Booklet for Facilitating Floodplain Restoration and Preservation Approaches in the Danube River Basin

Interreg
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Danube Floodplain

Imprint

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Overview and key aspects

Why should we care about floodplains?

- Flooding is a natural and an often common reality for many rivers. They can turn into disasters causing economic and environmental damage, health problems and even loss of human life. The areas next to rivers, covered by water during floods, are part of the river system. Known as floodplains, in their natural condition they help are an important part of the river system: they store water, filter nutrients, help the aquifers to be recharged, ensure a proper functioning of river ecosystems, and sustain the water quality and biodiversity.
- Danube River Basin's floodplains covered in the past wide stretches and had high ecological importance. Flood protection infrastructure, especially dykes, land use changes into arable lands and urban development have considerably fragmented floodplains along the Danube and its tributaries.
- To improve navigation, river channels are often straightened and dredged. Hydropower and water supply projects caused significant changes in hydrological regime and geomorphological processes influenced floodplains preservation.
- Consequently, the floodplain and wetland areas disconnection in the Danube River Basin has significantly decreased; therefore, restoration and preservation actions are needed.

How to act?

- Integration of the environmental objectives and flood risk management objectives requires moving away from the classical flood protection solutions to nature-based ones.
- Nature-based solutions refers to actions in which reducing the flood risk is provided, while at the same time natural properties of the floodplains are restored and preserved
- Because of the multiple benefits provided by natural floodplains, EU policies encourage floodplain restoration based on integrative plans and win-win solutions. Synergies between Flood Risk Management Plans (FRMP) and River Basin Management Plans (RBMP) should be mainly reflected by sustainable measures either addressed for the prevention and mitigation of floods, but in the same time for reaching the environmental objectives of the water resources.
- Agreement on the wide range of benefits provided by floodplains and river restoration could be ensured by using an approach rooted in ecosystem-based management when developing river basin and flood risk management plans.

1. Floodplain disconnection vs flood events in Danube River Basin

Floods in Danube River Basin

The Danube has a very complex hydrological system. Its flow characteristics change over large reaches, influenced by the main tributaries (e.g., Drava, Sava, Morava, Tisza).

During the last decades, Europe suffered major catastrophic floods along the Danube. Major flood events in the Danube River Basin of the recent past occurred in 2002, 2005, 2006, 2009, 2010, 2013 and 2014.

In 2006 high discharges on Danube and its main tributaries Tisza, Sava and Morava, due mostly to heavy rainfall but also to intensive and rapidly snowmelt led to a highest historical floods. More than 1000 kilometers of the Danube River registered a 100-year flood event. Highest historical flows and water levels were also recorded from Morava mouth to the southern tip of the Csepel Island in Hungary, downstream of the Tisza mouth in Serbia and along the whole lower Danube in Romania [DFPRBMP, 2015].

In 2010, the scattered character of the rainfall throughout the whole year and throughout the most of the Danube River Basin led to a high number of significant flood events.

In 2013 significant 100 years floods events has been registered almost simultaneously in Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania and Bulgaria.

Several gauging stations registered 200 even 500 years .

Floodplain disconnection in Danube River Basin

Disconnection of the former floodplains, not particularly on Danube River itself, but also on main tributaries causes loss of large water retention areas that mitigated flood risks in the past.

Former Danube floodplains covered an area of approximately 41,605 km^2 which is equal to about 3.3% of the total Danube catchment area. Total floodplain area for the Danube was reduced by 68% (80% for all assessed rivers) with differences for upper (75%), middle (79%) and lower (73%) Danube stretches .

In the same time, the 1st Danube River Basin Management Plan (DRBMP) from 2009 concluded that compared with the 19th century, less than 19% of the former floodplain area (7,845 km2 out of a once 41,605 km2) remain in the entire Danube River Basin (DRB)[3].

2. Active and potential floodplains - identification and evaluation

Conceptual approach

The conceptual approach (Figure 1) developed within the Danube Floodplain project has as starting point the identification and evaluation of active and potential floodplains along the Danube River and main tributaries. A holistic method for evaluating floodplains was further developed, serving as decision support for the relevant stakeholders and indicating where efforts of floodplain preservation or restoration should be spent first within an integrated flood risk management (FEM) [Habersack et al. 2015].

[1] Floods in June 2013 in the Danube River Basin https://www.icpdr.org/main/sites/default/files/nodes/documents/icpdr_floods-report-web_0.pdf

[2] WWF, May 2010 - Assessment of the restoration potential along the Danube and main tributaries

[3] https://www.icpdr.org/flowpaper/app/services/view.php?doc=drbmp-update2015.pdf&format=pdf&page={page}&subfolder=default/files/nodes/documents/

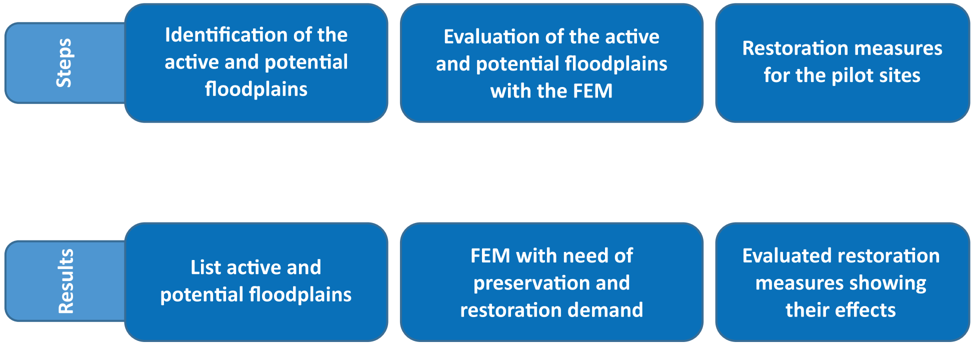


Figure 1 - Conceptual approach for active and potential floodplains identification and assessment processes (in the frame of the project)

Identification
Active floodplains

Defined as all areas that are still flooded during a HQ100[4] flood event - widely accepted as the design discharge level for flood protection measures along the Danube River in the frame of Danube FLOODRISK Project[5], the inventory of active floodplains provides the main spatial reference base, where other hydrological, hydraulic and biophysical parameters are analyzed.

Three delineation criteria was further used for the identification of the active floodplains:

- Ratio factor of width floodplain/width river - to identify the beginning and end of a floodplain (>1:1 for Danube River);

- Minimum size of an active floodplain- to avoid too small floodplains (>500 ha for Danube River);

[4] Flood which occurs statistically once in a hundred years
[5] https://www.danube-floodrisk.eu/

- Current hydraulic characteristics of the floodplain, like flow paths and stages may not be altered by the delineation (identified floodplains should represent the natural flow characteristics)

These criteria cannot only be used at the Danube River, but are applicable at every river. Only the values for the first two criteria have to be adjusted for the selected river. In general, the thresholds can be selected for each river individually under consideration of specific characteristics of the river and its floodplains.

Potential Floodplains

Following the identification of all active floodplains, a methodology was developed for the identification of potential floodplains. Potential floodplains have been considered as currently not inundated areas in the case of a HQ100, but with restoration measures, these areas can be reconnected to the river system leading to inundation during a HQ100 event.

In a first step, historical maps and/or inundation outlines of extreme floods[6] were used to identify former/historical floodplain. The Danube FLOODRISK project also provides inundation outlines for extreme flood events along the entire Danube River.

If settlements, critical infrastructures and streets are located in the historical/former floodplain, each country decides on their own on identification the related area as a potential floodplain (settlements, streets and critical infrastructures had to be protected by complementary local flood protection measures – e.g. protective walls, earth deposits/dikes).

[6] Flood which occurs statistically very rarely (e.g. once at 500 years or once at 1000 years)

If the historical/former floodplain is currently used by agriculture, each country decides on their own if land use change or any kind of compensation is possible or not. In case no feasible solution can be found, no potential floodplain will be identified.

Two types of potential floodplains, namely potential and "operational" potential floodplains has been initially considered in the context of the project. The difference between these two types is that the "operational" potential floodplains are identified and discussed with stakeholders, technical experts and decision makers. This was not done in the Danube Floodplain project.

Process of identification of potential floodplains includes 5 steps as following:

Step 1: Identify historical/former floodplains by using the extreme floods inundation outline from the Danube Atlas or historical maps.

Step 2: Exclude settlements, infrastructure and streets in the former floodplain.

Step 3: Exclude agricultural land where land use change or any kind of compensation is not possible.

Step 4: Define the floodplain restoration scenario for this potential floodplain. The scenario for the reconnection (e.g. cut of dike, removal of dike, land use change) will then be used for the modelling of the potential floodplains.

Step 5: Discuss with stakeholders to define the "operational" potential floodplain and the technical aspects of the reconnection. This is not done in the Danube Floodplain project

Evaluation
Floodplain Evaluation Matrix (FEM)

A holistic tool (Floodplain Evaluation Matrix -FEM) to evaluate river floodplains by considering multiple parameters that effect and determined the processes within these floodplains has been used in the Danube Floodplain Project. The Floodplain Evaluation Matrix (FEM) was developed by the Institute of Hydraulic Engineering and River Research at the University of Natural Resources and Life Sciences, Vienna (BOKU).

Considering FEM, a valuable decision support tool is available for relevant stakeholders to assess the multiple benefits that floodplain restoration and preservation as a sustainable non-technical measure can offer as it is demanded by the EU Floods Directive (2007/60/EC). In general, it allows the evaluation of various river reaches by setting up a priority ranking, which indicates where efforts of floodplain preservation / restoration should be spent first in order to obtain maximum benefits.

FEM parameters

For the Danube Floodplain project, the original FEM method was further developed to serve the project needs *(Figure 2)*. In order to get a reliable comparability. A minimum set of parameters was fulfilled by all the project partners. Additional parameters, suggested by partners were discussed, but not considered for the ranking list. The matrix itself consists of four categories of parameters: hydrology, hydraulics, ecology and socio-economic.

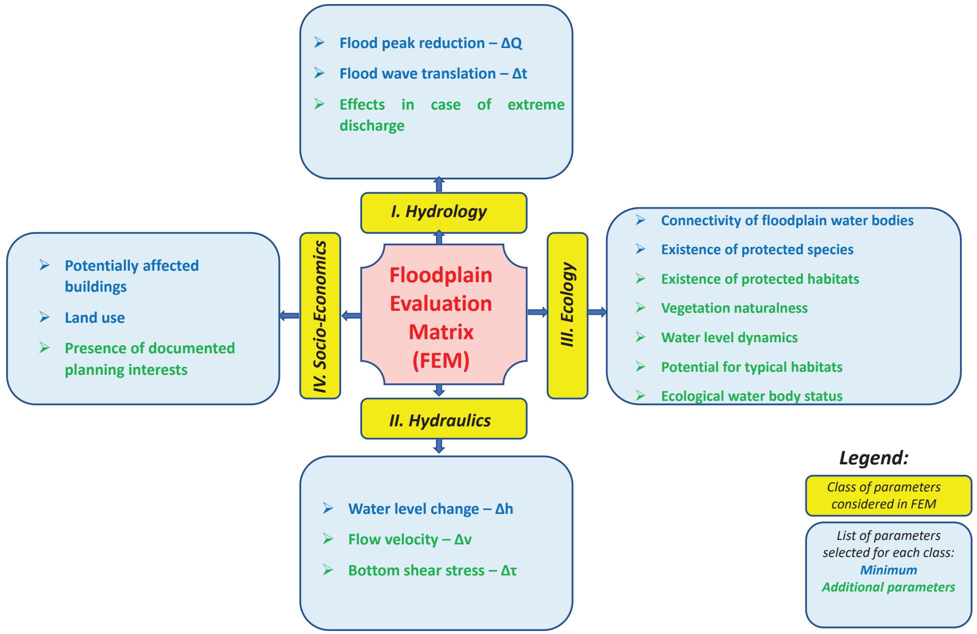


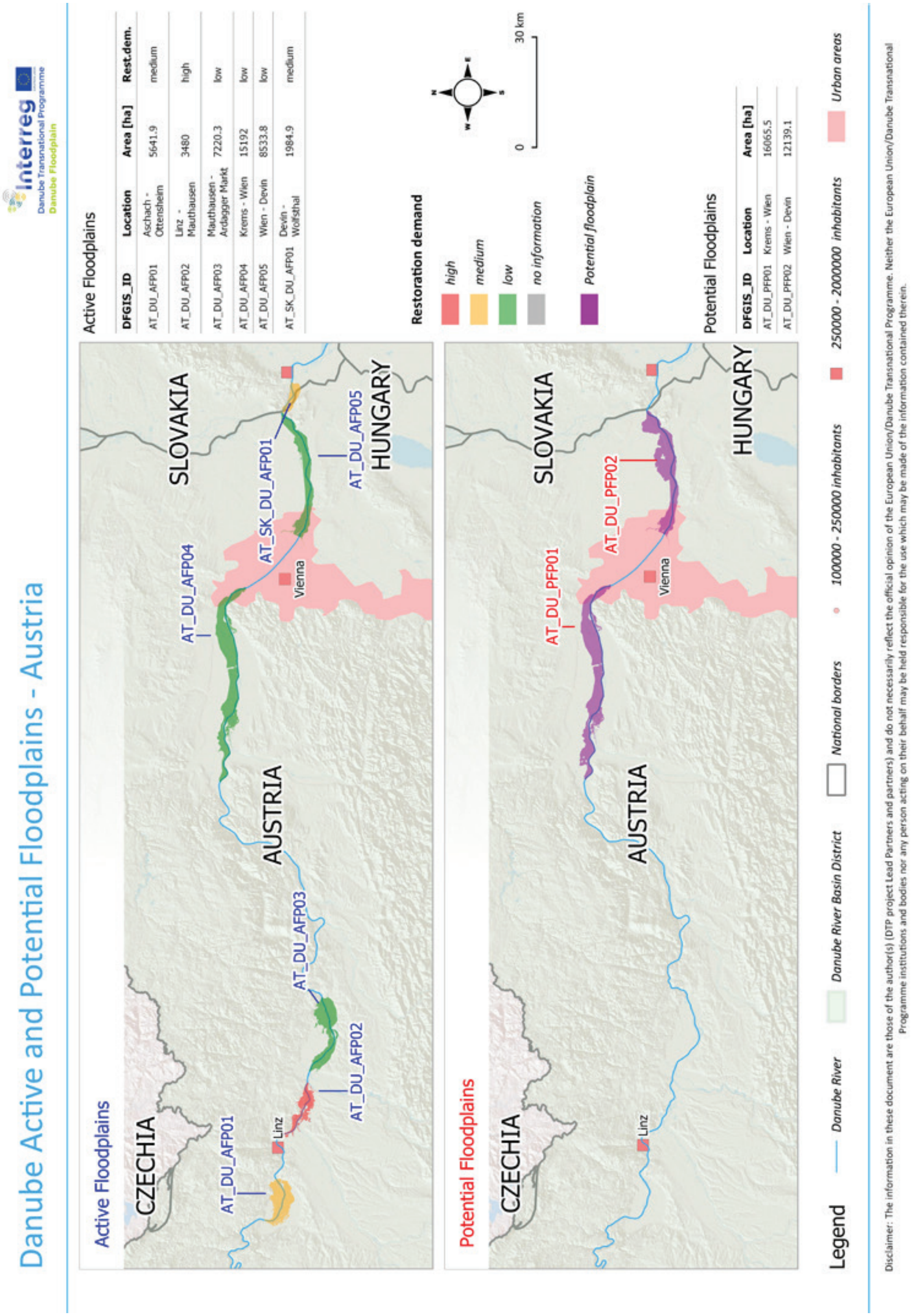
Figure 2 - Floodplain Evaluation Matrix developed in Danube Floodplain project for assessment active and potential floodplains

After the calculation of the minimum parameters for the active floodplain, the performance of each parameter was determined with the minimum parameters. Three levels of performance have been considered (high, medium and low). Thresholds to determine the performance of the floodplains for each parameter was also taken into account.

The thresholds can be selected for each river individually under consideration of specific characteristics of the river and its floodplains. It is recommended to start with the thresholds used at the Danube River and if necessary, adaptation (on tributaries) can be made

After determining the performance, the need for preservation and the demand for floodplain restoration can be evaluated. A floodplain has to be preserved if at least one parameter of the minimum set is evaluated with a high performance. Based on the minimum parameter evaluation, each floodplain is assigned to one of three groups (low, medium, high demand for restoration) depending on the achieved points in the FEM-evaluation

Danube active and potential floodplains and restoration demand are presented below:



Danube Active and Potential Floodplains - Germany

Interreg Danube Transnational Programme Danube Floodplain

Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
DE_DU_AFP01	Donaueschingen	973.3	
DE_DU_AFP02	Riedlingen	634.1	
DE_DU_AFP03	Oberelchingen - Lech	15554.4	medium
DE_DU_AFP04	Lech - Neuburg	3229.3	medium
DE_DU_AFP05	Bergheim - Ingolstadt	2192	high
DE_DU_AFP06	Neustadt - Weltenburg	1644.6	high
DE_DU_AFP07	Regensburg	745.3	high
DE_DU_AFP08	Geisling/Gmünd	1061.5	high
DE_DU_AFP09	Straubing - Isar	6716.4	medium
DE_DU_AFP10	Isar - Vilshofen	4531.1	medium

Restoration demand

- high
- medium
- low
- no information
- Potential floodplain

0 30 km

Potential Floodplains

DFGIS_ID	Location	Area [ha]
DE_DU_PFP01	Oberelchingen - Lech	16697.8
DE_DU_PFP02	Lech - Neuburg	3735.8
DE_DU_PFP03	Großmehring	493.5
DE_DU_PFP04	Katzau	308.6
DE_DU_PFP05	Geisling/Gmünd	2502.1

Legend: *Danube River* · *Danube River Basin District* · *National borders* · *100000 - 250000 inhabitants* · *250000 - 2000000 inhabitants* · *Urban areas*

Danube Active and Potential Floodplains - Hungary / Croatia / Serbia

Interreg Danube Transnational Programme Danube Floodplain

Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
HR_HU_DU_AFP01	Béda-Karapnacsa	4822.1	low
HR_RS_DU_AFP01	Kopački rit / Gornje Podunavlje	27994.1	low
HR_RS_DU_AFP02	Borovo / Vajska	1958.5	medium
HR_RS_DU_AFP03	Vukovar / Bačko Novo Selo	2462.3	medium
HR_RS_DU_AFP04	Mohovo / Karađorđevo	3001.2	medium
HR_RS_DU_AFP05	Ilok / Bačka Palanka	4922.2	medium
HU_DU_AFP05	Dunaföldvár	6377.7	high
HU_DU_AFP06	Paks	2034.8	medium
HU_DU_AFP07	Veránka-sziget	15904	low
HU_DU_AFP08	Bezerédy-sziget	901.1	low
RS_DU_AFP01	Futog-Beočin	3481.3	high
RS_DU_AFP02	Koviljsko-petrovaradi rit	7480.7	low
RS_DU_AFP03	Novi Banovci	2765.8	medium
RS_DU_AFP04	Beograd	1838.4	medium
RS_DU_AFP05	Pančevo	4323.5	medium

0 30 km

Restoration demand

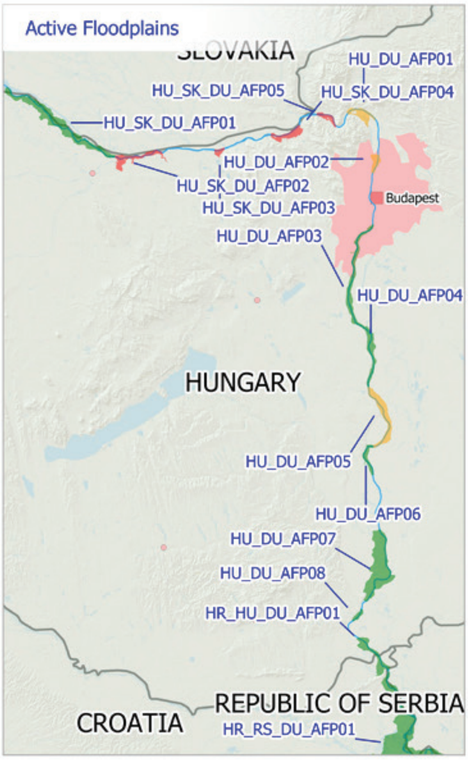
- high
- medium
- low
- no information

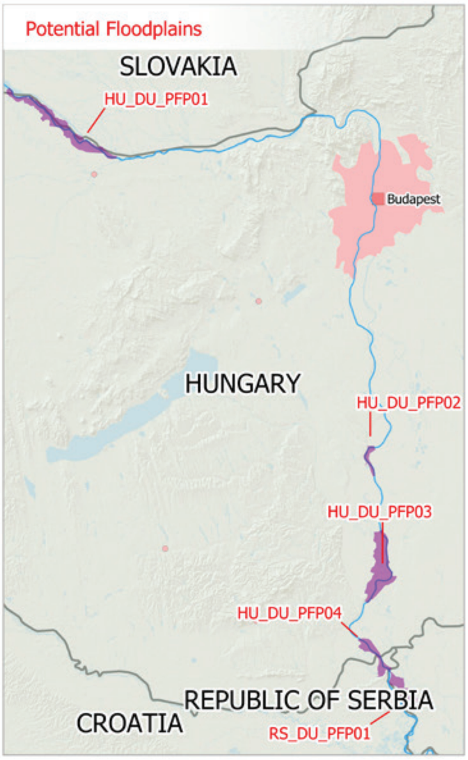
Potential Floodplains

DFGIS_ID	Location	Area [ha]
HU_DU_PFP02	Paks	2214.2
HU_DU_PFP03	Veránka-sziget	16171.6
HU_DU_PFP04	Béda-Karapnacsa	5470.6
RS_DU_PFP01	Siga - Kazuk	6057.5
RS_DU_PFP02	Vajska	5986.2
RS_DU_PFP03	Kamarište	10069.1

Legend: *Danube River* · *Danube River Basin District* · *National borders* · *Urban areas* · *100000 - 250000 inhabitants* · *250000 - 2000000 inhabitants* · *Potential floodplain*

Danube Active and Potential Floodplains - Hungary





Legend

- Danube River
- Danube River Basin District
- National borders
- Urban areas
- 100000 - 250000 inhabitants
- 250000 - 2000000 inhabitants
- Potential floodplain

Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
HR_HU_DU_AFP01	Béda-Karapnacsa	4822.1	low
HR_RS_DU_AFP01	Kopački rit / Gornje Podunavlje	27994.1	low
HU_DU_AFP01	Szentendrei-sz. North	3230.8	medium
HU_DU_AFP02	Szentendrei-sz. South	1817	medium
HU_DU_AFP03	Csepel-sziget	7077.8	low
HU_DU_AFP04	Dunaújváros	4472.1	low
HU_DU_AFP05	Dunaföldvár	6377.7	medium
HU_DU_AFP06	Paks	2034.8	low
HU_DU_AFP07	Veránka-sziget	15904	low
HU_DU_AFP08	Bezerédy-sziget	901.1	low
HU_SK_DU_AFP01	Szigetköz	14024.6	low
HU_SK_DU_AFP02	Gönyű	4059.2	high
HU_SK_DU_AFP03	Almásfüzitő	827.1	high
HU_SK_DU_AFP04	Esztergom	3118.2	high
HU_SK_DU_AFP05	Pilismarót	1492.6	high

Restoration demand

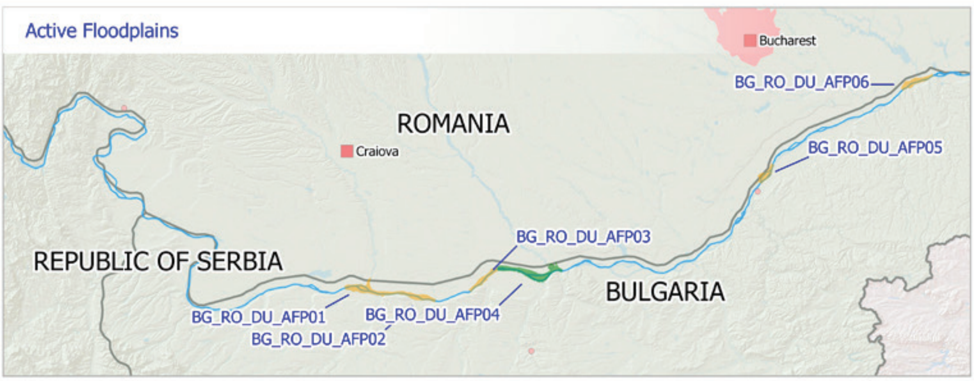
- high
- medium
- low
- no information

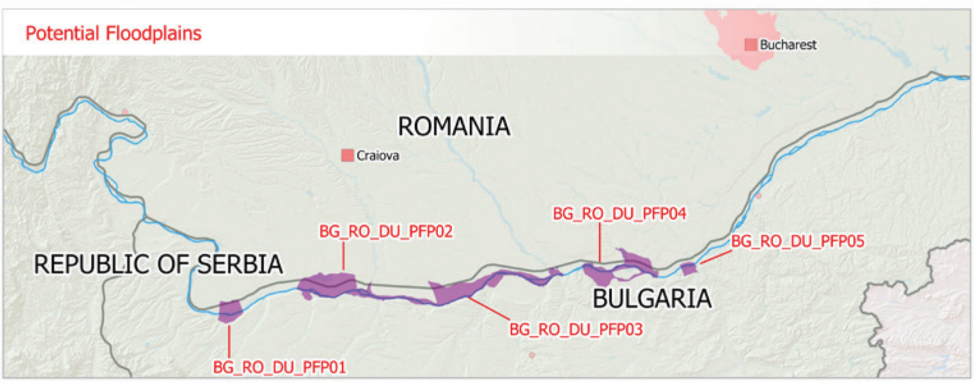
0 30 km

Potential Floodplains

DFGIS_ID	Location	Area [ha]
HU_DU_PFP01	Szigetköz	15711.3
HU_DU_PFP02	Paks	2214.2
HU_DU_PFP03	Veránka-sziget	16171.6
HU_DU_PFP04	Béda-Karapnacsa	5470.6
RS_DU_PFP01	Siga - Kazuk	6057.5

Danube Active and Potential Floodplains - Romania / Bulgaria





Legend

- Danube River
- Danube River Basin District
- National borders
- Urban areas
- 100000 - 250000 inhabitants
- 250000 - 2000000 inhabitants
- Potential floodplain

Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
BG_RO_DU_AFP01	RO: Ostroveni - Bistret; BG: Kozlodui - Oreahovo	6009.3	medium
BG_RO_DU_AFP02	RO: Dabuleni; BG:Leskovet - Ostrov	3227.4	medium
BG_RO_DU_AFP03	RO: upstream from Corabia; BG: Baikal - Ghighen	2932.6	medium
BG_RO_DU_AFP04	RO: downstream from Corabia - Islaz; BG: Zagrajden - Somovit	8162.3	low
BG_RO_DU_AFP05	RO: Giurgiu; BG: Marten	2534.8	medium
BG_RO_DU_AFP06	RO: Chiselet-Dorobantu; BG: Popina	3357.8	medium

Restoration demand

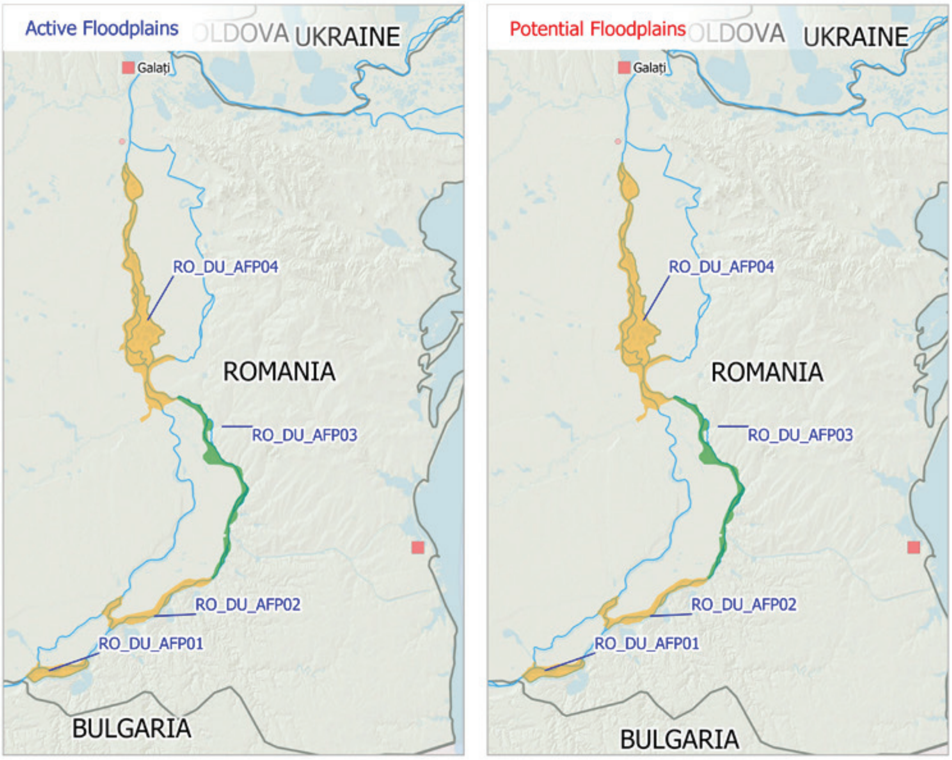
- high
- medium
- low
- no information

0 30 km

Potential Floodplains

DFGIS_ID	Location	Area [ha]
BG_RO_DU_PFP01	RO: Desa; BG: Slivata - Orsoia	8276.8
BG_RO_DU_PFP02	RO: Bistret - Bechet; BG: Dolni Tibar - Oreahovo	27972.8
BG_RO_DU_PFP03	RO: Bechet - Turnu Magurele; BG: Oreahovo - Cerkovita	30972
BG_RO_DU_PFP04	RO: Traian - Zimnicea; BG: Deagas Voivoda - Svistov	20450
BG_RO_DU_PFP05	RO: Nasturelu; BG: Novgrad	3169.1

Danube Active and Potential Floodplains - Romania



Legend: *Danube River* · *Danube River Basin District* · *National borders* · *Urban areas* · *100000 - 250000 inhabitants* · *250000 - 2000000 inhabitants* · *Potential floodplain*

Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
RO_DU_AFP01	Calarasi	5027.5	medium
RO_DU_AFP02	Oltina - Rasova	7944.7	medium
RO_DU_AFP03	Rasova - Cernavoda - Harsova	9358.1	low
RO_DU_AFP04	Harsova - Braila	29876	medium

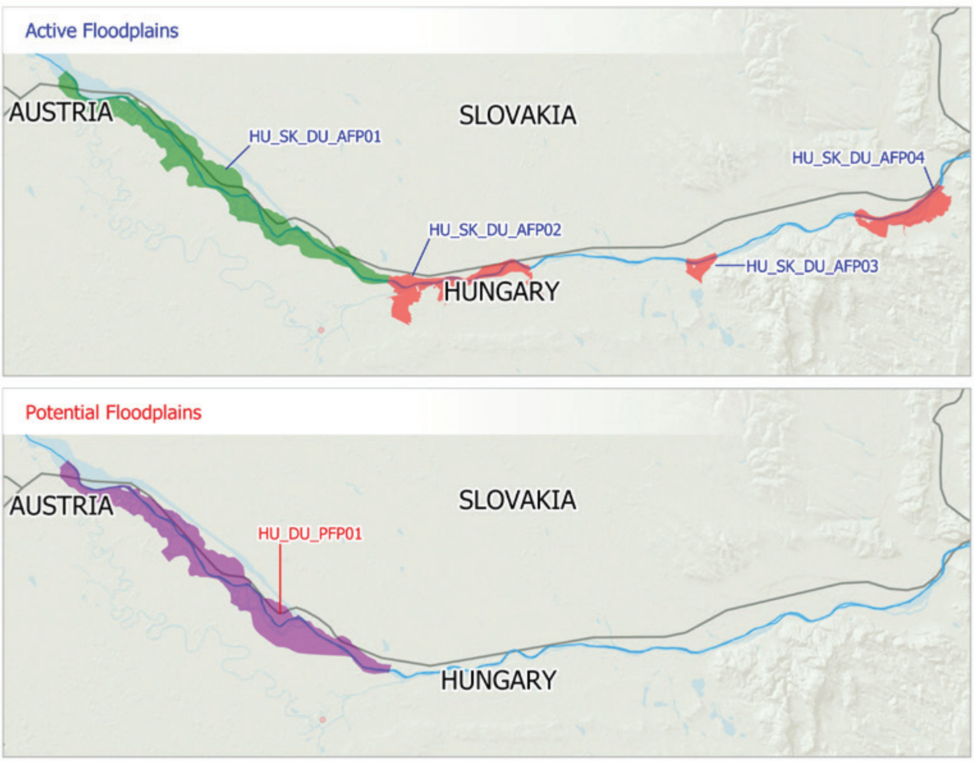
0 — 30 km

Restoration demand: *high* · *medium* · *low* · *no information*

Potential Floodplains

DFGIS_ID	Location	Area
RO_DU_PFP01	Borcea Buliga	857.9
RO_DU_PFP02	Bentu	68.6
RO_DU_PFP03	Garliciu	1083.8
RO_DU_PFP04	Tichilesti	31808.3
RO_DU_PFP05	Cotu Pisicii	1163.5

Danube Active and Potential Floodplains - Slovakia / Hungary



Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
HU_SK_DU_AFP01	Szigetköz	14024.6	low
HU_SK_DU_AFP02	Gönyű	4059.2	high
HU_SK_DU_AFP03	Almásfüzitő	827.1	high
HU_SK_DU_AFP04	Esztergom	3118.2	high

Restoration demand: *high* · *medium* · *low* · *no information* · *Potential floodplain*

0 — 30 km

Potential Floodplains

DFGIS_ID	Location	Area [ha]
HU_DU_PFP01	Szigetköz	15711.3

Legend: *Danube River* · *Danube River Basin District* · *National borders* · *100000 - 250000 inhabitants* · *250000 - 2000000 inhabitants* · *Urban areas*

3. Scenarios for restoration and preservation

Overview on scenarios

Three restoration scenarios (current state scenario and two restoration scenarios) in five pilot areas (Begecka Jama, Bistret, Krka, Middle Tisza, and Morava, shown in Figure 3) have been investigated. After an agreement on the explicit restoration measures in each scenario with the stakeholders, three two-dimensional (2D) hydrodynamic models for the pilot areas were set up.

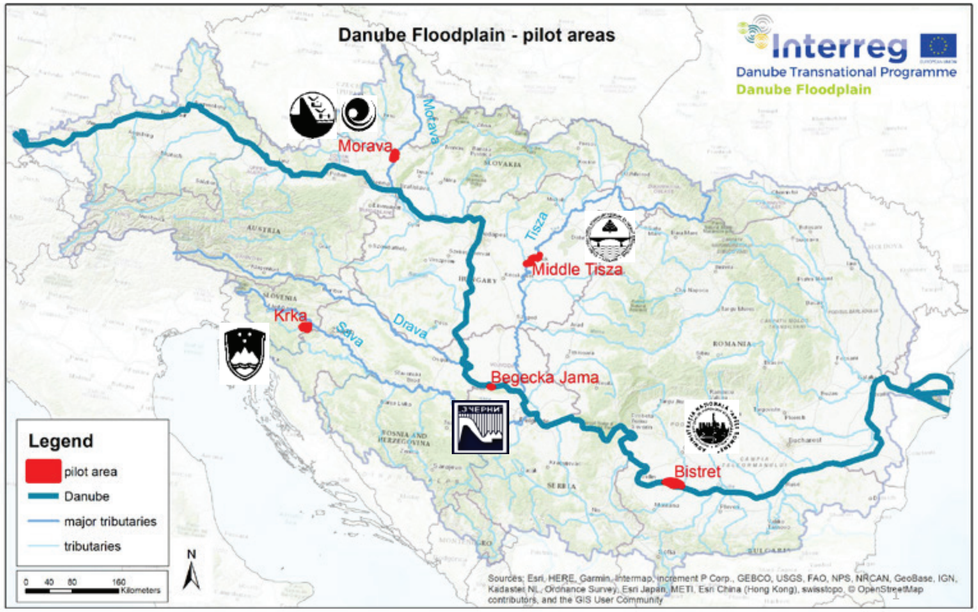


Figure 3 - The pilot areas where the 2D hydrodynamic modeling was applied in the frame of the Danube Floodplain project

1. Current State (CS)
The first model represents the current state of the area (CS). It was set up based on a recent high-resolution digital elevation model (DEM) and up-to-date ground survey data. It is the base model for the restoration scenarios models.

2. Realistic restoration scenario 1 (RS1)
In the second 2D model **(realistic restoration scenario 1; RS1)** all planned measures were implemented, e.g. dike relocation, modification of land cover and river geometry.

3. Optimistic restoration scenario 2 (RS2)
Furthermore, an optimistic scenario model **(optimistic restoration scenario 2; RS2)** was developed which includes more extensive measures. With this approach, the maximum capacity of flood protection obtained by restoration measures in the pilot areas without consideration of real limitations is shown.

Additional info:

In cooperation with national authorities, as well as, the identified stakeholders two restoration scenarios were developed, specific for each pilot area. The planned restoration measures were discussed with relevant stakeholders on a stakeholder workshop in each of the pilot areas, including various domains like fishery, agriculture, shipping, municipal authorities, nature protection, residents, etc.

To quantify the effects of the two restoration scenarios, the simulation results of both were compared with the current state scenario.

Cost Benefit Analyses (CBA) and ecosystem services (ESS) approach

Among other challenges, e.g., developing and implementing a common agreed methodology for floodplain delineation, the Danube Floodplain Project faces the challenge of developing a common methodology for conducting a Cost Benefit Analysis (CBA). A classical or standard CBA in flood risk management considers as benefits the avoided flood risk. In addition, for demonstrating the profitability of the floodplain restoration measures for flood risk mitigation, an extended cost-benefit analysis (extended CBA) can be used to estimate other ecosystem services of floodplains and show their additional value. In other words, the avoided flood risk benefit as result of the floodplain restoration measure is completed with ESS benefits as result of the same measure.

The *Figure 4* synthesizes the workflow of the extended CBA for floodplain restoration measures in the Danube Floodplain Project.

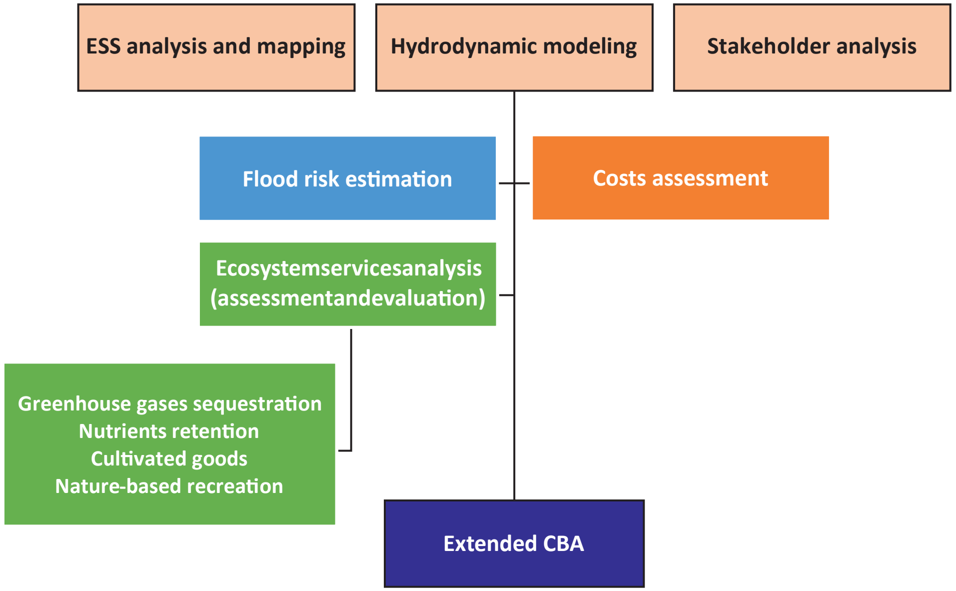


Figure 4 - Workflow of the extended CBA for floodplain restoration measures in the Danube Floodplain Project

As the figure shows, three kinds of input data, were required for conducting the extended CBA (ESS analysis and mapping, hydrodynamic modeling, and stakeholder analysis). As in a standard CBA, the costs and the flood risk were estimated. The extension of the standard CBA consisted then in the quantitative assessment and evaluation of other four ESS groups, besides flood mitigation (greenhouse gases sequestration, nutrients retention, cultivated goods, and nature-based recreation).

Ecosystem Services analysis and mapping

The aim of using the ESS approach in the Danube Floodplain Project was to show the benefits and value of ecosystems to society and to improve the conditions for sustainable management of nature and ecosystems at the Danube River Basin. The ecosystem services were assessed based on stakeholders' feedbacks in pilot areas enriched with analyses on land cover/land use data from Copernicus (European Environment Agency, 2012) and additional CORINE land cover data (European Environment Agency, 2018) mainly with the help of responsible project partners of the pilot areas (and some external experts

not related to the project). These analyses and data were georeferenced, which played a significant role in understanding ecosystem services processes and identifying the potential ecosystem services hotspots and low spots for restoration projects. For a consistent approach, the project team developed and used a scale of intensity for provisioning and regulating ecosystem services.

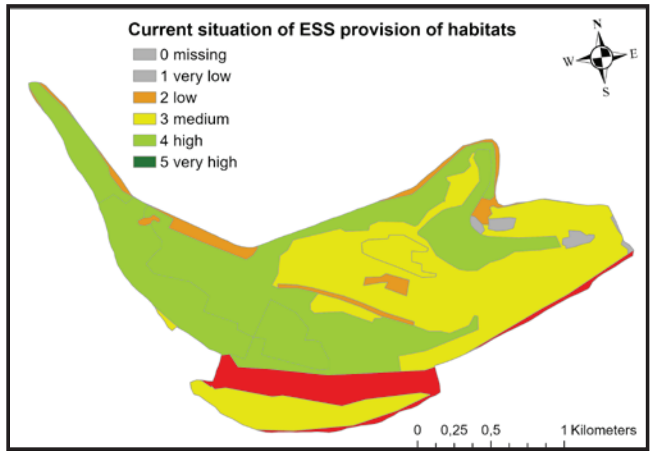
The intensity of services was derived from the level of details for individual ecosystems in each pilot area and the values of all ecosystem services were divided in classes using two approaches: an assessment by stakeholders and an assessment by using land use/land cover data.

Assessment by stakeholders: the stakeholders ranked the value of used ecosystem services after restoration from 0 to 5 (Figure 5). Since the measures can also result in one of the ESS no longer being provided, the benefits must be ranked zero (no benefit).

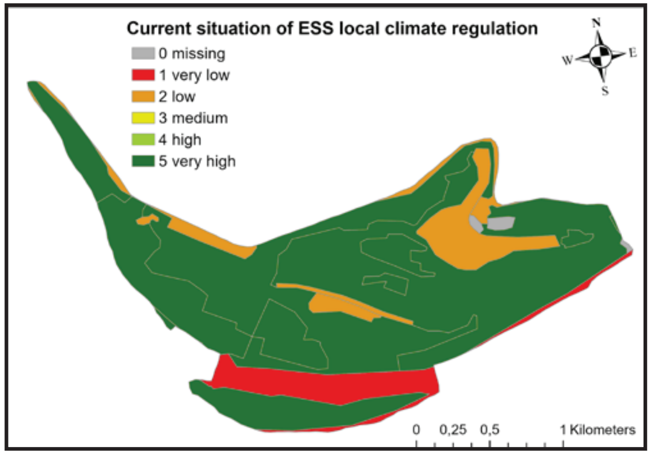
Class	0	1	2	3	4	5
Intensity	Missing	Very low	Low	Medium	High	Very high

Figure 5 - Class intensity -assessment by stakeholders

Examples: Begecka Jama pilot area



Intensity of the ecosystem services provision of habitat



Intensity of the ecosystem services local climate regulation

Assessment by using land cover/land use data. By jointly classifying all provisioning and regulating ESS, areas with a particularly high provision of ESS (so-called hot spots) and also areas with a very low provision of ecosystem services (so-called cold spots) can be easily identified. The ranking values was established from 1 to 5 *(Figure 6)*

Class	1	2	3	4	5
Intensity	Missing to very low	Low	Medium	High	Very high

Figure 6 - Class intensity using land cover/land use data

Examples: Begecka Jama pilot area

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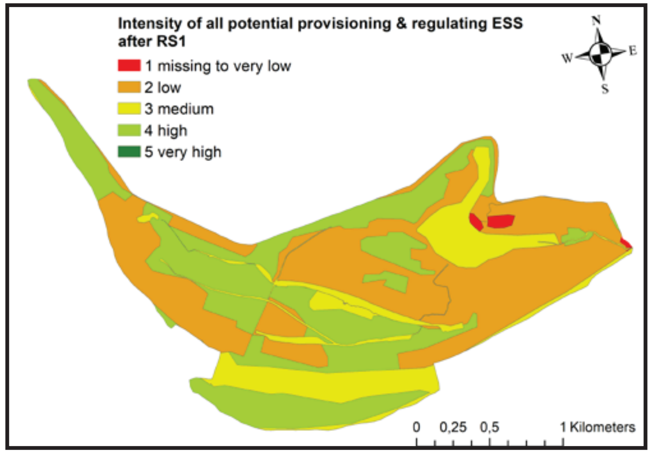

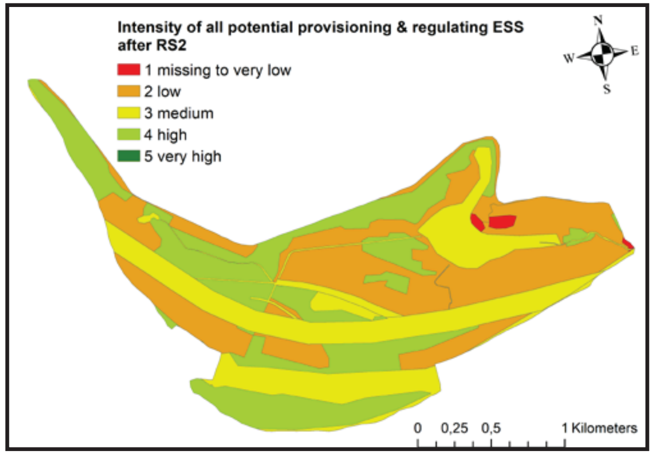

Habitat modelling

General aim of the habitat modeling work within the Danube Floodplain Project was to evaluate whether a certain floodplain restoration measure is capable of improving typical floodplain habitats. Such prediction was made based on environmental co-variables, like water depth, flood duration, flow velocity, etc. (Guisan and Zimmermann, 2000; Maddock et al., 2013). At the basis of the method, there is a conceptual understanding of how these environmental factors influence habitats and the species living in them. Therefore, quantitative formulations were made to link habitats and environmental variables.

The results of meso-scale biodiversity assessment in the pilot areas showed that floodplain habitats, and thus biodiversity, can benefit from increasing or restoration of the lateral connectivity, as intended by the majority of restoration scenarios.

However, while the assessment on the meso-scale shows the general tendency for the development of habitats, a micro-scale analysis could have given insights on the level of species or specific communities. Still, this requires in-depth knowledge of the setting and cannot be obtained without extensive fieldwork.

4. Catalogue of "win-win" restoration and preservation measures

Danube Floodplain project deals also with an inventory of floodplain restoration measures transposed into a catalogue.

Literature and several specific websites *(e.g., http://nwrm.eu/measure/floodplain-restoration-and-management)* already comprise a wide range of floodplain restoration and preservation measures. Therefore, the Catalogue aims to combine in the first way the experience of countries in implementing these kinds of measures in the frame of River Basin Management Plans, Flood Risk Management Plans, but also synthesize the proposed measures developed in the frame of restoration scenario for DFP project pilot's area.

Catalogue of "win-win" floodplain restoration and preservation measures propose a variety of key structural measures addressed to restoration and preservation the natural function of the river that will reduce flooding, improve water status and biodiversity, and revitalize social and economic conditions of the communities

The structure of the Catalogue covers four main sections, types of measures, win-win effect, ecosystem services, effect on floodplain evaluation matrix *(Figure 7):*

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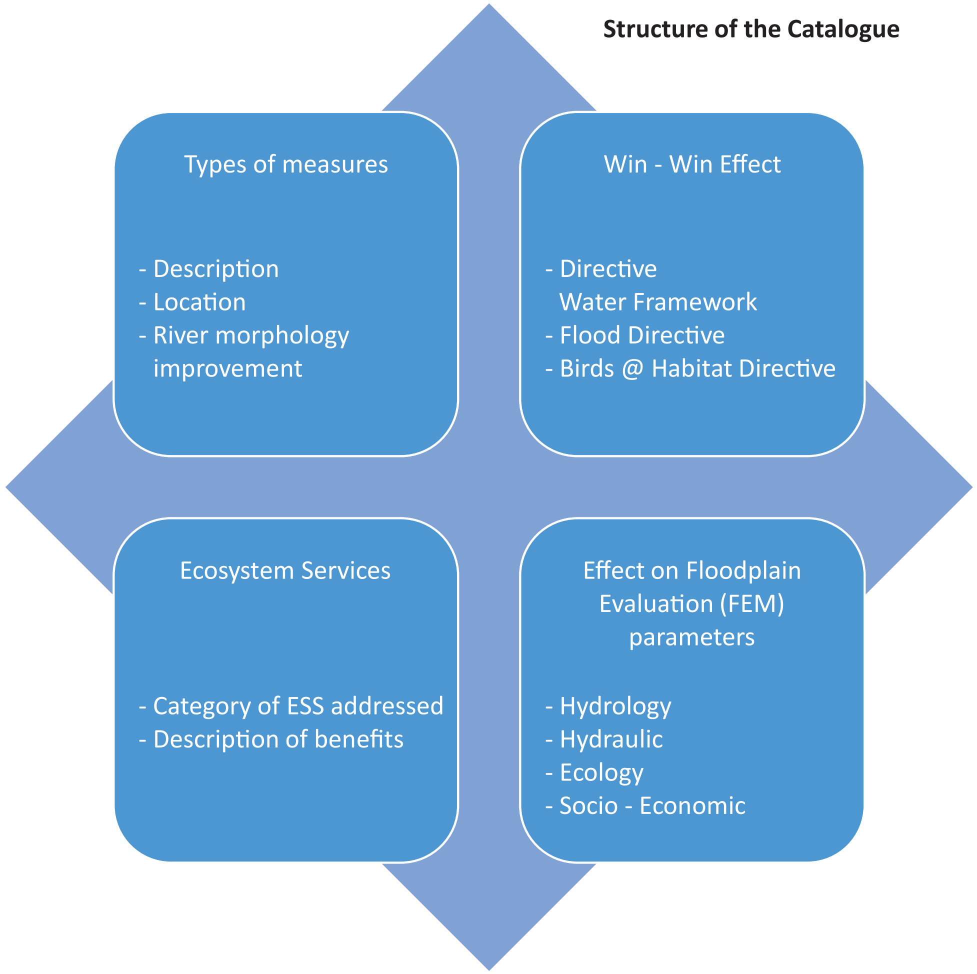

A synthesis of floodplain restoration and preservation measures included in the Catalogue is presented in the *Figure 8*

Technical works (constructions)	*Floodplain morphology restoration (land cover and lateral branches)*	*River morphology restoration (river channel geometry alteration)*	*Support measures*
-Dike relocation -Dike removal -Dike slitting -Implementing culverts/inlet sluices into the dike -Lowering dikes in different locations -Removal of weirs -Operational mode changing of dams /hydropower plant -Adequately designed and positioned culverts.	-Land use conversion towards natural conditions -Creating retention ponds -Increasing the roughness of floodplain (afforestation) -Creating flood control channels -Re-connection of lateral branches/ oxbows -Deepening lateral branches/ oxbows	-River widening by construction of new lateral channels -Increasing the roughness in the river channel. Restoration of natural substrate -Removing parts or the entire bank stabilizations/embankments -River bank re-vegetation -Initiate meandering of river course by using river engineering structures -Reconstruction of groynes	-Research, studies, scientific projects -Administrative and legislative measures

Figure 8 - Synthesis of floodplain restoration and preservation measures

5. Tools for assessing restoration projects

A general evaluation tool (FEM-Tool) for assessing floodplain restoration projects was developed in the Danube Floodplain project. The tool based on table calculation or GIS software is addressed to possible later assessment of other restoration projects ensuring a simplified and standardized assessment of floodplain restoration projects.

FEM-Tool offers the possibility to enter all relevant input data and proceed the FEM results leading to a recommendation if a restoration project should implement or not. Basic form of the FEM-Tool was created in Microsoft Excel. Macros are used to proceed the entered input data automatically.

Figure 9 shows an overview about all possible input data that can be included in the FEM-Tool.

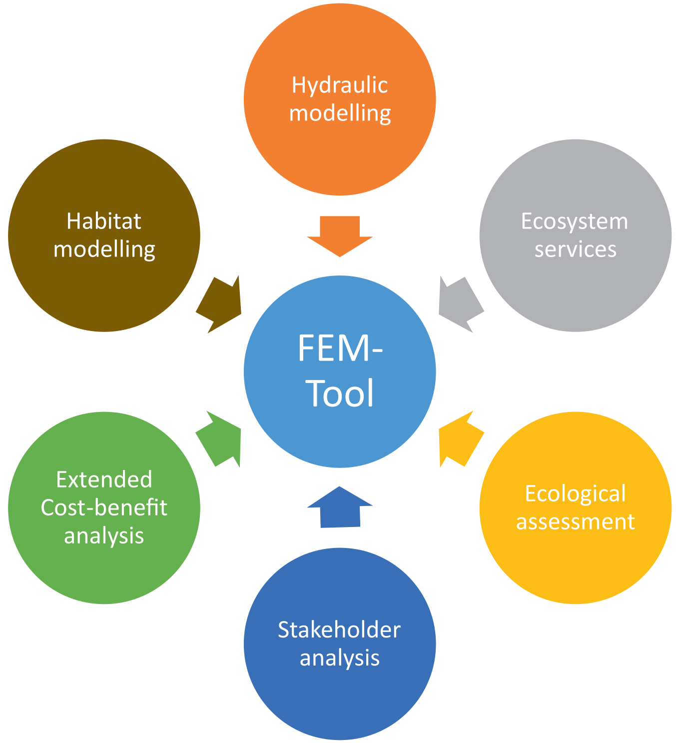

Figure 9 - Overview about all possible input data that can be included in the FEM-Tool.

Evaluation of a restoration project with the FEM-Tool is based on two main steps. First, evaluation of the current state of an active floodplain with the FEM method followed by an assessment of the restoration state, including stakeholder analysis, FEM analysis, ecosystem services, habitat modelling.

An overview including the FEM-Tool is presented in the *Figure 10.*

The FEM-Tool will be further developed in the Danube Floodplain project's extension period. It is recommended to use the upgraded FEM-Tool. Nevertheless, the overarching principles of the tool are the same in the basic as well in the upgraded version.

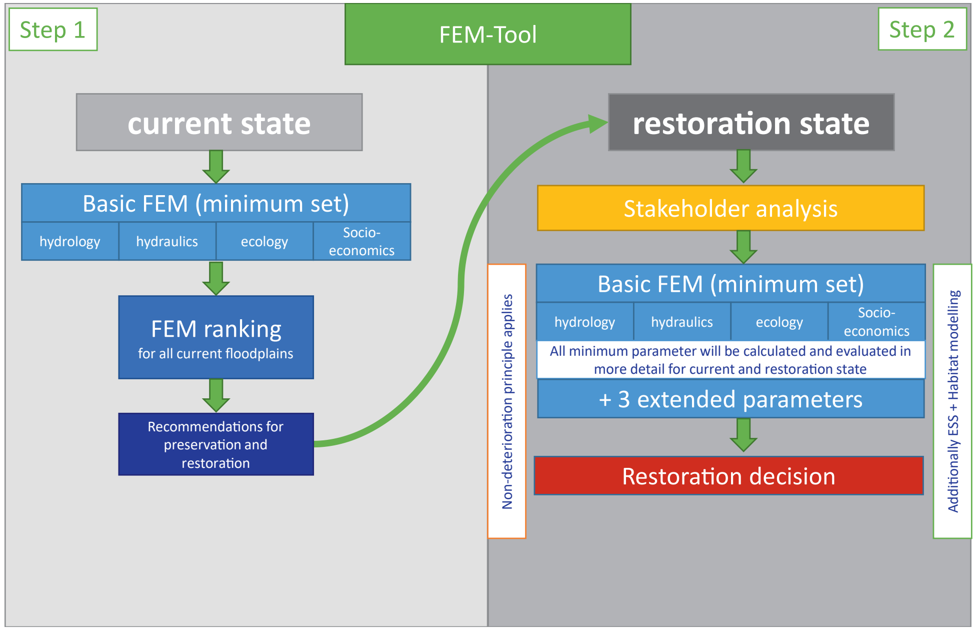

Figure 10 - Overview including the workflow of the FEM-Tool