties are always included in models and become larger where more parameters have to be estimated (Pappenberger et al., 2005). One limitation of this project is that uncertainties were not evaluated. For further assessments, it is recommended to include an uncertainty analysis for the model following (e.g. Beven and Freer, 2001 or Blasone et al., 2008).

Implementing the roughness parameters in restoration scenarios, the sensitivity of the model to changes of roughness parameters should be assessed in a first step. Following, the roughness parameter should be selected and adjusted in the model according to the desired reality representation of the restoration scenario. That means, if the land is to be converted to a floodplain forest, the roughness coefficient should change correspondingly, according to the local conditions.

For a comprehensive study, such as the Danube Floodplain Project, and when different models are created by different modelers, comparisons must be only made on an equal basis, i.e. when the models are of comparable quality. Further, flood risk estimations must be comparable. Flood risk is only relevant where the flood hazard can cause adverse impacts, i.e. if assets are exposed and vulnerable (Peduzzi et al., 2009). Thus, the modeling area should not only include the area where restoration measures are implemented but also those areas where the impact of flood risk reduction should be perceptible. As modeling a larger area is related to an increase in required data and computational power, a feasible solution should be identified together with all project partners to include relevant structures like cities, industries, or infrastructure.

Within a large project (research or also a real restoration project), many partners, stakeholder, etc. are involved. Results obtained by one partner are relevant for others to build upon. This is the foundation of sustainable research. Thus, besides the extent of the modeled area, a common basis on the simulated scenarios shall be agreed on by all project partners. This is not only true for the determination of restoration scenarios to obtain comparable results, but also for the implemented hydrological scenarios. In flood risk management, a discharge corresponding to an HQ_{100} is often applied to assess the impacts of extreme floods. However, in terms of a world subjected to climate change and a resulting possible increase of frequency and intensity of heavy precipitation events (Kundzewicz et al., 2014) higher return periods should be also assessed. Considering the possibility of failure of existing flood protection structures, due to the occurrence of a flood exceeding the usual design flood HQ_{100}, the impact of restoration measures, in that case, could be assessed. On the other hand, for some assessments, return periods of lower frequency are relevant (e.g. HQ_1 for habitat modeling or the assessment of ecosystem services). Unilaterally determining the implementation will impede additional assessments and decrease the project outputs comprehensiveness. Therefore, scenarios are optimally determined within a discussion including all involved members.

As already mentioned, 2D-hydrodynamic models are suitable to get detailed spatial insights into the hydraulic impacts of floodplain restorations. However, to get an overview of the total effects along a larger area (here, the whole Danube River), 1D models can be applied. This was done within Activity 4.2 of the project (Danube Floodplain, 2020c). With this approach, it is possible to assess the effect of multiple floodplains on flood peak reduction and the temporal displacement (lag of the flood wave's arrival at a certain location) along the river.

Finally, it is recommended to make all applied models open to the project partners, the scientific community, and relevant stakeholders. This enhances transparency and a sustainable and continued use of the modeled results.

5. Recommendations in terms of Biodiversity Assessment (Habitat Modeling)

Adapted from Danube Floodplain (2020c)

Assessing biodiversity in the context of floodplain restoration means assessing the suitability of certain areas to serve as a habitat for typical floodplain ecosystems. Habitat modeling is an appropriate method for such assessment. These models link abiotic habitat conditions like flood duration or flow velocity to habitat preferences of species or habitat characteristics in general. There are different options available for creating this linkage, a comprehensive overview is given in deliverable 4.2.3 (Danube Floodplain, 2020c). In general, models parameterized by expert knowledge are recommended as typically the required input data for purely data-driven models based on statistical learning is not available. A promising option is fuzzy logic-based models which allow combining different kinds of input data and knowledge. Regardless of the specific approach chosen, a successful habitat model needs to represent the major drivers of ecosystem development for a specific environment.

Floodplain ecology is mainly driven by the connectivity between the channel and the floodplain. Specifically, four types of connectivity can be discriminated: longitudinal, i.e. in the upstream-downstream direction, lateral, i.e. via surface flow between the channel and the floodplain, vertical via groundwater, and temporal, considering the flow regime of a river. Within the habitat modeling work of the Danube Floodplain Project, only lateral floodplain connectivity was considered, due to the nature of the hydraulic models and the hydrological scenarios used in the activities antecedent to the habitat modeling. This gives only a partial picture since the vertical connectivity via the groundwater is not considered. For a more comprehensive assessment of the ecological impact of floodplain restoration, the other types of connectivity (longitudinal, vertical, and temporal) should also be estimated. In its simplest form, longitudinal connectivity could be assessed by network indices like the dendritic connectivity index proposed by Cote et al. (2009). This index requires only a river network along with the information where longitudinal barriers are located. However, this is only a descriptive indicator for longitudinal connectivity and does not allow to assess the ecological impact of barriers directly. Closely linked to the longitudinal connectivity is the temporal connectivity, i.e. the magnitude, duration, timing, and frequency, as well as the rate of change of the discharge regime. These parameters together form the flow regime of a river. They are crucial for the development of ecosystems as many riparian species are adapted to a specific flow regime (Hayes et al., 2018). Including the effect of the flow regime and its modifications in habitat modeling in a detailed way requires hydraulic modeling of the actual discharge of the river. Here, hydraulic modeling focused on habitat assessment differs from hydraulic modeling for flood risk assessment which focuses on discharge for certain return periods rather than on the actual discharge situation during normal flow conditions. In addition to the temporal connectivity, vertical connectivity (i.e. the connectivity between surface water and groundwater) is an important hydrological factor for riparian ecosystem development. This includes the depth of the groundwater table as well as the soil moisture regime arising from the capillary rise of the water (Naiman et al., 2005). Despite this relevance, the surface water-groundwater interaction is not included in common 2D hydraulic models as used for flood risk analysis. Thus, to capture the vertical connectivity, coupled surface water-groundwater modeling ideally along with soil moisture modeling would be necessary. Summarizing the ideas from this paragraph, the hydrological control of riparian ecosystem development is complex. Capturing this complexity in habitat modeling requires hydrological/hydraulic modeling approaches different from those used for flood risk assessment even if the fundamental principles remain the same. Thus, if detailed habitat modeling is intended to be included in restoration planning, sufficient time and resources for establishing hydraulic models representing the flow regime and surface water groundwater connectivity should be included.

Such detailed habitat assessment should also include a rigor validation while the evaluation of the results in deliverable 4.2.3 (Danube Floodplain, 2020c) has been based on a plausibility check only as no field data has been available for validation. For future projects, validation should be based on field data independent from the data used for model calibration. For this purpose, precise locations of species abundances in the pilot areas are necessary. In this context, precise means a spatial accuracy below the resolution of the data used for modeling. If for instance, the resolution of the habitat model is 5 m, the accuracy of the species' locations should be below this range. This is already beyond the accuracy of a standard GPS device as commonly used in field surveys. Thus, the positions need to be either collected in sufficient accuracy e.g. by using GNSS devices or they need to be corrected based on expert judgment.

These high demands of detailed habitat models along with the high number of pilot areas and potential indicator species lead to the consequence that the habitat modeling within the Danube Floodplain Project has been carried out on the meso-scale only. Detailed modeling of individual species for a range of different habitat types in all pilot areas and scenarios of the Danube Floodplain Project was beyond the scope of deliverable D 4.2.3 (Danube Floodplain, 2020c). Nevertheless, we provide an overview of habitat modeling at the micro-scale, along with suggestions on indicator species to assess biodiversity in the floodplains along the Danube. Future projects with more time and resources available for habitat modeling could base upon these suggestions and develop detailed habitat suitability maps.

5.1 Floodplain habitat modeling at the micro-scale

At the micro-scale, the suitability of each location to be a habitat for a specific species can be predicted (Zavadil and Stewardson, 2013). The databases of the Natura 2000 and the Emerald network are a good source of information for restoration planning as they offer quite consistent data. Previous studies have already proved their suitability for analyzing site conditions and perform restoration planning (Cortina and Boggia, 2014). Funk et al. (2019) suggest 10 species as relevant indicator species for assessing the ecological status of floodplains along the Danube. Table 2 gives an overview of species suitable for assessing the habitat conditions of the Danube Floodplain pilot areas in more detail.

Table 2. Indicator species for habitat modeling on the microscale (based on Funk et al., 2019).

Indicator type	Species	Indicator value	Pilot area where applicable
Indicators for lateral connectivity of oxbows and backwaters	Gymnocephalus baloni (fish)	Reophilic species migrating between main channel and side arms	Begecka Jama, Bistret, Morava, Tisza
Indicators for vertically connected backwaters and ponds	Bombina Bombina Bombina variegata (amphibian)	Indicator for pond-like (i.e. only vertically connected) waterbodies	Begecka Jama, Bistret, Morava, Tisza, Krka
	Misgurnus fossilis (fish)	Stagnophilic species preferring low-velocity ponds with aquatic vegetation	Begecka Jama, Bistret, Morava, Tisza, Krka
Indicators for the aquatic-terrestrial transition zone	Chenopodion rubri (plant) Bidention spp.	Herbaceous plant species growing in the aquatic-terrestrial transition zone; Indicator for water level dynamics	Begecka Jama, Bistret, Morava, Tisza
Indicators for general lateral floodplain connectivity	Alnus glutinosa (plant)	Woody plant species being part of the softwood riparian forest	Begecka Jama, Bistret, Morava, Tisza, Krka
	Quercus robur (plant)	Woody plant species belonging to the hardwood riparian forest	Begecka Jama, Bistret, Morava, Tisza, Krka
Indicator of general naturalness	Lutra lutra (mammal)	Indicator for general ecological integrity on the floodplain as this mammal depends on natural conditions without anthropogenic disturbance	Begecka Jama, Bistret, Morava, Tisza

However, for such in-depth assessment, detailed information on species as well as on natural condition are required to make accurate predictions. Accurate information on the species is necessary for two possible forms: precise abundance locations in a statistically meaningful number or in-depth knowledge on the local habitat preferences of the species under consideration. Both sources of information were quite limited within the Danube Floodplain Project.

Of course, further species groups are suitable as an indicator for floodplain habitat conditions as well, such as mollusks (*Mollusca*) or ground beetles (*Carabidae*). They can be used for a complementary assessment of the habitat conditions. However, their assessment in terms of habitat modeling is challenging, as their specific habitat requirements related to hydrological dynamics are still not fully understood. The species listed in Table 2 are linked to the different meso-habitat types of floodplains (channel, laterally connected oxbows, ponds and backwaters, laterally connected floodplains, and aquatic-terrestrial transition zone). Thus, modeling the habitat suitability of these indicator species on the micro-scale can deliver further insights into the effect of restoration measures on biodiversity. In general, a meso-scale habitat modeling approach as suggested in D4.2.3 (Danube Floodplain, 2020c) is capable to provide an overview of the ecological effect of restoration measures and allows us to compare different scenarios with feasible effort. Habitat modeling on the micro-scale gives more detailed insights and allows an evaluation based on specific target species e.g. in the frame of the EU Habitats Directive. However, such modeling is data demanding and labor-intensive what should be considered when it is intended to incorporate micro-scale habitat modeling in restoration planning.

6. Recommendations in terms of Ecosystem Services: Mapping and Modeling

Adapted from Danube Floodplain (2019), Danube Floodplain (2020b), Danube Floodplain (2021b), and Perosa et al. (2021b)

6.1 Recommendations for Involvement of Stakeholders in Ecosystem Services Identification, Evaluation, and Assessment

In their floodplain restoration project at the Tisza, Guida et al. (2015) only focused on the hydrodynamic consequences of floodplain restoration and called for estimation of additional potential benefits of floodplain reconnection (such as water quality regulation) with stakeholder perspectives, since the stakeholder involvement paradigm plays a minor role in the Tisza Basin (Halbe et al., 2018).

Within the Danube Floodplain Project, we addressed this lack of stakeholder engagement, by hosting stakeholder workshops in January and February 2019 (Danube Floodplain, 2019). There, stakeholders shared information on which ecosystem services are used within the pilot area, at which intensity they are used, and how they would change as a result of restoration scenarios. For this purpose, the restoration scenarios were presented by the local water authorities or by national project partners. Additionally, if restoration actions had not been determined at the time of the meeting, stakeholders were involved in the restoration planning process.

The information obtained during the stakeholder workshops on ecosystem services but also drivers and pressures was of great help for collecting a lot of information on the pilot areas that finally led to the mapping of the ecosystem services. The results of these workshops were used as input data for the ecosystem services assessment. We were also able to bring together different views. This was partly due to the targeted invitation of stakeholders, so that a mix of national, sectoral agencies, NGOs, local self-government and local and international organizations, and even the general public in the case of Krka, participated in the workshops.

To assess ecosystem services with the help of stakeholders, a stakeholder analysis is required in advance to identify the relevant target groups. For this purpose, the following questions were considered:

- Who benefits from the pilot area?
- Who is active in the pilot area?
- Who is familiar with the pilot area?
- Who knows the ecological situation of the pilot area?
- Who can be affected by the planned measures?

These questions were of great help to identify relevant stakeholders in the pilot areas. In addition, a list of ecosystem services typical for rivers and floodplains, prepared in the research project 'River Ecosystem Service Index' (Podschun et al., 2018), was used to check whether the stakeholders selected by the questions covered all of these ecosystem services. Thus, the aim was to ensure that enough experts/actors participated in the workshops for the assessment of ecosystem services and their intensity of use.

Once the stakeholders for the workshop had been identified, it was also necessary to determine how the workshop should be conducted to ensure homogenous implementation in all pilot areas on the one hand, and, on the other hand, to obtain the results in the form required for further processing. Questionnaires or discussion groups are particularly suitable for identifying and assessing the intensity of use of ecosystem services. The advantage of discussion groups is based on several points. Discussion groups, provided they are held in small groups, lead to a lively discussion among the participants. The participants can not only contribute their knowledge and experiences from the pilot area but also exchange them directly with the other participants. And this ensures that not only the interest of individual participants is captured and that a possible over-representation or under-representation of individual target groups prevents an over-evaluation or under-evaluation of individual ecosystem services.

The first step in the ecosystem service assessment process is to identify the most important ecosystem services provided or used in a pilot area. This is where the knowledge of stakeholders or other actors in the pilot area is of great value. In particular, the ecosystem services used can be identified with the help of stakeholders and the intensity of use can be estimated or assessed by them. Also, cultural ecosystem services such as cultural heritage or education and research can be better identified and assessed by stakeholders than by analysis and assessment of other data such as land cover and/or land use. Therefore, the involvement of local stakeholders in particular, but also the general public, is extremely useful.

After the assessment of ecosystem services and their intensity of use for the current situation and the restoration scenarios, the results should be reviewed. This can be done not only by the project partners responsible for the pilot area but also by the stakeholders. Therefore, a second workshop is recommended in which the results of the ecosystem service assessment in the respective pilot area are presented and subsequently discussed with the participants. Thus, the results can be reviewed and improved. Unfortunately, in the Danube Floodplain Project, due to strict travel restrictions caused by the covid-19 pandemic, a second workshop with the project partner responsible for the ecosystem services assessment could not be conducted.

Although useful, some limitations can be found in the stakeholder engagement methodology. First, we did not specifically differentiate between the floodplain area's upstream or downstream stakeholders (who would e.g. benefit from the flow of water services). Second, a broader consultation may have described and judged the ESS differently (Merriman et al., 2018). Third, the covid-19 pandemic affected the second part of the project, by forcing local project partners and stakeholders to cancel the second round of stakeholder workshops or to organize the meetings online. Moreover, not all stakeholders were familiar with the concept of ecosystem services and not enough time was available to present the concept in detail and to get the required feedback from stakeholders. The rating and prioritizing of ESS during a stakeholder workshop proved to be very difficult, as different stakeholders and interest groups had differing views of the values of a certain ESS. A farmer and a conservationist have very differing views on what is important for the area and what the values of the ESS in the area are.

As mentioned in the recommendations regarding the design and planning of restoration measures (Section 3.1), stakeholders should have a key role in the whole process of floodplain restoration. However, reaching stakeholders is not always an easy task, and some stakeholder engagement strategies should be applied to invest the limited time and resources effectively.

Therefore, different recommendations and lessons learned were collected from the PPs. First of all, personal communication should be supported by presentations of the actual situation and possible solutions during meetings in the local areas. Stakeholder workshops proved to be a constructive way of communicating our ideas to the stakeholders as well as receiving views and suggestions from them. The organizers should make sure that the workshops are interactive and that the widest possible professional range and knowledge participates, from experts to the local population. In addition, informal conversations on a one-to-one basis provided a more in-depth perspective, the opportunity to clear up any misunderstandings or questions, and built a relationship of trust between stakeholders, authorities, and decision-makers.

Regarding the content of the workshops, the concept of ESS must be presented and explained understandably to the stakeholders at the beginning of the event. Also, the local PPs would have wished for a follow-up session with expert PPs, to have information on whether the workshops met the expectations. Additionally, more details should have been collected about the statements of the stakeholders, to be able to verify them. In fact, some stakeholders gave information, which proved to be wrong afterwards.

From the organizational point of view, communication in the mother tongue of the stakeholders is a necessary precondition for the events. Secondly, field visits could be included and multiple workshops could be organized to reach as many stakeholders as possible. This would allow forming a forum of stakeholders. Finally, stakeholders should be kept updated about the developments of the restoration projects, to maintain the cooperation, and even the schedule should be planned to have more meetings in the second half of the project. This would enable clarification of questions and uncertainties and give more possibilities for information exchange.

Nevertheless, the pilot area responsible PPs managed to raise considerable interest in the project and the proposed measures amongst the local public and received some interesting feedback, which is indicative of the fact that the implemented approach was successful in terms of getting stakeholders involved. Moreover, the PPs appreciated the experience with such a multi-layered approach to dealing with floodplains and see this as a good basis for dealing with similar restoration cases in the future.

6.2 Recommendations for Ecosystem Services Assessment

Floodplain restoration is a solution with great potential but these nature-based solutions (NBS) are difficult to finance, because, when compared to technical measures, they require a wider land usage and a more innovative approach to maintain comparable risk reduction and local economical expenses (Pugliese et al., 2020). Therefore, we need to consider the co-benefits of the NBS, namely the various ESS provided, to have a more integrative picture of the effects of floodplain restoration measures. So far, the concept of ESS was poorly integrated into ecosystem management and flood risk decision-making in countries of the DRB (Petz et al., 2012). ESS quantification could help in implementing integrated planning strategies and improving regional policy-making (Petz et al., 2012). As stated above, these steps should also be implemented by including stakeholders' consultation. In the case of the Danube Floodplain Project, some floodplain restoration measures in the pilot areas could not be justified for merely flood risk purposes. Therefore, using ESS assessment and monetization is valuable leverage to promote floodplain restoration measures.

Various tools exist to estimate the co-benefits of NBS, such as ARIES (Villa et al., 2014) or InVEST (Sharp et al., 2014). These tools usually apply to national or regional scales and make it difficult to include stakeholders' points of view in the modeling because of the scale itself. On the contrary, the Toolkit for ESS Site-based Assessment (TESSA) (Peh et al., 2017) is a PDF-based platform that aims at enhancing stakeholders' engagement in decisional processes and has the advantage of a shorter application time, the accessibility to local non-specialists (Pandeya et al., 2016), and its suitability for local scale applications. Also, this tool is thought for the applications at the local scale. According to some PPs, MAES and Copernicus could show some flaws on the micro-scale. As an example, in Begecka Jama a recently cut forest area was recognized as grassland, although during the time of the implementation of the Danube Floodplain Project this area has already been planted with trees.

One of the major challenges of tools such as TESSA to assess floodplain values is the comprehensive integration of the large spectrum of ESS. Existing studies focused mainly on provisioning and regulating ESS, neglecting the cultural and supporting ESS. For example, the value of biodiversity is missing from TESSA's applications on floodplains and the local climate regulation is missing from Merriman et al. (2018). This led to global overexploitation of provisioning services in the recent past (Kumar, 2012) and an unbalanced consideration of ESS for the planning and management of ecosystems (Derts and Koncsos, 2012). Although this allows more ESS-aware decision-making, we recognize that "not all ESS can be maximized simultaneously" (Birch et al., 2014).

As described in Deliverables 4.3.1 (Danube Floodplain, 2021a) and 4.3.2 (Danube Floodplain, 2021b), we estimated co-benefits of floodplain restoration for flood risk reduction in terms of monetized ESS in four pilot areas of the Danube catchment, by also including stakeholder engagement. The conclusions of the work are threefold. We estimated the added value of the co-benefits of river and floodplain restoration to test the floodplain restoration's quality and effectiveness. We showed that the planning of this nature-based solution should not only use standard methods (e.g. hydrodynamic modeling) to support decision-making but also assess ecosystem services for a more holistic picture of the potential consequences of the potential NBS. We provided an example with a mixed application of TESSA and alternative methods.

A fifth pilot area (Middle Tisza) was estimated with another method, i.e. a spreadsheet tool was developed by the Regional Centre for Energy Policy Research (REKK) to take care of the necessary calculations on ESS and also to ensure that none of the cost or benefit items are neglected. Moreover, REKK proposed a decision support scheme that considers the most important issues to accomplish a flood risk reduction planning with a wide range of natural and social conditions to fulfill.

From deliverable D 4.3.1 (Danube Floodplain, 2021a) results, it is interesting to note that the restoration projects have a different impact on different types of ecosystem services. The provisioning ESS (here represented by the cultivated goods) are decreasing in all pilot areas for our tested floodplain restoration measures, while the regulating and cultural services are increasing in a much more complex spectrum of services. These results are in line with previous results from floodplain restoration analyses in Nepal by Merriman et al. (2018) and the U.K. by Peh et al. (2014). The results of the ESS assessment shown in deliverable D 4.3.1 (Danube Floodplain, 2021a) can be the basis for further analysis of the interaction among ESS, such as the nexus analysis approach suggested by Fürst et al. (2017) and Babí Almenar et al. (2021). This could help us better understand the cause-effect relationship of benefitting from one ESS group (e.g. provisioning) to the availability of other ESS groups (e.g. regulating or cultural).

Moreover, TESSA is a helpful tool. The guidelines gave a clear overview of the necessary steps to follow for a quick ESS estimation in the pilot areas. Although the steps are clear and easily implementable, the collection of the big amount of input data is highly time-intensive and requires many resources and contacts to local authorities. On the one hand, we encourage the utilization of TESSA for the further evaluation of other kinds of NBS. On the other hand, we invite TESSA's developers to complement methodologies of ESS assessment, e.g. by adding guidelines for online interviews or by adding the possibility of using social media, not only for data collection but also for the design of NBS. For example, we recommend the applied methodology of online interviews on social media as a valuable tool to estimate nature-based recreation, due to its easy implementation and the provision of valuable input data to apply the travel cost method (TCM).

Geographic information capacity also played a significant role in understanding ESS processes (Sutherby and Tomaszewski, 2018) and in finding the potential ESS hotspots and low spots of restoration projects. Therefore, general actions to improve the ESS assessment at the local level might involve creating a standardized GIS version of the TESSA models, to represent its results spatially. These could be refined for specific regions, e.g. by using local community knowledge. We considered the implementation of the TESSA methodology on a python script written for QGIS (GitHub, 2020) as crucial. Once the script was finally written, this choice allowed including input data from freely available sources, but it also decreased the execution time of TESSA tasks. Our technique shows an advantage over some more time-demanding software, but these (e.g. InVEST or ARIES) might also be tested as a supplement or for results' validation, in case more time, data, and resources might be available.

6.3 Limitations

Although we consider the results of TESSA's application useful for a preliminary evaluation of floodplain restoration measures, we found some points of potential improvement. Firstly, in our results, we show the need for TESSA to add more ESS within the tool, specifically concerning habitat services.

Secondly, as also recognized by Merriman et al. (2018), the nature of the tool makes TESSA prone to represent mainly those ESS that are the easiest to monetarize. Without straightforward methods, the other ESS are therefore in danger of being overlooked and under-represented. Accordingly, our results include all ESS for which we found readily available methods to estimate their monetary values because we wanted to use a common unit of measure for comparing the scenario and the pilot areas. This means that we neglected other ESS, for which no available methods or data existed, such as noise regulation or local climate regulation. We decided to exclude these ESS from our estimation, also reinforced by the assumption that the floodplain restoration would have a low impact on the mentioned ESS. In fact, noise regulation and local climate regulation are two ESS, which would most likely be affected in urban areas but not by much in our rural study sites. However, stakeholders recognized noise regulation as a floodplain service during the workshop in the Morava pilot area and at a later stage in Krka.

We also encountered difficulties in estimating harvested wild goods, due to high data-demand. Also, the change in the amount of harvestable goods is very unpredictable for the relatively small changes in our pilot areas, proven by the fact that stakeholders had heterogeneous and weak opinions on the consequences of the restorations with regards to harvested wild goods.

The value of water provisioning was also not estimated, because of data scarcity. TESSA's suggestions are to apply the substitution costs method to estimate this ESS, by using the cost-based method of replacement costs. The replacement costs can use costs of alternative ways, in which the same ESS would be provided in the pilot area. For example, the price of water bottles that would be bought by the population could be used to estimate the replacing costs of the drinking water supply that is not given by the river. Another way of estimating the replacement costs is to consider the costs of extracting water from the area by pumping it from the groundwater. These ways of estimating the value of ESS require much data and have not been implemented in the Danube Floodplain Project.

In addition, we agree with Merriman et al. (2018), who judged the methods suggested by TESSA to assess water quality as too coarse or too time-consuming. Nevertheless, we do not want to undermine the importance of investing time and resources in the proper estimation of ESS and we recognize that sometimes an easy and quick solution is not possible to understand complex phenomena. ESS values corresponding to nutrient retention have the lowest effect on the total ESS valuation for three pilot areas out of four. The methodology used is a new suggestion for the TESSA toolkit, in case no available measurement data and no modeling resources would be available. Data from other studies could also be used as a source of information. For example, Doll et al. (2020) found out that for their urban stream restoration project, on average 9% to 15% of the total annual streamflow volume accessed the floodplain, but the percentage of annual streamflow volume that was potentially treated ranged from 1.0% to 5.1%.

As for other studies conducted with TESSA (Peh et al., 2014), the missing ESS quantitative estimations lead to a more conservative result. On one hand, the inclusion of stakeholders in the estimation process allows to include the qualitatively indicated ESS in the decision-making process. On the other hand, a bigger picture including all non-monetized ESS would be preferable. As an example, the added values of cultural ESS and pollination ESS were not included in the estimation, due to difficulties in monetarization for the former, and challenges in knowing about pollinators in the areas for the latter. These factors could potentially be included by a higher engagement of stakeholders, as done by Pugliese et al. (2020).

We also want to underline that the scale of the estimation is highly affecting the accuracy of the results. In contrast to other river-related disciplines (e.g. hydrological modeling, hydrodynamic modeling), the estimation of ESS at the local scale is made more difficult the smaller the pilot area gets and remains a task with high complexity. The biggest difficulties were encountered by the data collection. For example, the application of the FAOSTAT data at the national level would be more appropriate for catchment scales, other than for floodplain scales. Also in another example, i.e. flood-caused damage estimation, national-level data were used in form of the flood-damage functions, which could have been more accurate, if local damage or exposure data would have been available. In this respect, it should be considered that our findings are based on a limited amount of local-specific data. Connected to this problem, it should be underlined that the selection of the extension of the pilot area has a major influence on the final results, e.g., a wider area or an additional area with negative impacts could strongly bias the results.

Besides the above-mentioned phenomena, several other steps of our work are affected by uncertainty, such as the fit of the Poisson distribution to estimate the visitation rates as a function of the travel costs or the timeframe used for the monetary values. In deliverable D 4.3.1 (Danube Floodplain, 2021a), we presented the first attempt of error estimation. However, dealing with many variables for different ESS, there are even more input variables that should be considered to provide a meaningful error estimation. To fulfill this task, we should put up a new system to consider all possible sources of uncertainty of the ESS estimations, e.g. by using a Monte Carlo simulation. Moreover, most of this uncertainty does not affect the overall results, which present the percentage change for each ecosystem service between the two states. For each metric, the error should be similar for both the current state and restoration states (Birch et al., 2014).

7. Recommendations in terms of profitability assessment (Extended Cost-Benefit-Analysis)

Adapted from Danube Floodplain (2020a), Danube Floodplain (2020b), Danube Floodplain (2021b), and Perosa et al. (2021b)

By analyzing the results of the extended cost-benefit analysis (CBA) through ESS presented in deliverable D 4.3.1 (Danube Floodplain, 2021a), we could evaluate which floodplain restoration scenarios hypothesized for the pilot areas are profitable. In this way, we brought further evidence in favor of floodplain restoration measures to be implemented for the general benefit of the communities. In fact, without considering the co-benefits of NBS, floodplain restoration measures would have much lower chances of being accepted by decision-makers and stakeholders. The extended CBA process is graphically conceptualized in Figure 2. The description of the methodology to assess the ESS and their inclusion in the extended CBA can be found in Deliverable D 4.3.2 (Danube Floodplain, 2021b).

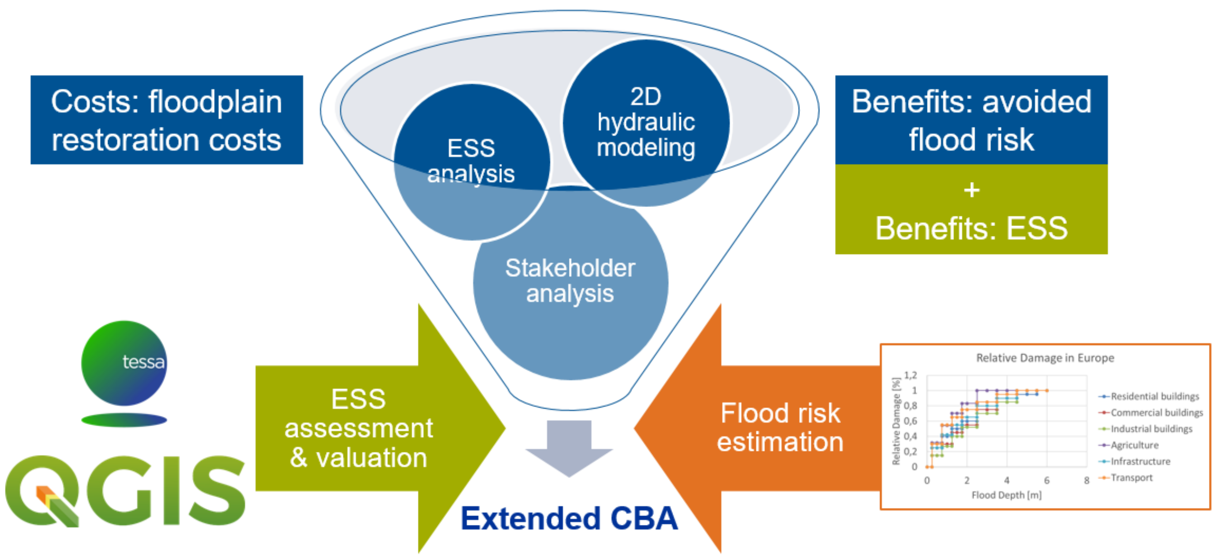

Figure 2. Workflow of the extended cost-benefit analysis for floodplain restoration measures in the Danube Floodplain Project.

In multiple pilot areas (Begecka Jama, Krka, and Morava), the standard CBA (which only includes flood risk mitigation as a benefit) misses to recognize the profitability of the restoration measures, which is instead identified by the extended CBA, both when looking at the benefits-costs-difference (BC-difference) and the benefits-costs ratio (BCR). These parameters predict better overall restoration effects for either the realistic or the optimistic restoration scenarios. If the standard CBA results were to be used, floodplain restoration would not be shown as profitable (BCR<1 and BC-difference < 0). Therefore, in these two pilot areas, when omitting ecosystem services from the equation, the restoration loses its profitability advantage.

Nevertheless, the other pilot area evaluated with the homogenous extended CBA (i.e. Bistret, excluding Middle Tisza), deliver contradicting results. By looking at Bistret results, we can tell that the CBA is not always the right way to evaluate floodplain restoration projects, or more generally nature-based solutions. In fact, for this pilot area, the extended CBA shows not fully profitable results, although improving compared to the standard CBA. Unfortunately, our results cannot prove the profitability of restoration scenarios when comparing thrm with the current state.

When examining these results and suggesting which scenarios should be implemented, we should remember that some uncertainty factors could substantially modify the results, in addition to the ones affecting ESS assessment. First, the costs and benefits values are influenced by the parameters used for discounting. Secondly, we should keep in mind that the carbon stocks have not been included in the calculations. Moreover, we point out that the costs for the restoration measures were roughly estimated and that they might change, as usual, during the implementation process. Therefore, decision-makers should remember the presence of uncertainty, when using these results for decision-making (Perosa et al., 2021a).

In decision-making for flood risk purposes, the goal might be to obtain a BCR slightly higher than 1, which would mean that there is a balance between investment costs and returning benefits. In the case of an extended CBA including ecosystem services evaluation, we should ask ourselves whether our goal should be to maximize a BCR, or whether we should focus on other CBA parameters, such as the benefit-costs differences or a benefits-vs.-costs-graph.

Another important question to answer is whether in the future we should avoid showing the different results between a standard and an extended CBA. On one hand, by keeping both CBA methods, decision-makers might still perceive the standard CBA as the reference method to trust, and might not take seriously the results of an extended CBA. On the other hand, comparing the standard CBA with the extended CBA might be a way to show the limitations of a commonly accepted methodology and put traditional methods into question.

As a final remark, we underline that the CBA is only one part of a bigger picture that should be considered when meeting decisions in terms of flood risk management and nature-based solutions. Engineers, experts, and researchers should only provide the tools and results to allow decisions to be taken. Ultimately, decisions are met by the politicians and, in practice, these will always be influenced by the political will of international, national, or local governments and by the civil movements of the time.

8. Concluding Remarks

Adapted from Danube Floodplain (2019), Danube Floodplain (2020b), Danube Floodplain (2021b), and Perosa et al. (2021b)

Floodplain restoration is seen as a win-win NBS for flood risk. In fact, the technical measures used in the last century to protect us against extreme flood events have proved to be not resilient for two reasons. In some cases, the possibility to further raise dykes has been depleted, a problem, which might get relevant in the future due to climate change; in other cases, grey infrastructure, i.e. hard engineering structures, deal with the flood risk problem in an isolated and unilateral manner, for example by neglecting ecological and societal aspects (Grover and Krantzberg, 2013). Differently, floodplain restoration might modify the relation of humans to floodplains, and how the former can benefit from the latter, i.e. floodplain restoration can improve various floodplains' ecosystem services (ESS).

There are many possibilities to improve the good ecological and chemical state of rivers and floodplains and to decrease flood damages and therefore flood risk. Most restoration measures affect both. However, not all measures are win-win solutions. On one hand, some restoration measures (such as the creation of near-natural forests in active floodplains) fulfill the Water Framework Directive (WFD) while increasing the local flood risk, by extending the flood duration in the area. On the other hand, some measures fulfill the Floods Directive (FD) but can have negative impacts on biodiversity. Removal of shrubs and herbs in the riparian zone leads to a loss of habitats. Therefore, attention should be paid to what degree such habitats remain in the adjacent active floodplain or can be reestablished. Such aspects should be considered when planning flood risk reduction measures.

ESS assessment and inclusion into a cost-benefit analysis (CBA) can be useful for decision-makers to locate where to build or restore ecosystems (Sutherby and Tomaszewski, 2018). Policy-makers and researchers should give stakeholders a greater role in the design of floodplain restoration measures and their evaluation, including ESS assessment and monetarization. At the same time, researchers should develop new methodologies to rapidly evaluate the missing ESS types, which are not included in commonly used ESS assessment guidelines (TESSA) or software (InVEST, ARIES, etc.). Although some progress has been made using the methodology of Activity 4.3, a rapid approach assesses only a part of all ESS potentially provided by floodplains. Finally, we underline that the extended CBA is only one part of a bigger picture to consider when meeting decisions in terms of flood risk management. Final decisions are always going to be taken by politicians.

We finally call for better inclusion of stakeholders and ESS assessment in the Danube River Basin Management Plans, referring to the guidelines of the Sustainable Development Goals. Project partners also suggested including all project results into protected area management plans, in cooperation with a stakeholder forum, which should be established by the protected area managers. Different purposes are at the basis of these recommendations: to encourage sustained, inclusive, and sustainable economic growth (Goal 8); to facilitate sustainable management of water (Goal 6), and to preserve terrestrial ecosystems (Goal 15) (United Nations General Assembly, 2015).

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