Act. 4.3

Extended Cost-Benefit Analysis Results

Deliverable D 4.3.1

Report on assessment results of the CBA applied to the pre-selected pilot areas including ESS, stakeholders and biodiversity as input for 4.4.1 and therefore part of the feasibility studies in output 4.1.

WP	WP4: Flood prevention pilots
Activity	Activity 4.3
Deliverable	D 4.3.1 Report on assessment results of the CBA applied to the pre-selected pilo areas including ESS, stakeholders and biodiversity as input for 4.4.1 and therefore part of the feasibility studies in output 4.1
Activity-leader	TUM and CUEI
Deliverable prepared by	Francesca Perosa (TUM), Veronika Zwirglmaier (TUM) Johanna Springer (TUM) Prof. Markus Disse (TUM)
Involved partners	All partners from countries with pre-selected pilot areas, CUEI, WWF HU, TUM, REKK
Connection with other deliverables/outputs	D 4.1.1, D 4.2.2, D 4.2.3, D 4.3.2, and output 4.1

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Content

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1. Summary

Deliverable D 4.3.1 presents the results of including the estimation of ecosystem services in a standard cost-benefit analysis (CBA), resulting in an “extended cost-benefit analysis”. Following the methodology presented in Deliverable D 4.3.2, we show the results of six ecosystem services (ESS) types, estimated by applying the Toolkit for Ecosystem Service Site-based Assessment (TESSA) and complementary methodologies (e.g., stakeholder engagement). The ESS estimations were used to include (in monetary values and discounted) the co-benefits of floodplain restoration measures into CBA analyses. Herein, we present the outcomes of four pilot areas of the Danube Floodplain Project (Begecka Jama, Bistret, Krka, and Morava). The total annual added value of the ESS benefits of the “realistic” floodplain restoration measures, was estimated at approximately 1.2 million USD^{2019}/yr in Begecka Jama, 601,000 USD^{2019}/yr in Bistret, 1.0 million USD^{2019}/yr in Krka, and 0.7 million USD^{2019}/yr in Morava. For “optimistic” restoration measures, the total annual added value of the ESS benefits was estimated at approximately 1.5 million USD^{2019}/yr in Begecka Jama, -255,000 USD^{2019}/yr in Bistret, 237,000 USD^{2019}/yr in Krka, and 3.1 million USD^{2019}/yr in Morava. Considering the costs of the measures and the discounting of the ESS added values, the extended CBA results are promising. In Begecka Jama, Krka, and Morava at least one restoration measure (realistic or optimistic) lead to a benefits-costs-ratio (BCR) approximately equal or higher than 1, when using an extended CBA. The standard BCR shows instead results smaller than one and closer to zero for both restoration scenarios (between 0 and 0.4). In Bistret instead, the extended BCR are always higher than the standard BCR but do not get close to 1. Although the restoration measures do not seem to be profitable in Bistret, the “realistic” restoration measure reaches and extended BCR of 0.43, a valid value for a habitat restoration project. Finally, Annex A2 to this deliverable shows the results of an additional ESS assessment in the Bistret pilot area (prepared by Dr. Mihai Adamescu) and of the extended CBA in the Middle Tisza pilot area (prepared by the Regional Centre for Energy Policy Research, REKK).

2. Introduction

Adapted from Danube Floodplain (2020a) 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. 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 European Union (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. These are the Water Framework Directive (WFD) (European Parliament, 2000), the Flood Risk Directive (FD) in 2007 (European Parliament, 2007), and the Flood Risk Management Directive (FRMD), to reduce the damage caused by floods to human health and human life, environment, cultural heritage, and economic activities and infrastructure (European Parliament, 2007). Since floods do not stop at borders, the management units are the river basins, as for the Danube catchment.

Floodplain restoration is seen as a win-win nature-based solution (NBS) for flood risk. 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 solutions, 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. NBS can improve various floodplains' ecosystem services (ESS). For example, potential ESS of floodplain reconnection are flood depth reduction, which can reduce flood risk, or a better river-floodplain connection, which enhances ESS such as water quantity and quality regulation (Guida et al., 2015). Floodplain restoration is a solution with great potential but these 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 benefits of the NBS, namely the various ESS provided, to have a more integrative picture of the effects of floodplain restoration measures. We want to address the problem that the concept of ESS is for now 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). These steps should also be implemented by including stakeholders' consultation.

Some studies analyzed the ESS values of floodplains at the Danube catchment level (UNDEP/GEF, 1999, Perosa et al., 2021a). However, the results of the qualitative studies on floodplain restoration and their ESS were conducted for specific sections or tributaries of the Danube, and single or few ESS. For example, Petz et al. (Petz et al., 2012), Derts and Koncsos (Derts and Koncsos, 2012), and Grover and Krantzberg (Grover and Krantzberg, 2013) show the dominance of food provisioning ESS in the floodplain areas of the biggest Danube's tributary, the Tisza river. Guida et al. (Guida et al., 2015) only focused on the hydrodynamic consequences of floodplain restoration at the Tisza and call 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). This deliverable contains results of an extended cost-benefit analysis for restoration measures aimed at analyzing the profitability of floodplain restoration measures, by considering the ecosystem services provided by the floodplains.

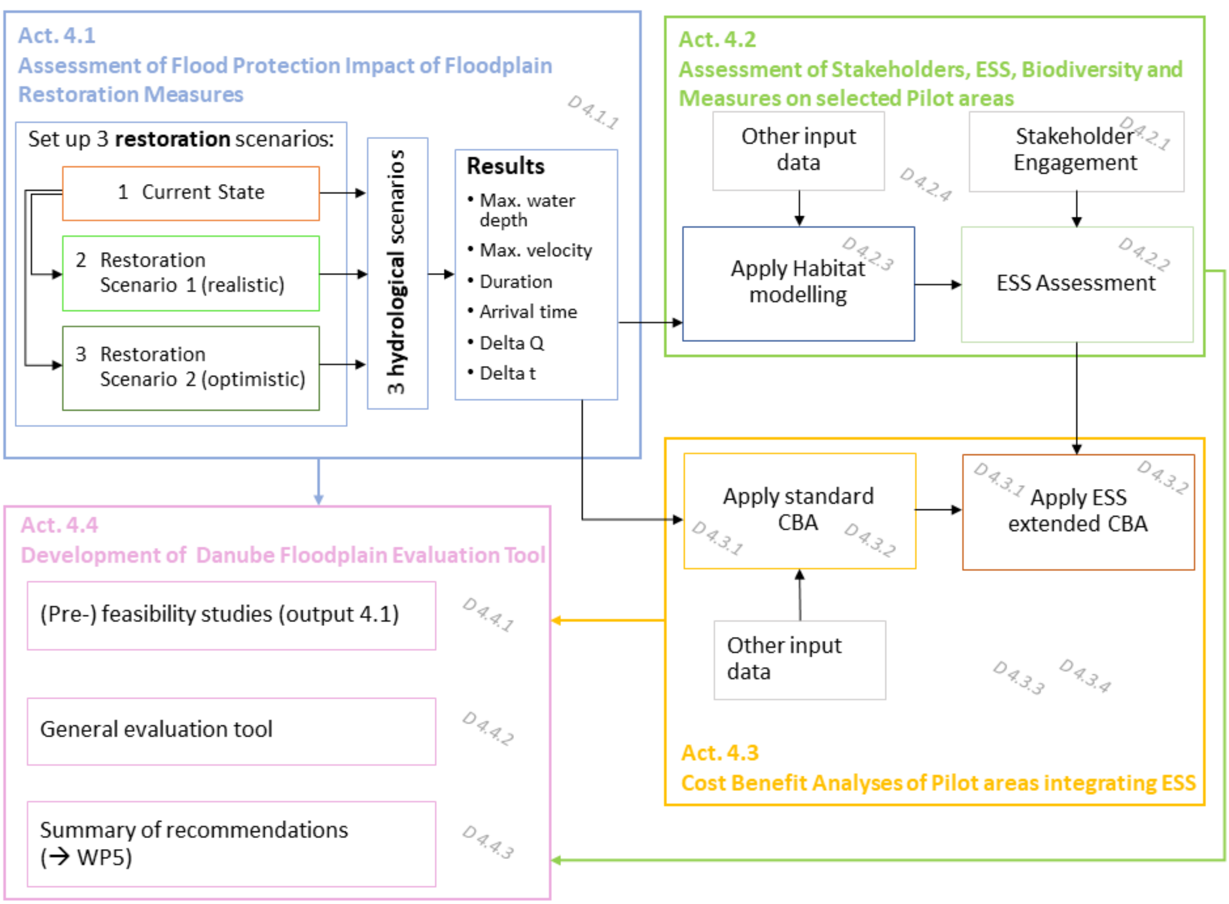


Figure 1. Flow chart of the tasks in WP4 in the pilot areas including activities and deliverables

Figure 1 shows the framework, in which this deliverable is included, namely work package 4 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 the ecosystem services and the 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 Transnational Programme, 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 also about 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, 2019) and the report about the ecosystem services mapping (Danube Floodplain, 2020b) created the basis for further analysis 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.

3. Pilot Areas

Adapted from Danube Floodplain (2020a)

3.1 Location of the Pilot Areas

There are five pre-selected pilot areas chosen for the Danube Floodplain Project in the Danube basin. Two are situated directly along the Danube River and three at tributaries to the Danube. Figure 2 shows the location of all the pilot areas in the Danube Basin. Figures 3 to 7 show the topographic and aerial maps of the individual pilot areas. The geographical and hydrological characteristics of the five pilot areas as well as the investigated restoration measures are summarized in chapter 3.2.

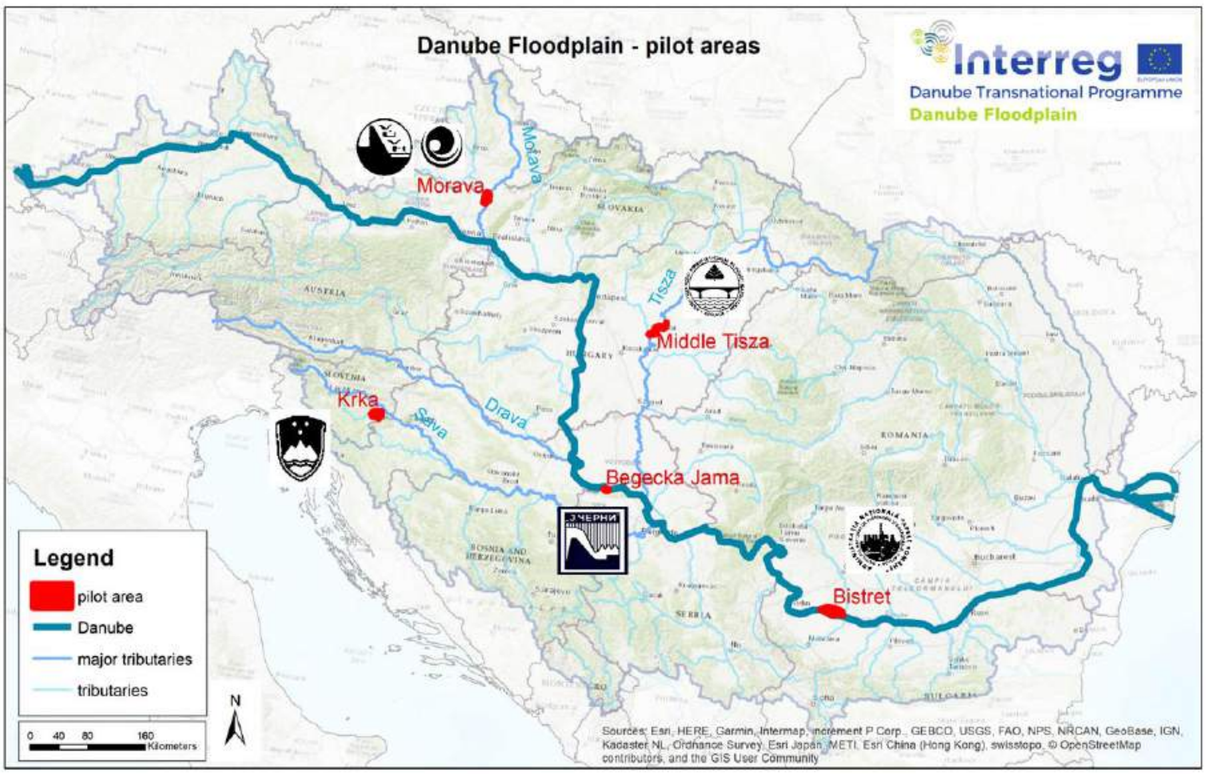


Figure 2. Location of the five pilot areas in the Danube Basin with the responsible partners

Begecka Jama at the Danube in Serbia (Figure 3), is investigated by the Jaroslav Cerni Water Institute (JCI).

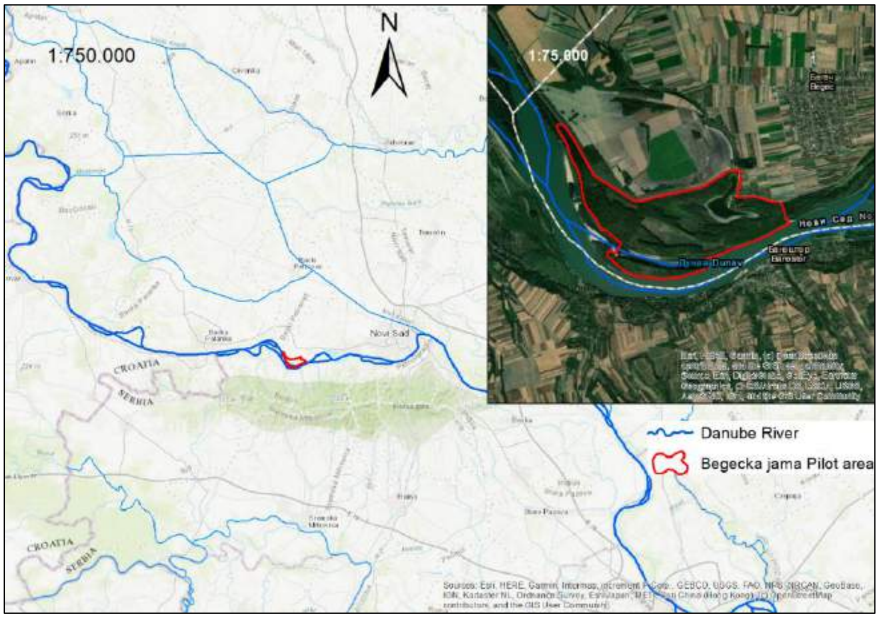


Figure 3. Topographic and aerial map of the Begečka Jama pilot area

Bistret at the Danube in Romania (Figure 4), is investigated by the National Administration ”Romanian Waters” (NARW) and the National Institute for Hydrology and Water Management of Romania (NIHWM).

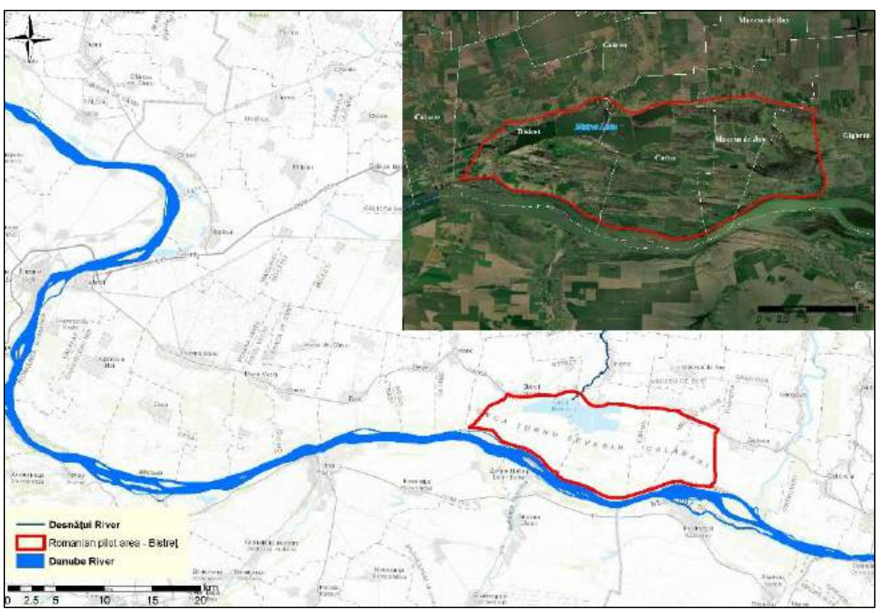


Figure 4. Topographic and aerial map of the Bistret pilot area

Kostanjevica na Krki (Krka) at the Krka River in Slovenia (Figure 5), is investigated by the Slovenian Water Agency (DRSV).

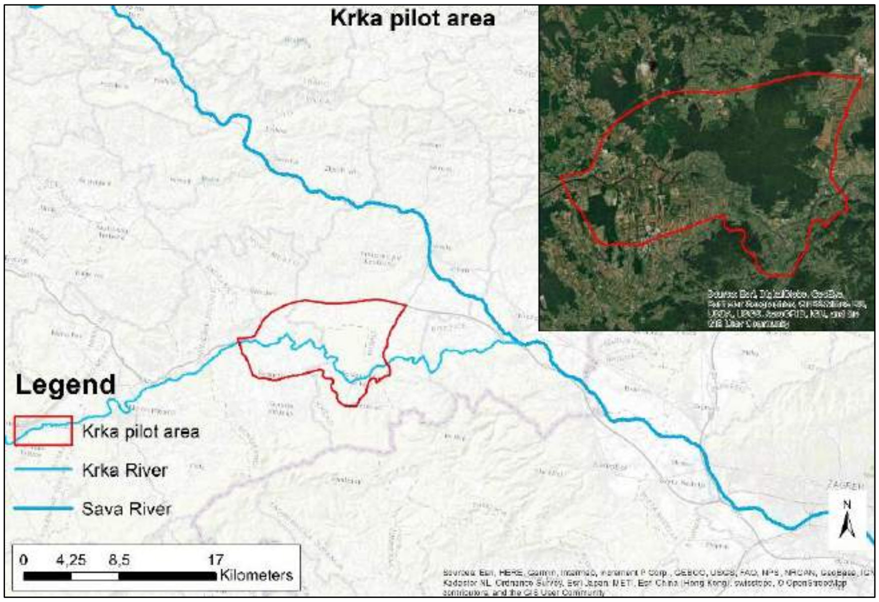


Figure 5. Topographic and aerial map of the Middle Tisza pilot area

Middle Tisza at the Tisza River in Hungary (Figure 6), is investigated by the Hungarian Middle Tisza District Water Directorate (KOTIVIZIG).

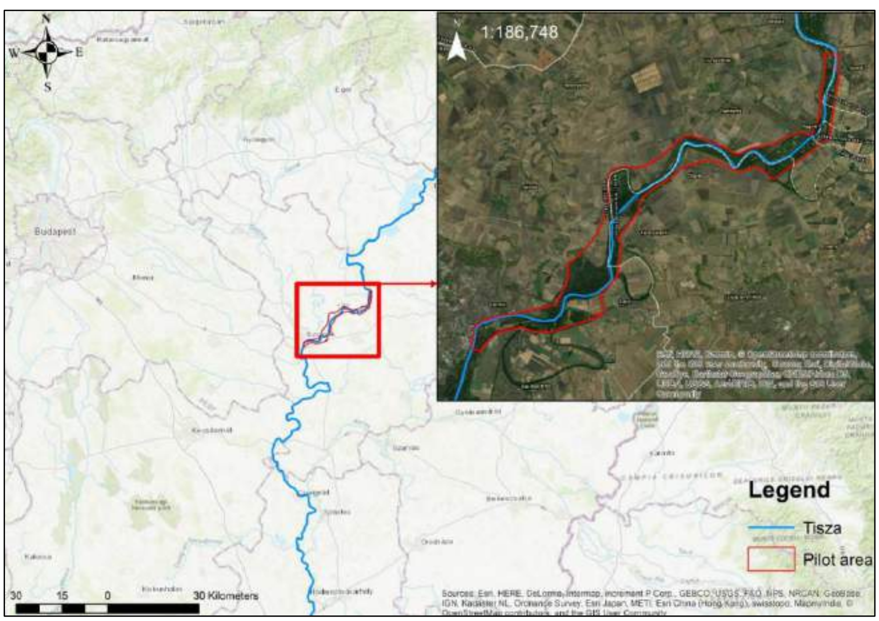


Figure 6. Topographic and aerial map of the Middle Tisza pilot area

Morava at the Morava River at the border between the Czech Republic and Slovakia (Figure 7), is investigated by the Czech Morava River Basin Authority (MRBA) and the Water Research Institute of Slovakia (VUVH).

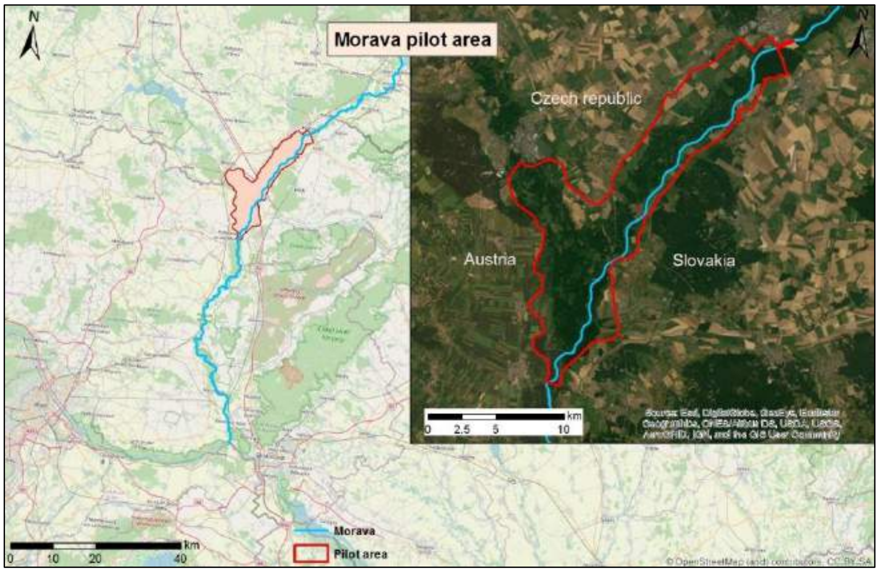


Figure 7. Topographic and aerial map of the Morava pilot area

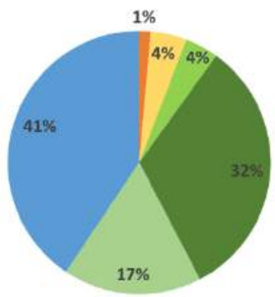
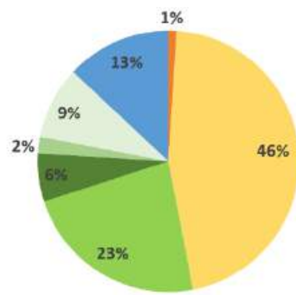
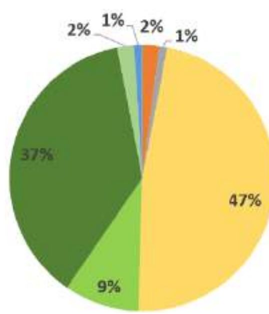
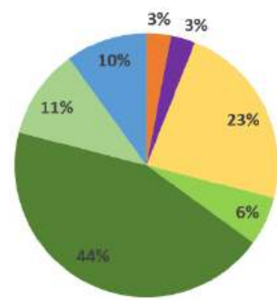
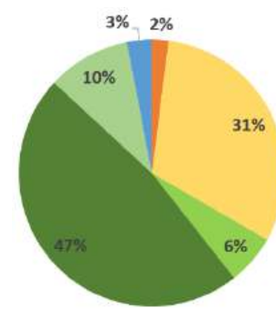
3.2 Characteristics of the Pilot Areas

The five pre-selected pilot areas show different properties in size, from 10km^2 in the Begecka Jama area to 177 km^2 at the Romanian Danube in Bistret, but also in geographical characteristics and land use. Further, the purpose of restoration follows different motivations, e.g. flood risk management, reconnecting old oxbows and reactivating the floodplain, enhancing the ecological conditions to improve habitats for plant and fish species, or promoting sustainable development and ecotourism. The planned restoration measures also differ. Mainly, dike relocation, land use change, or excavation and reactivation of old oxbows are implemented by topographical adjustments of the 2D model. Table 1 comprehensively summarizes the characteristics of each pilot area in detail.

Table 1. Characteristics of the five pilot areas in the Danube Floodplain Project

Pilot Area	**Begecka Jama**	**Bistret**	**Krka**	**Middle Tisza**	**Morava**
River	Danube	Danube	Krka	Tisza	Morava
Country	Serbia	Romania	Slovenia	Hungary	Slovakia, Czech Republic
Responsible PP	JCI	NIHWM/HARW	DRSV	KOTIVIZIG	VUVH/MRBA
Pilot area size [km^2]	10.13	176.98	85.56	49.51	147.37
Geographical / morphological characteristics	Begecka Jama Nature Park (BJNatP) is located on the active floodplain on the left bank of the Danube River, upstream from the City of Novi Sad. The length of the area is approx. 7,8 km (rkm 1.276+200-1.284), while the central point is 45° 13' 23“N, 19° 36' 23“E. Formerly, it was part of a larger floodplain, that was reduced to the current extent due to agricultural development and flood protection measures implemented in the early 18th century. Several geomorphologic types of fluvial erosion of different ages - islands, natural levees (ridges), oxbow lakes, and backwaters, created mutually by fluvial	The Bistret pilot area is located on the left bank of the Danube river, just upstream of the confluence with the Jiu river. It has an average length of approx. 24 km and an average width of about 7 km. The average altitude of the land in the Bistret enclosure is 27.50 mdMN, and the average slope is approx. 0.00833%. The Bistret area also includes the Bistret lake in which the Desnatui tributary flows. The area is delimited in the south by the defense dikes from the Danube, in the west by the compartmentalization dike between the Rast enclosure and the Bistret enclosure, in the north	The Kostanjevica na Krki pilot area is combined from the Kostanjevica na Krki town, Krakovski forest, and Šentjernej field. It is situated in the SE part of Slovenia, at (45°50'46'' N 15°25'29'' E, altitude 155m). The pilot area is influenced by moderate continental climates. The whole area has a natural water retention function. The main watercourse is the Krka river (94 km, 2,315 km^2). In the upper part, where the river is in a gorge, there are many karstic underground springs. The surface tributaries appear in the lower part of the Krka river where the valley widens. Some of them	The Middle Tisza region is a meandering river section. Flood risk and vulnerability are of particular importance in the area. After the river regulation in the 19th–20th centuries, both riversides showed dykes construction. These dyke sections protect the settlements, industrial zones, and arable lands from flood events. The Middle Tisza section is the lower section of the river, so this area can accumulate more sediment on the floodplain area and lose the conveyance capacity between the dykes. In the floodplain the main land use type is the forest, the second is	The Morava River is a lowland river, in the past strongly meandering. Extensive river training works were done (channel straightening, cut-off meanders, uniform channel with bank protection, reduction of floodplain areas, interruption of longitudinal continuity by weirs and sills). Other characteristics are: the confluence of Morava and Thaya on the CZ side with a large retention area to release flood discharges; several villages along the area but outside the floodplain area; modeling area delineated by present flood dykes and the

Pilot Area	Begecka Jama	Bistret	Krka	Middle Tisza	Morava
	erosion and reclamation-enabled the development of a mosaic of wetland habitats at different stages of succession of floodplain vegetation, which represent a refuge for many animal and plant species. BJNatP is an important reproduction area for many fish, amphibians and bird species. The status of the wetland habitats (oxbows, backwaters, wet meadows, marshes) and the hydrological regime have significantly deteriorated over the past 30 years due to siltation and aggradation caused by both natural processes and anthropogenic activities (forestry, pollution from the surrounding arable land, flood protection). Intensive land use caused habitat degradation and fragmentation. River training and flood protection measures disrupted the dynamics of flood events. The planting	by the Bistret lake and the terrace, and in the east by the main irrigation channel Macesu-Nedeia. In the northern terrace area are the localities Bistret, Plosca, Dunareni, Sapata, Macesu de Jos. The average altitude of the terrace is about 31 mdMN. In the pilot area, drying and irrigation systems and pumping stations are executed. The main pumping stations that ensure the drying of the area are SP-Malaians in the upstream end which also ensures the gravitational discharge of Lake Bistret when flows on the Danube are less than aprox. 8000 m^3/s, SP-Stejaru, and SP-Nedeia located in the downstream end of pilot area.	(Radulja, Sajovec, Lokavec, Senuša) discharge into the Krka river near the pilot area. The lower part of the river is characterized by slow river flow and extensive flood plains – one of them is Krakovski forest, which represents the largest remnant of lowland floodplain forest in the country (consisting of Pseudostellario–Quercetum and Pseudostellario europaeae-Carpinetum (tree species such as Quercus robur, Carpinus betulus, Alnus glutinosa are characteristic here). Beside the Krka river itself, it is the Krakovski forest which is important on the European level by its habitat and species diversity (protected under the Habitat and Bird Directives, and Natura2000). Šentjernej field is covered mostly by meadows, farmland, and scattered settlements.	crops and we can find some other less land use type (e.g. pasture).	retention area on the confluence with Thaya river.

Pilot Area	Begecka Jama	Bistret	Krka	Middle Tisza	Morava
	and management of poplar plantations enabled the spreading of invasive plant species, whilst the backwaters, oxbows and wet meadows are being filled up due to forestry activities and needs. The area became less attractive for visitors due to the loss of aesthetic and recreational values.		Kostanjevica na Krki is an important cultural and historical site. Geologically and geomorphologically it is largely a tectonic lowland depression on the carbonate geological basis, filled with clay-gravel sediments.		
Land cover (European Environment Agency, 2018) of the 2D model area					
		settlement; crops; other natural vegetation	sealed; pasture; marshes	industry; forest; water bodies	
Current ecological status and deficits	The pilot area belongs to the Danube River Water Body RSD8: Danube between Novi Sad and HR-RS State border. The status assessment below is taken	3 Surface Water Bodies has been identified for the active floodplain: - RORW14-1-27_B172 Desnatui -Ac. Fantanele -Ac. Bistret in moderate	General information on the Krka (section Otočec – Brežice) Water body, according to the RBMP for Danube basin district:	The Middle Tisza River is a natural category with heavily modified sections. This section of the river, based on physico-chemical data	Heavily modified water body (HMWB) - Ecological status: 3 - moderate; Hydro-morphological quality: 4 - poor

Pilot Area	Begecka Jama	Bistret	Krka	Middle Tisza	Morava
	from the Danube RBMP update 2015, ICPDR (DanubeGIS): - The water body is provisionally HMWB, - The chemical status is poor (assessed with low confidence), - The ecological potential is moderate (assessed with medium confidence).	ecological status (river continuity and morphological conditions in moderate status). Moderate status for fish fauna (caused by upstream river dam Fantanele) - RORW14-1-27-8_B176 Buzat - izvor - cf. Desnatu;RORW14-1-27-7_B175 Baldal (Jivan) - izvor - cf. Desnatui in good ecological status - Good chemical status with a small increasing for CCOCr for all WB	- Overall ecological status: GOOD - Significant diffuse pressures: Agriculture - Significant point pressures: Communal waste waters, Industrial waste waters - Significant hydro-morphological pressures: Land use in the riparian area - Other significant anthropogenic pressures: No Protected areas: - The entire area is characterized by high biodiversity. More than 50 species from the Natura2000 protected species list can be found in the river and on its floodplains. Some of them are on the International Union for the Conservation of Nature and Natural Resources red list.	supporting biology, has excellent potential and the concentrations of the hazardous substances we studied did not exceed the environmental quality limit. The narrow strip of floodplains between the dams of the Tisza active floodplain, plays an important role in the migration and spreading of aquatic and aquatic habitats as ecological or green corridors. The floodplain of the Middle Tisza, due to its function as a core area and as an ecological corridor, is of great natural value and is of great ecological importance. Unfortunately, nowadays floodplains are the most important routes and channels for the invasion of invasive plant species. This process could significantly reduce biodiversity in the future. In addition, floodplain management is in many cases not consistent with the	

Pilot Area	Begecka Jama	Bistret	Krka	Middle Tisza	Morava
				requirements of natural floodplain habitats. The area is also part of the Middle Tisza (HUHN10004) Special Protection Area and the Middle Tisza (HUHN20015) Special Area of Conservation.	
Major restoration purposes	- Adequate water supply throughout the year in the Begecka Jama lake, oxbows and channel system, and improving habitats for aquatic species - Increase in the water surface area and depth of the oxbows and existing channels - Increase in biodiversity and spawning areas as a result of habitat restoration - Increasing the types of ecosystem services, as well as improvement of the quality and quantity of existing ecosystem services of the area	- Flood protection for population (major damages during 2006 flood) - Sustainable development and ecotourism	Improvements for: - Flood risk management - Nature protection - Forestry	- Increasing conveyance capacity/ floodplain area - Decreasing flood hazard	- Improvement of flow conditions in the river floodplains concerning flood protection and nature protection goals - Optimization of water regime in the floodplains - Enhancement of conditions for diverse biotopes, which can be found in the area of interest - Improvement of conditions for fish migration

Pilot Area	Begecka Jama	Bistret	Krka	Middle Tisza	Morava
Restoration measures Scenario 1 - realistic	- Cleaning and widening of the existing connecting channel between Danube River and Begecka Jama lake and weir reconstruction which allow fish migration - Floodplain DEM modification via the deepening of existing oxbows and channels and the excavation of new channels between the deepened oxbows, which would allow for the controlled inflow/outflow from the system - Increase the diversity of the river morphology as a result of the excavation, deepening and cleaning of oxbows, and existing and new channels. - Creation of new fish spawning areas contributes to the maintenance and increase of biodiversity.	- Construction of a recreational and fish-farming lake (200 ha) in the area of Rast - Relocation of the dikes in the confluent area of Desnaţui River with Bistret Lake - Creation of a large water drainage channel to supply Lake Bistret and to facilitate the natural flow of Desnatui River back in the Danube	SC1 - Scenario 1 is a combination of a corridor enabling floodplain activation and measures to increase water conductivity in the river bed through Kostanjevica, thus lowering water levels within the settlement. It comprises 2 measures: K1- river bed deepening of the northern stream of the Krka river through Kostanjevica, and inundation at the bifurcation, and K3- a corridor to the floodplain, length 650 m, width 45 m.	- Increase floodplain area: Dike relocation - Land use change: Arable land to pasture - Create a fish spawning area	- removal of weirs - Removal or adjustment of selected barriers (weirs, sills) - removal of levees - relocation of flood dykes (to include the cut off sidearms in the floodplain area)
Restoration measures Scenario 2 - optimistic	- Cleaning and widening of the existing connecting channel between Danube River and Begecka Jama lake and weir reconstruction which	- Additional dike relocation from the Danube close to the villages along the alluvial terraces	SC2 - Scenario 2 is a combination of 4 measures, being three corridors enabling floodplain activation, and additional measures	- Increase floodplain area: Dike relocation and Controlled dike overtopping - Land use change: Plough (cultivated) land	- RS1 + relocation of flood dykes (further than in RS1) - Renewal of river pattern

Pilot Area	Begecka Jama	Bistret	Krka	Middle Tisza	Morava
	allow fish migration - Floodplain DEM modification via the deepening of existing oxbows and channels and the excavation of new channels between the deepened oxbows, which would allow for the controlled inflow/outflow from the system - Increase the diversity of the river morphology and diversity of cross profiles of the river as a result of the excavation, deepening and cleaning of oxbows, and existing and new channels as well as the widening of the existing river channel. - Creation of new fish spawning areas contribute to the maintenance and increase of biodiversity.		within the river bed in Kostanjevica: K1– river bed deepening of the northern stream of the Krka river through Kostanjevica, and inundation at the bifurcation; K2– a corridor to the floodplain, length 950 m, width 30 m; K3– a corridor to the floodplain, length 650 m, width 45 m; K4– a corridor to the floodplain, length 280 m, width 60 m.	to pasture - Vegetation regulation: Controlled afforestation - Create wetland habitats (eg. lake)	Reconnection of oxbows with the main Morava channel (at the present state they are behind the dyke) Deepening of existing oxbows
Major recent floods	2006: HQ100	2006: >HQ100 (ICPDR, 2008)	2010: HQ100	2000: ~HQ100	2010: >HQ100 (ICPDR, 2012)
	2010: HQ10-20 (HIDMET, 2014)	2010: >HQ20 (ICPDR, 2012)			
HQs investigated	HQ2-5	HQ2	HQ2-5	HQ2, HQ5	HQ5
	HQ10-20	HQ10	HQ10	HQ10, HQ30	HQ10
	HQ100	HQ100	HQ100	HQ100	HQ100

3.3 Restoration Scenarios in the Pilot Areas

The responsible project partners develop two restoration scenarios (RS1 and RS2) individually in cooperation with national authorities as well as the identified stakeholders (Table 1 and Table 2). The planned restoration measures are discussed on two stakeholder workshops in each of the pilot areas with relevant stakeholders – fishery, agriculture, shipping, municipal authorities, nature protection, residents, etc. The results of these stakeholder meetings are summarized in deliverable D 4.2.1 (Danube Floodplain, 2019).

In Table 2, a summary of all restoration measures in the pilot areas for both scenarios is given. Different kinds of restoration measures, e.g. in-stream measures which change the roughness and the shape of the riverbed, alterations in the floodplain size (through e.g. dike relocation), as well as morphological and/or land cover changes in the floodplain are determined. The main purpose of the restoration measures is to re-establish as far as possible the natural floodplain conditions and to achieve a win-win situation for both the environment and flood protection.

After an agreement on the explicit restoration measures in each scenario with the stakeholders, the project partners set up the three 2D models for the pilot areas:

1. **Current State (CS)**
   The first model represents the current state of the area (CS). It is set up based on a recent high-resolution 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 are 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) is 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.

To estimate the ecosystem services, we classified the habitat types of the pilot areas on the spatial level into six different categories: tree-dominated, grass-dominated, crop-dominated (rice paddies or no rice cultivations), wetland-dominated areas, or others. This classification varies according to the above-described scenarios and the corresponding maps can be seen in "Annex A1. Habitat Types according to Scenarios".

Table 2. Restoration measures determined and implemented for the realistic implementation scenario (RS1) and the optimistic implementation scenario (RS2) for the five pilot areas

Restoration scenario	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2
Which measures are implemented in the pilot areas?	**Begecka Jama**		**Bistret**		**Krka**		**Middle Tisza**		**Morava**	
1. constructions										
1.1 dike relocation			X	X			X	X	X	X
1.2 dike removal				X			X	X		
1.3 controlled dike overtopping / gaps in the dike			X				X	X		
1.4 removal of weirs									X	X
1.5 change operation mode of weirs	X	X								X
1.6 migration permeability at weirs	X	X								
1.7 removal of culverts										
2. land cover and lateral branches										
2.1 convert land cover towards natural conditions				X			X	X		
2.2 modify floodplain DEM	X	X			X	X	X	X	X	X
2.3 increasing the roughness of floodplain (afforestation)								X		
2.4 create and connect new lateral branches or pools / new water regime	X	X	X	X	X	X				
2.5 create retention areas / flood channels			X		X	X		X		
2.6 connection of lateral branches/oxbows	X	X	X							X
2.7 deepening lateral branches/oxbows	X	X								X
2.8 reconnect old oxbow										X
2.9 increase floodplain area				X	X	X	X	X	X	X
3. river channel geometry alteration										
3.1 increasing the roughness in the river channel (according to natural bedrock)										
3.2 widening of the river channel		X			X	X				
3.3 increase of the river bed (decrease of water depth)										
3.4 increase the diversity of the river morphology (riffles, pools, potholes, sand or gravel banks, cut banks and slip-off-slope, broader and narrower passages of the river,...); diversity of cross profiles of the river	X	X								
3.5 removing bank stabilizations / embankments							X	X		
3.6 riparian vegetation (increase roughness, stabilizes the riverbank, decreases nutrient inflow)										
3.7 implementing groynes, boulders, or dead wood to initiate meandering										
3.8 change course of river (meandering)										X
3.9 removing ground sills, plunges									X	X
3.10 create fish spawning areas	X	X						X		
3.11 Removing sand bars							X	X		

4. Methodology

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

The methodology used to derive the results described in this deliverable is described in detail in deliverable D 4.3.2 (Danube Floodplain, 2021). In the following subchapters, we provide a summary of the main concepts followed for the estimation of the results.

4.1 Analysis of the Pilot Areas in Terms of Ecosystem Services

Various tools exist to estimate the 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. In addition, this tool is thought for applications at the local scale. TESSA was applied so far only once at the DRB to analyze agricultural ESS and payment schemes (Martino and Muenzel, 2018). We found three studies that recently used TESSA to examine floodplain restoration measures and recommended its future application. Fazaa et al. (2018) analyzed a floodplain in Southern Iraq and Merriman et al. (2018) applied TESSA for the estimation of five wetland ESS in Nepal, namely three provisioning ESS, greenhouse gases sequestration, and nature-based recreation. A local, rapid analysis of wetland restoration in the UK was conducted by Peh et al. (2014) and represents the only European application on the topic.

One of the major challenges of methods and tools, 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). To fill this research gap, we included six ESS in our evaluation methods. Although this allows more ESS-aware decision-making, we recognize that "not all ecosystem services can be maximized simultaneously" (Birch et al., 2014).

Another major challenge to estimate the benefits of floodplain restoration is a still missing systematic method to be applied. One reason for that is the need for more application examples. In fact, the fourth step for flood management developing in the direction of integrated approaches is to test innovative flood management strategies in pilot projects (Halbe et al., 2018). This deliverable is aiming at filling this gap, also by testing the same methodology for four pilot areas at the same time.

4.2 Analysis of the Pilot Areas in Terms of Profitability with an Extended Cost-Benefit Analysis

The cost-benefit analysis (CBA) is a decisional method that estimates the economic efficiency of alternative options, by comparing the benefits derived from an option with the associated costs (ICPDR, 2015a). The extended CBA is the more appropriate method for evaluating public policies than a simple financial CBA since government interventions are often related to the provision of public goods and ecosystem services (ICPDR, 2015a). In flood risk management, the costs and benefits addressed in an extended CBA may include indirect and non-priced external effects (ICPDR, 2015a), such as environmental effects.

In the Danube Floodplain Project, a consistent extended CBA was applied to four pilot areas, allowing a comparison among four spatially and distant analyses, also in terms of implemented restoration measure, by including the benefits that nature brings to humans, i.e. the ecosystem services, that would otherwise be neglected in decision-making (Schägner et al., 2013). The extended CBA process is graphically conceptualized in Figure 8. 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, 2021).

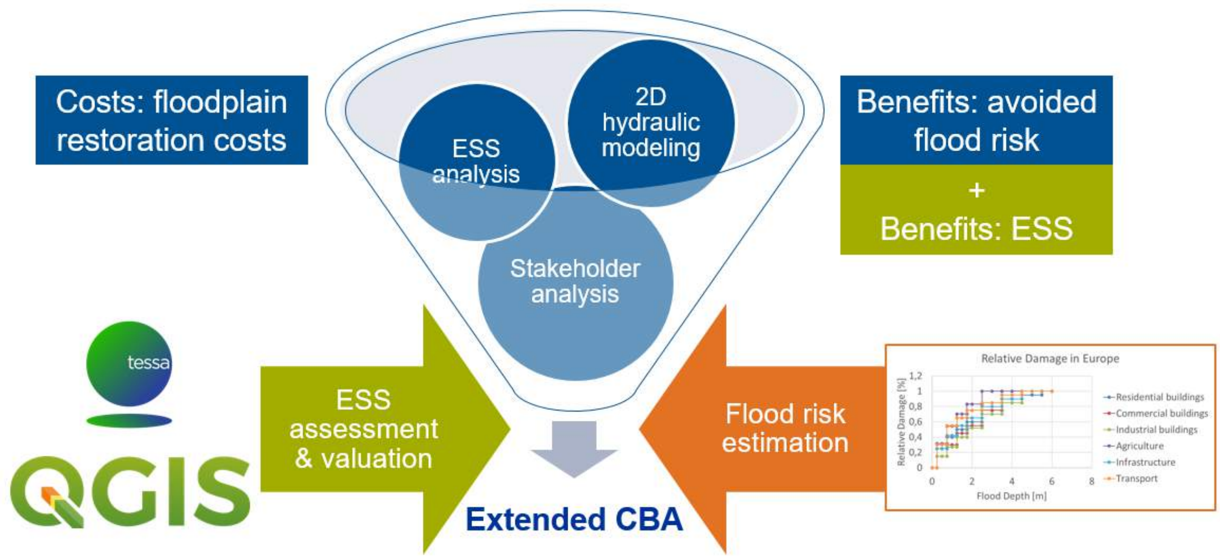


Figure 8. Workflow of the extended cost-benefit analysis for floodplain restoration measures in the Danube Floodplain Project.

5. Results

Adapted from Perosa et al. (2021b)

In the following subchapters, we provide the estimated results of the ESS assessment, evaluation, and inclusion into the extended CBA. The results of the extended CBA assessed for the Middle Tisza pilot area are separately presented in another report (Annex A2).

5.1 Results of Stakeholders' Consultation

The combination of the stakeholder workshops and an expert-based analysis of land uses (Danube Floodplain, 2019; Danube Floodplain, 2020b) resulted in digital maps for the current state scenario and one for the restoration scenarios in pilot areas, although it was not possible to represent in this way all restoration scenarios for all pilot areas (Danube Floodplain, 2020b). The maps are in shapefile format and include in their attribute tables the corresponding ESS types and intensities. The maps are shown in detail in deliverable D 4.2.2 (Danube Floodplain, 2020b). In case no maps were available for specific restoration scenarios, we adapted the current state scenarios maps based on expert knowledge. In total, 12 maps were used as input data for the ESS assessment.

5.2 Results of Global Climate Regulation

The results of carbon storage are presented in Table 3. For all four pilot areas and all scenarios, the largest carbon stock is represented by soil organic matter and the smallest by either below-ground or litter and dead wood carbon. As a result of forest- or grass-dominated area conversion in alternative to crop-dominated areas, the general response of the floodplain restoration measures is the carbon stocks increase, besides for the case of the restoration scenario 1 in Bistret.

In RS1, carbon storage would increase by around 2% in Begecka Jama and Krka, it would not change in Morava, and it would decrease by 0.25% in Bistret. This would lead to a total gain of stock monetary value (not annual) of 66,000 USD^{2020} for Begecka Jama and 750,000 USD^{2020} for Krka, while in Bistret 0.4 million USD^{2020} would be lost as a total static value (not annual).

In RS2, carbon storage would increase by 12.5%, 75.8%, 1.8%, and 0.06% for the Begecka Jama, Krka, Morava, and Bistret areas respectively. This would lead to a gain of stock monetary value in the area of 0.4 (for Begecka Jama) to 4.0 (for Morava) and 0.1 (for Bistret) million USD2020 as a total static value (not annual).

The monetary values are the result of multiplying the stored carbon and the GHGs flux in CO_2 equivalents times the values of the CO_2 emissions taxation systems documented in the report of the World Bank (World Bank, 2020), i.e. 19 USD^{2020} per metric tons of carbon dioxide equivalent (tCO2e) (World Bank, 2020).

Table 3. Carbon storage results for the pilot areas, where the total carbon stocks are calculated as the sum of above-ground biomass (ABG), below-ground biomass (BGB), litter biomass (LB), dead wood biomass (DWB), and soil organic carbon (SOC).

Carbon stocks	**Begecka Jama**			**Bistret**			**Krka**			**Morava**		
	CS	**RS1**	**RS2**	**CS**	**RS1**	**RS2**	**CS**	**RS1**	**RS2**	**CS**	**RS1**	**RS2**
AGB [ton C]	7334	7917	10608	529,651	528,197	530,129	151883	155343	155175	491909	491909	530,037
BGB [ton C]	1985	2029	2220	96,056	95,965	96,276	47471	46520	46467	154727	154727	165,638
LB + DWB [ton C]	2806	2866	3132	133,139	133,067	133,450	18708	19782	19762	122896	122896	131,320
SOC [ton C]	37417	37676	39769	1,637,108	1,632,641	1,637,469	337059	344286	343898	1217660	1217660	1,218,105
Total Carbon Stocks [ton C]	49541	50489	55730	2,395,955	2,389,870	2,397,324	555121	565932	565302	1987192	1987192	2,045,100
Total Carbon Stocks [USD2020]	3,451,356	3,517,400	3,882,523	166,918,176	166,494,256	167,013,556	38,673,443	39,426,596	39,382,706	138,441,043	138,441,043	142,475,306
RS1-CS [ton C]		948			-6,085			10,811			0	
RS2-CS [ton C]		6,189			1,369			10,181			57,908	
ES value of the RS1 [USD2020]		**66,044**			**-423,920**			**753,153**			**0**	
ES value of the RS2 [USD2020]		**431,167**			**95,380**			**709,263**			**4,034,264**	

Table 4. Greenhouse gases flux results for the pilot areas (negative net values indicate equivalent CO2 emissions; positive net values indicate equivalent CO2 sequestration).

GHG flux		**Begecka Jama**			**Bistret**			**Krka**			**Morava**	
	CS	RS1	RS2	CS	RS1	RS2	CS_v2	RS1	RS2	CS	RS1	RS2_v2
Carbon Stock Increment [ton CO2/yr]	5,104	4,957	4,237	69,942	70,763	70,558	32,259	30,620	30,584	104,985	104,985	113,219
Carbon Stock Losses [ton CO2/yr]	-45,577	-38,694	-38,694	-432,846	-432,846	-432,846	-786,634	-786,636	-786,636	-107,853	-107,853	-107,853
CO2 Em. [ton CO2/yr]	0	0	0	0	0	0	0	0	-221	-6,966	-6,966	-6,731
CH4 Em. [ton CO2/yr]	-9	-9	-9	-1	-1	-1	-437	-424	-423	-1,127,132	1,127,132	-1,027,194
N2O Em. [ton CO2/yr]	-9	-9	-9	-8,551	-8,508	-8,529	1,013	-990	-989	-5,715	5,715	-5,252
GHGs flux [ton CO2/yr]	-40,493	-33,755	-34,477	-371,458	-370,592	-370,820	-755,826	-742,096	-757,683	-1,142,681	-1,142,681	-1,051,802
RS1-CS [ton CO2/yr]		6,738			865			13,730			0	
RS2-CS [ton CO2/yr]		6,016			638			-1,857			90,879	
ESS value of the RS1 [USD2020/yr]		**128,022**			**16,443**			**260,869**			**0**	
ESS value of the RS2 [USD2020/yr]		**114,304**			**12,124**			**-35,284**			**1,726,694**	

Table 4 shows the net GHGs fluxes in the current and restoration scenarios, where the negative values represent equivalent CO_2 emissions and positive values represent equivalent CO_2 sequestration. The results are dominated by CO_2 emissions due to the carbon stock losses, if the tree-dominated areas would be considered to be harvested or affected by other disturbances. Emissions of N_2O and CH_4 also show some (substantial in Morava) effects on the overall GHGs balance in all pilot areas and scenarios.

In the restoration scenarios compared to the current scenario of Begecka Jama, the corresponding increase of sequestration of equivalent CO_2 is 16.6% in RS1 and 14.9% in RS2.

In Bistret, the afforestation causes an increase in CO_2 sequestration in both RS1 (by 0.23%) and RS2 (by 0.17%). The results of Bistret are based on the assumption that wood harvesting is taking place only on the tree-dominated area that belonged to the CS. The new-forested areas are not going to be affected by wood harvesting.

In Krka, the additional presence of wetlands results in a positive (by 1.8% in RS1) or a negative (by 0.3% in RS2) effect on equivalent CO_2 emissions.

In the Morava area, the sequestration of equivalent CO_2 increases by 8.0% for the RS2 due to an increase of carbon stock and a decrease in methane emissions. RS1 in Morava shows no effect in terms of GHGs flux.

5.3 Water-related services: Flood mitigation

In terms of flood mitigation, the scenarios tested in the pilot areas show inhomogeneous results. As Table 5 shows, at Begecka Jama the annual value of flood mitigation provided by the NBS within the 2D model zone was estimated to decrease by 0.02% (RS1) and 0.07% (RS2), a value that could have also been affected by the accuracy of the estimation itself. Similarly, the RS1 in Bistret shows a slight flood risk increase of 0.46%, which gets prominent for RS2 (by 45.18%).

The modeled flood risk benefits of flood storage resulting from floodplain restorations in Krka and Morava are instead positive (respectively by 1.32% to 2.16% and 47.19% to 43.67%), though merely affected by the small difference in water level. The floodplain's ESS flood mitigation is shown in terms of the expected annual flood-caused damage, i.e. not in terms of ESS benefits.

Table 5. Results of flood risk estimation for the pilot areas

Flood risk reduction		Expected annual flood-caused damage [EUR2019/yr]	CS - RS1 [EUR2019/yr]	CS - RS2 [EUR2019/yr]	percentage CS - RS1	percentage CS - RS2
Begecka Jama	CS	1,660,519	-306	-1,099	-0.02%	-0.07%
	RS1	1,660,825				
	RS2	1,661,618				
Bistret	CS	6,664,491	-30,702	-3,010,876	-0.46%	-45.18%
	RS1	6,695,193				
	RS2	9,675,367				
Krka	CS	3,824,913	50,645	82,634	1.32%	2.16%
	RS1	3,774,268				
	RS2	3,742,279				
Morava	CS	1,276,834	602,559	557,580	47.19%	43.67%
	RS1	674,274				
	RS2	719,254				

5.4 Water-related services: Nutrients retention

The results on the ESS value of total nitrogen (TN) retention (Table 6) depend on the amount of filtered volume and the flooded area size. For Begecka Jama, depending on whether the filtered volume or the flooded area of tree-, grass-, and wetland-dominated areas are decreasing or increasing after implementing the potential restoration, the ESS value is also decreasing (in RS1 by 4.8%) increasing (in RS2 by 6.2%). In Krka and Bistret, the estimated nutrients retention ESS value would increase in both restoration scenarios (in RS1, by 10.1% and 37.2% respectively, and in RS2, by 9.7% and 1300% respectively). On the other hand, the flooded area is decreasing in Morava with the restoration measure and its corresponding ESS value decreases by 28.2% in RS1 and by 8.0% in RS2.

5.5 Cultivated goods

The results of cultivated goods' provisioning ESS value for crops, livestock, and aquaculture are reported in Table 7. All scenarios of Begecka Jama include, according to the stakeholders, no or negligible cropland nor aquaculture, while the livestock products provisioning value would decrease by 2.9% (RS1) and by 16.4% (RS2), in case of the floodplain restoration measures. In Bistret, restoration scenarios would cause a decrease in cultivated areas. However, for the Bistret pilot area, we assumed that the fish revenue would increase if the restoration would be implemented since a more natural habitat and new spawning areas would be created. Therefore, we applied a multiplication factor to the aquaculture results of 0.8 for CS, 1.1 for RS1, and 1.2 for RS2. Consequently, an ESS value gain by 3.7% due to RS1 and by 5.2% due to RS2. In Krka, we estimated that the mean annual net benefit from this type of provisioning ESS would decrease by less than 1% for both restoration scenarios, due to the substitution of a part of the area's cropland and grasslands with wetlands. In Morava, the RS1 does not bring any change in the cultivated goods ESS value. For RS2 instead, the tree-dominated areas would increase and would cause a lower presence of livestock with its consequent lower revenue (2.9%) for the pilot area's cultivated goods ESS value.

Table 6. Results of nutrients retention ESS value for the four pilot areas. The retained and filtered water volume was extracted according to the description presented in Deliverable D 4.3.2.

Nutrients retention	**Begecka Jama**			**Bistret**			**Krka**			**Morava**		
	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2
Retained and filtered water volume [m³]	14,864,416	14,897,355	15,694,581	168,651,209	180,037,266	369,155,727	5,371,641	5,397,090	5,364,732	15,504,891	12,667,543	15,664,573
Flooded area (tree-, grass-, and wetland-dominated) [ha]	106.15	100.84	106.81	728.05	935.57	4619.21	252.64	276.78	277.41	1,475.67	1,296.58	1,343.49
ESS value [USD2019/yr]	1,974	1,879	2,097	153,594	210,696	2,133,031	1,698	1,869	1,862	28,620	20,545	26,325
RS1-CS [USD2019/yr]		-95			57,102			171			-8,075	
RS2-CS [USD2019/yr]		123			1,979,437			164			-2,295	

Table 7. Results of cultivated goods provisioning ESS value for the four pilot areas (for the unit prices used, please refer to Deliverable D 4.3.2)

Cultivated good	**Begecka Jama**			**Bistret**			**Krka**			**Morava**		
	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]
Crops	0	0	0	2,044,251	2,036,531	2,036,770	203,577	203,571	201,686	373,192	373,192	356,923
Livestock	16,305	15,838	13,637	10,275,688	10,259,072	10,275,688	1,617,430	1,615,233	1,613,937	15,283,932	15,283,932	14,827,595
Aquaculture	0	0	0	1,433,214	1,970,669	2,149,821	3,398	3,008	3,398	110,248	110,248	124,546
SUM	16,305	15,838	13,637	13,753,153	14,266,272	14,462,279	1,824,405	1,821,812	1,819,021	15,767,372	15,767,372	15,309,064
RS1-CS		-467			513,119			-2,593			0	
RS2-CS		-2,668			709,126			-5,384			-458,309	

5.6 Nature-based recreation

The sample size of quantitative studies was calculated as suggested by TESSA (Peh et al., 2017). The precision level is approximately 80% for Begecka Jama, 63% for Bistret, 65% for Krka, and 55% for Moravawhen (taking the mean and standard deviation of the results of the first ten surveys). This corresponds to sample sizes of 134 for Begecka Jama, 56 for Bistret, 47 for Krka, and 50 for Morava. Based on the interviews for the census of visitors to the area, we used as number of visitors per year to each pilot area of 10,000 for Begecka Jama (only given value), 100 for Bistret (only given value), 25,000 for Krka (average of two values), 100,000 for Morava (median of three values). According to NARW, the increase in visits would be much higher than what was assumed from the results of the survey. Therefore, we multiplied the expected number of visits in Bistret by a factor of 2, with a resulting number of visits per year of 100 (CS), 371 (RS1), and 383 (RS2). A representation of the respondents' age is shown in Figure 9, where we can see all generations represented.

Table 8 shows the corresponding results. All four pilot areas show an increase of the recreational ESS value in case the NBS would take place for both restoration scenarios, besides for RS1 I Morava. The ESS value increases because the visit numbers would increase, since we kept the consumer surplus the same for CS, RS1, and RS2. In RS1, the benefits from recreation would increase by 76%, 271%, 21%, and 0% for Begecka Jama, Bistret, Krka, and Morava respectively. In RS2, the benefits from recreation would increase by 102%, 283%, 5%, and 20% for Begecka Jama, Bistret, Krka, and Morava respectively.

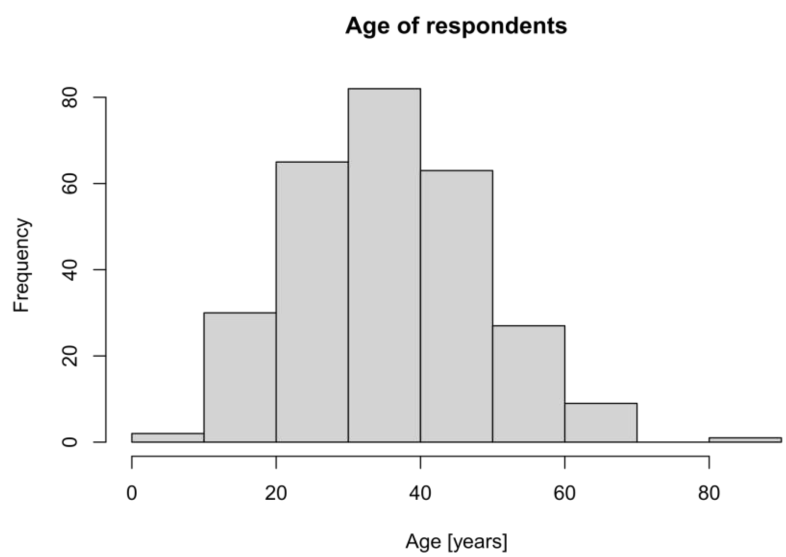


Figure 9. Distribution of the age of respondents to the questionnaires on nature-based recreation for all four pilot areas

Table 8. Results of nature-based recreation ESS value for the four pilot areas

	Begecka Jama			**Bistret**			**Krka**			**Morava**		
Consumers surplus [EUR2019/visit]	122.70			77.18			128.09			55.27		
	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2
Nature based recreation [EUR2019/yr]	1,227,040	2,178,571	2,478,123	7,718	28,605	29,573	3,202,233	3,863,188	3,367,349	5,527,168	5,527,168	6,630,320
Area [ha]	393.86			38,304.01			4,114.80			17,067.63		
Nature based recreation per unit [EUR2019/ha·yr]	3115.42	5531.33	6291.89	0.20	0.75	0.77	778.22	938.85	818.35	323.84	323.84	388.47
RS1-CS [EUR2019/yr]	951,530			20,886			660,954			0		
RS2-CS [EUR2019/yr]	1,251,083			21,855			165,115			1,103,152		

5.7 Sum of all Ecosystem Services

As seen in Table 9, the total absolute value of the ESS benefits of the realistic floodplain restoration measures, i.e. RS1, without considering the gains in carbon stocks, was estimated at approximately 1.2 million USD^{2019}/yr in Begecka Jama, 0.6 million USD^{2019}/yr in Bistret, 1.0 million USD^{2019}/yr in Krka, and 0.7 million USD^{2019}/yr in Morava. For RS2, the total absolute value of the ESS benefits was estimated at approximately 1.5 million USD^{2019}/yr in Begecka Jama, 237,000 USD^{2019}/yr in Krka, and 3.1 million USD^{2019}/yr in Morava. On the contrary to the other three pilot areas, Bistret does not show an ESS increased value due to the RS2 measure, whereas ESS losses of around 255,000 USD^{2019}/yr. These sums do not include the carbon storage values, because these are not expressed in monetary value per year, whereas only in static monetary value.

However, the total added value of the NBS in terms of ESS is not homogeneously distributed among the ESS types. Table 9 and Figure 10 display the annually added ESS values of the floodplain restoration for all pilot areas according to ESS type, where we can observe how ESS types contribute in terms of annual monetary values in the pilot areas. While the most affecting ESS types are not constant among pilot areas, nutrients retention is constantly the least contributing ESS to the sum of benefits for Begecka Jama, Krka, and Morava. However, in Bistret, nutrients retention ESS of RS2 represents the second most important contribution.

Figure 11 to Figure 14 show for the pilot areas the resulting maps of added ESS value, as a direct impact of the hypothetical restoration measures, where carbon storage values were excluded here as well. From all eight maps, we observe that the regions with the highest increase in ESS value per unit area are the ones directly affected by the floodplain restoration.

Table 9. Summary of the ESS values results shown in the previous tables and their sum, i.e. added ESS value of the floodplain restoration scenarios RS1 (a) and RS2 (b) in comparison to the current state (CS) homogenized to USD^{2019}/yr in all four pilot areas

	Begecka Jama		Bistret		Krka		Morava	
	RS1 - CS	RS2 - CS	RS1 - CS	RS2 - CS	RS1 - CS	RS2 - CS	RS1 - CS	RS2 - CS
Carbon storage [USD^{2020}]	66,044 [55,616; 86,900]	431,167 [363,088; 567,325]	-423,920 [-557,789;-356,985]	95,380 [80,320;125,500]	753,153 [634,234;990,991]	709,263 [597,274; 933,241]	0 [0;0]	4,034,264 [3,397,275; 5,308,241]
GHGs flux [USD^{2020}/yr]	128,022 [107808;168450]	114,304 [96256;150400]	16,443 [13,846;21,635]	12,124 [10,210;15,953]	260,869 [219679;343249]	-35,284 [-46426;-29713]	0 [0;0]	1,726,694 [1454058; 2271965]
Flood mitigation [USD^{2019}/yr]	-343 [-542;-253]	-1231 [-2205;-857]	-30,702 [-40,533; -25,292]	-3,010,876 [-5,935,315; -2,026,662]	56,714 [34126;119259]	92,535 [59409;181015]	674,759 [519266;962987]	624,390 [480462;891081]
Nutrients retention [USD^{2019}/yr]	-95 [-1787;592]	123 [44;320]	57,103 [55,654;57,103]	1,979,437 [1,960,579;1,979,437]	171 [-1096;712]	164 [61;412]	-8075 [-31290;4474]	-2295 [-4931;-902]
Cultivated goods [USD^{2019}/yr]	-487 [-786;-368]	-2783 [-4494;-2104]	535,180 [71,284;533,195]	739,613 [120,322;738,961]	-2705 [-2978;-2466]	-5615 [-5845;-4823]	0 [0;0]	-478,013 [-496348;-465927]
Nature-Based Recreation [USD^{2020}/yr]	1,065,543 [994551;1147450]	1,400,989 [1307647;1508680]	23,389 [21,657;25,423]	24,473 [22,661;26,601]	740,150 [680974;810590]	184,899 [170116;202496]	0 [0;0]	1,235,333 [1180181;1295892]
SUM [USD$^{2019-20}$/yr]	1,192,641 [1,099,244; 1,315,871]	1,511,402 [1,397,248; 1,656,439]	601,412 [121,908;612,063]	-255,228 [-3,821,543;734,291]	1,055,199 [930,706; 1,271,344]	236,699 [177,315; 349,387]	666,683 [487,976; 967,462]	3,106,108 [2,613,422; 3,992,110]

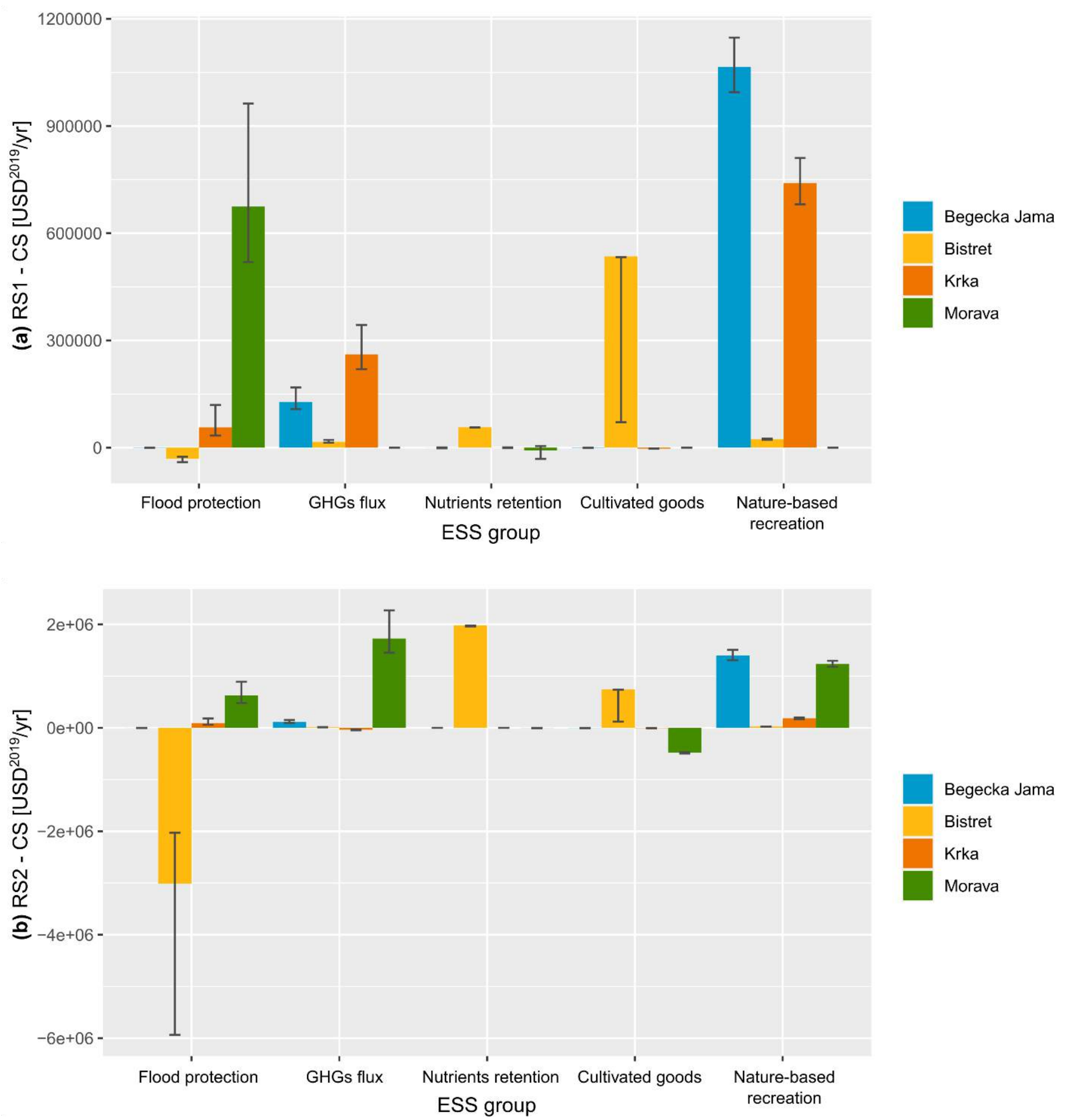


Figure 10. Added ESS value of the floodplain restoration scenarios RS1 (a) and RS2 (b) in comparison to the current state (CS) homogenized to USD^{2019}/yr in all four pilot areas

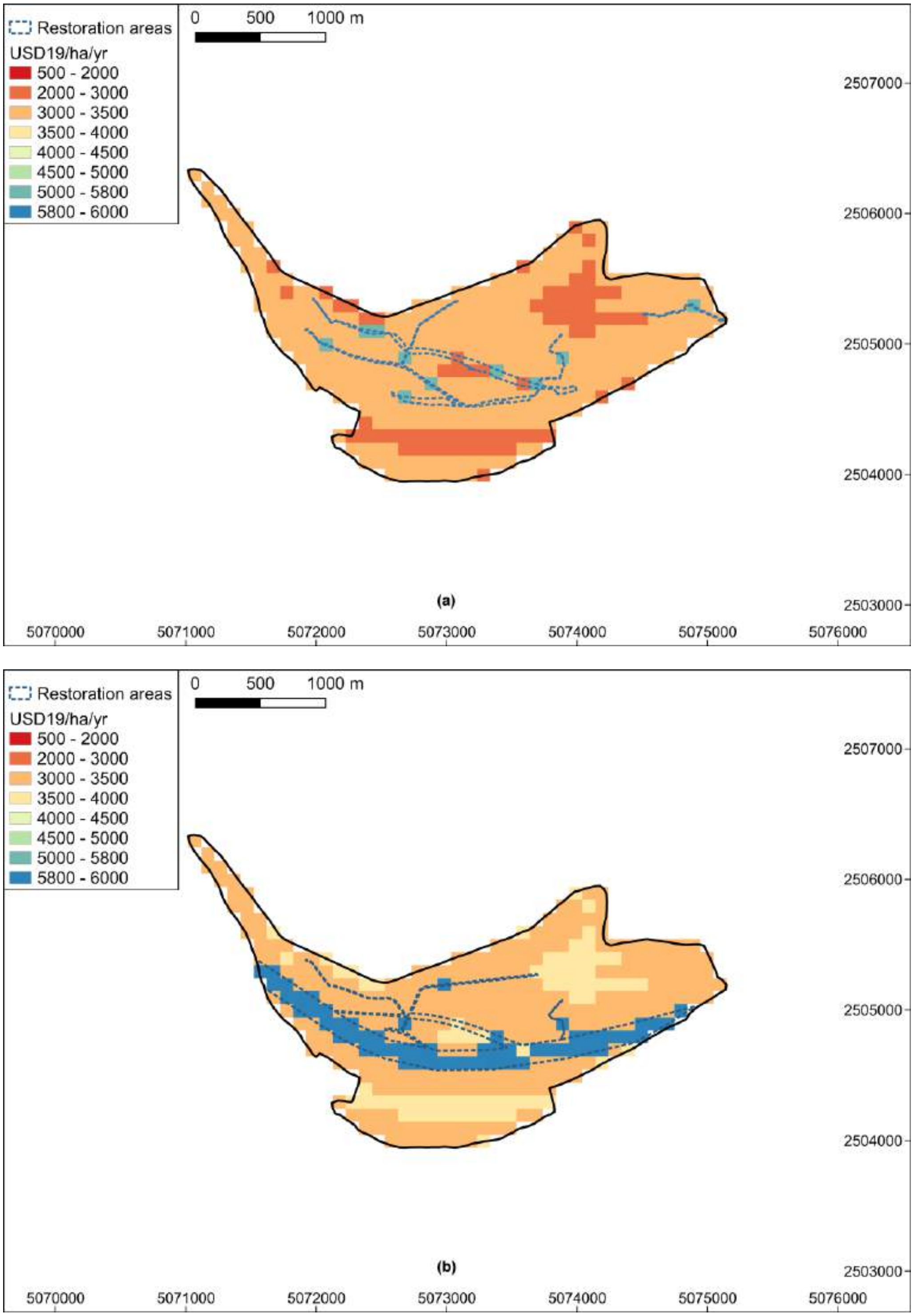


Figure 11. Map of the sum of ESS added value (excluding carbon storage) of the floodplain restoration measure by unit area (homogenized to USD2019/ha/yr) in Begecka Jama for RS1 (a) and RS2 (b) restoration scenarios. Adapted from Perosa et al. (2021b).

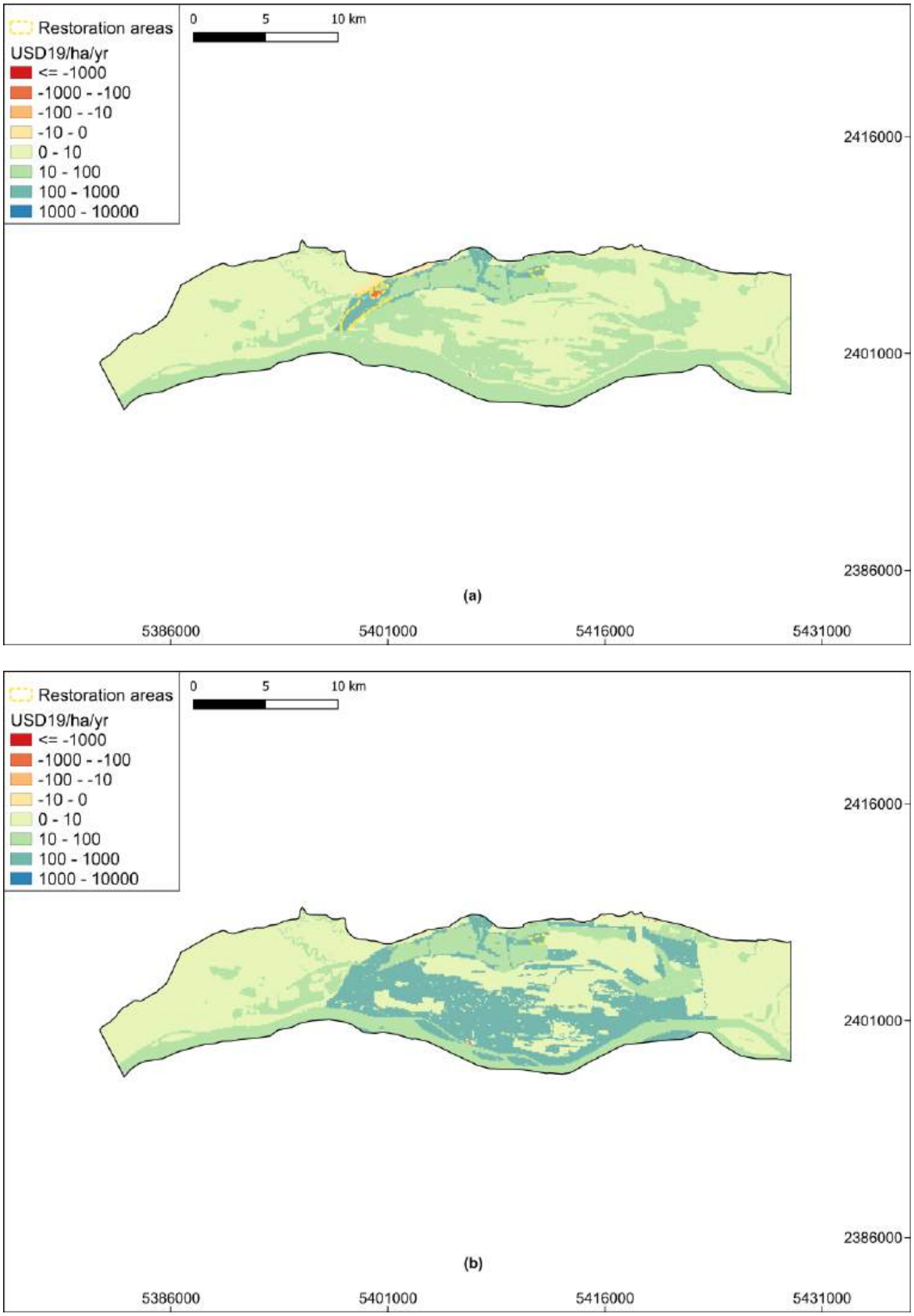


Figure 12. Map of the sum of ESS added value (excluding carbon storage) of the floodplain restoration measure by unit area (homogenized to USD2019/ha/yr) in Bistret for RS1 (a) and RS2 (b) restoration scenarios.

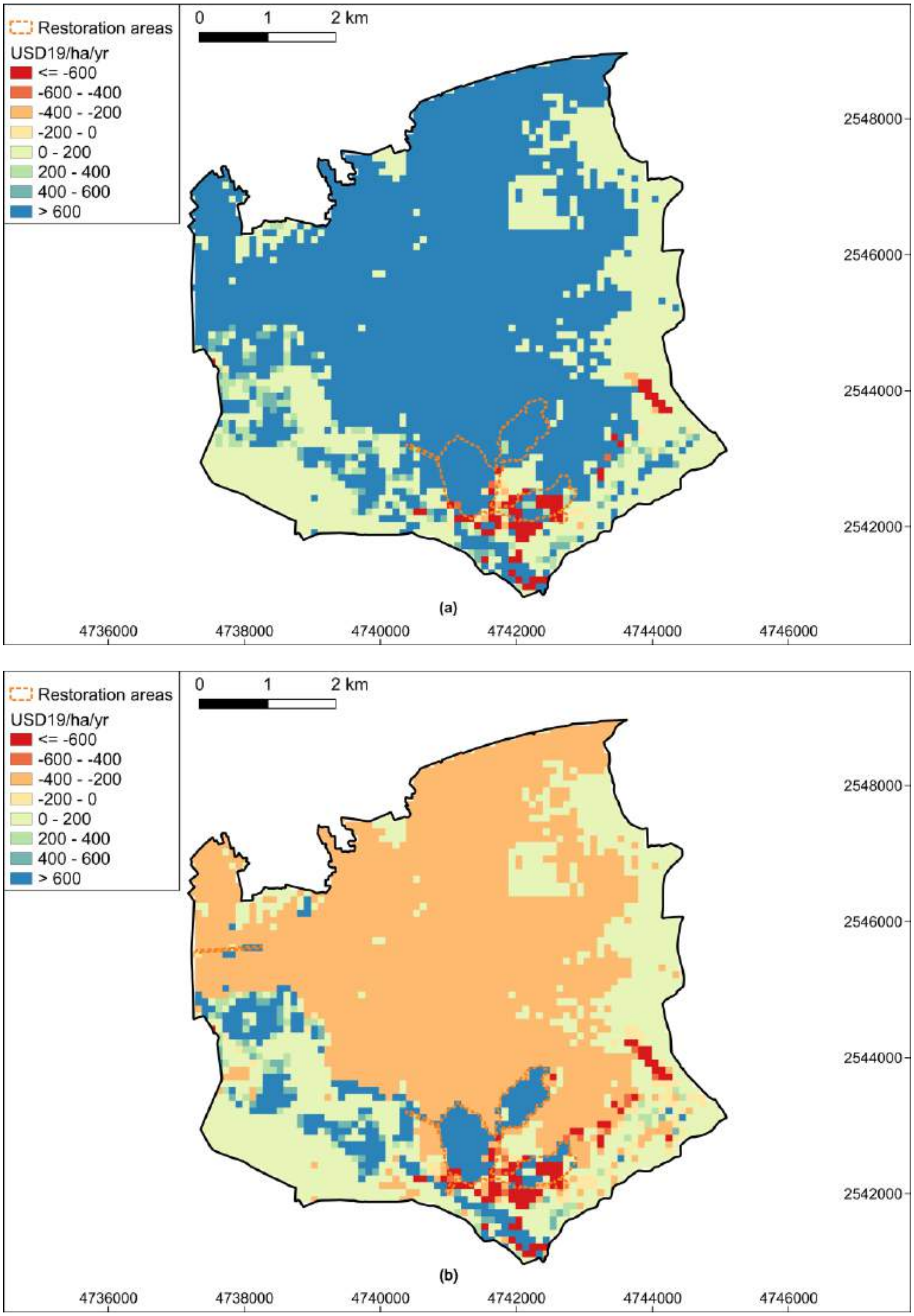


Figure 13. Map of the sum of ESS added value (excluding carbon storage) of the floodplain restoration measure by unit area (homogenized to USD2019/ha/yr) in Krka for RS1 (a) and RS2 (b) restoration scenarios. Adapted from Perosa et al. (2021b).

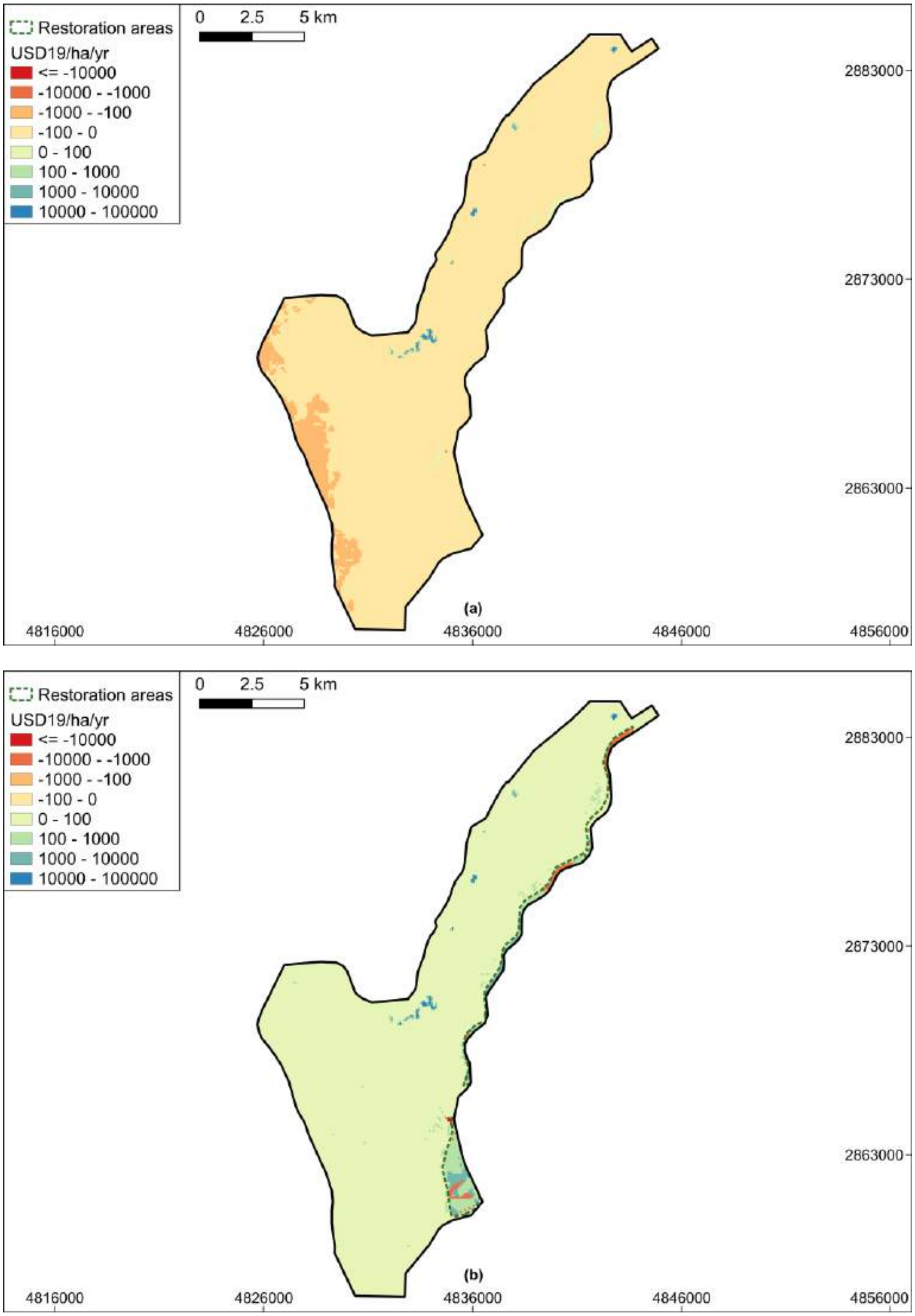


Figure 14. Map of the sum of ESS added value (excluding carbon storage) of the floodplain restoration measure by unit area (homogenized to USD2019/ha/yr) in Morava for RS1 (a) and RS2 (b) restoration scenarios. Adapted from Perosa et al. (2021b).

The bar plots in Figure 15 also display the NBS added value per unit area. Krka and Morava show comparable trends, in which the added ESS values are of the same order of magnitude for flood mitigation (1) and nature-based recreation (2). The latter has instead the highest value per area unit for Begecka Jama, which is also mainly profiting from the RS in terms of GHGs sequestration and nutrients retention. On the contrary to the other three pilot areas, Bistret shows ESS losses in terms of flood mitigation.

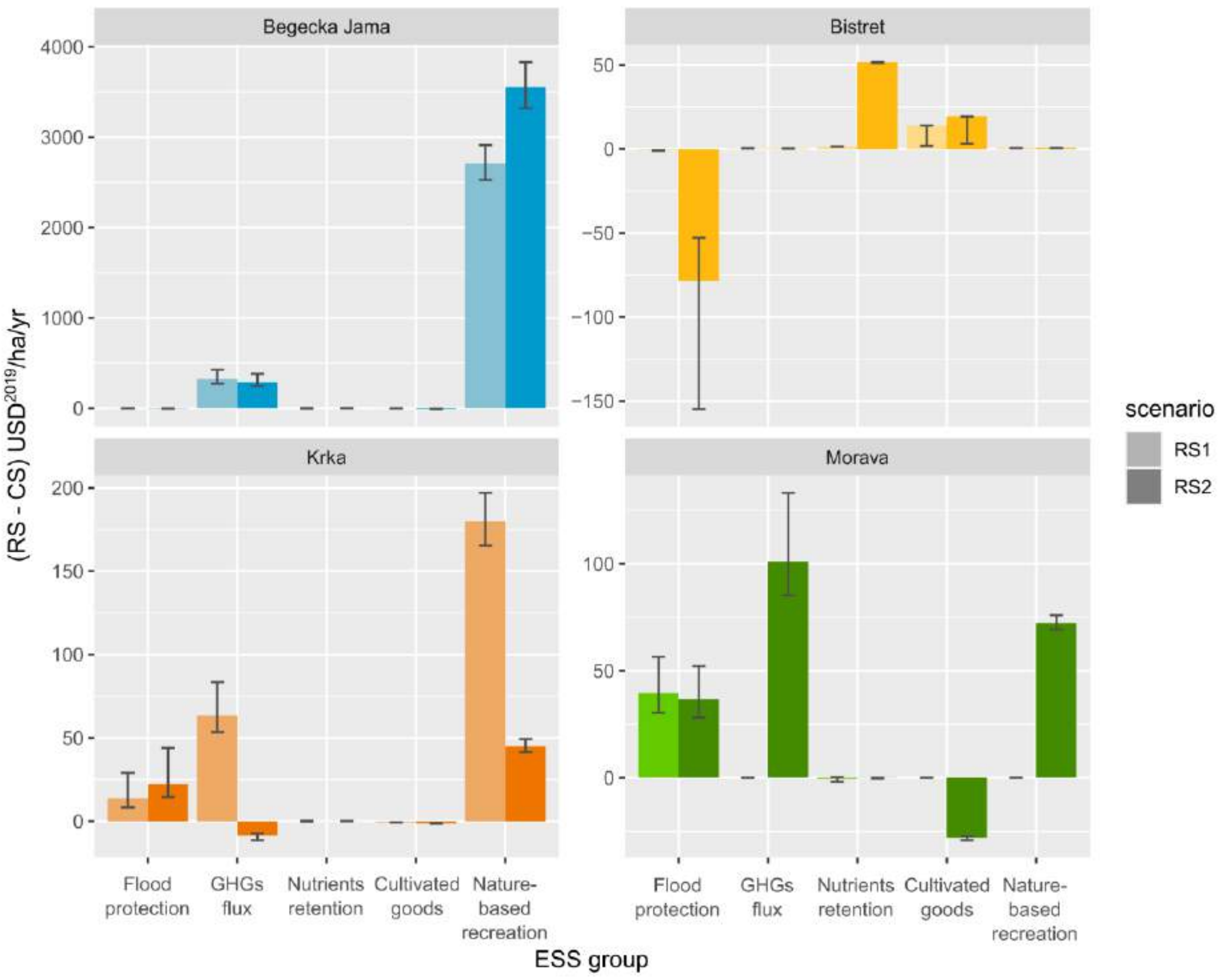


Figure 15. Added ESS value by unit area of the floodplain restoration scenarios RS1 and RS2 in comparison to the current state (CS) homogenized to USD^{2019}/ha/yr in all four pilot areas: (a) Begecka Jama, (b) Bistret, (c) Krka, and (d) Morava. Adapted from Perosa et al. (2021b).

5.8 Extended Cost-Benefit Analysis

To finalize the cost-benefits analysis (CBA), the benefits and the costs were compared with each other for all pilot areas. Before comparing them, benefits and costs were discounted, assuming the discounting parameters presented in Table 10.

Table 10. Parameters used for the cost-benefit analysis

Parameters for discounting
r = 0.04
N = 50

The costs of the restoration measures were provided by the pilot areas responsible partners are discounted and shown in Table 11.

Table 11. Costs of the restoration measures as communicated by the pilot area responsible partners and then discounted according to Table 10

	Costs [USD^{2019}] (discounted)		
	CS	RS1	RS2
Begecka Jama	0	1,468,645	33,843,628
Bistret	2,965,530	33,109,297	40,919,918
Krka	1,650,730	4,439,600	6,225,913
Morava	1,482,765	57,134,067	67,492,409

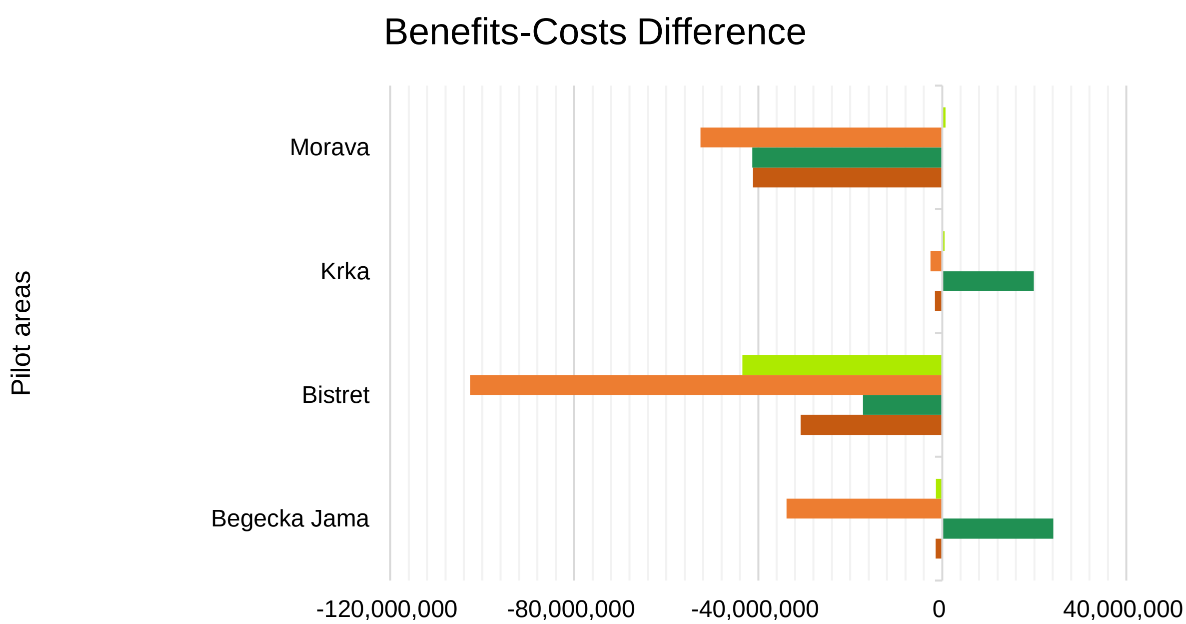
We compared the scenarios' benefits and the costs with each other in two ways: by subtracting the costs from the benefits (Figure 16), and by dividing the benefits by the costs (Figure 17), obtaining the benefits-costs ratio (BCR). As shown in Figure 16, the difference between discounted benefits and costs is only positive when considering all ESS, i.e. when the extended CBA is implemented.

In Begecka Jama, RS1 is the only scenario where the benefits (estimated with the extended CBA) are higher than the costs (by 33.9 million USD^{2019}). Due to the high costs of RS2, the benefits-costs difference would be negative by estimating it with both standard and extended CBA.

The discounted benefits do not always overdo the discounted costs even when applying the extended CBA: in Bistret, all methods and all restoration scenarios show negative benefits-costs differences, which are however not so extreme for the extended CBA, meaning that the additional ESS add the value of the restoration projects.

Nevertheless, an exemplary case is given by Krka, where the restoration scenarios have always positive benefits-costs differences (19.9 million USD^{2019} with RS2 and 510,000 USD^{2019} with RS2) when evaluating them with the extended CBA, while always negative differences (-1.6 million USD2019 with RS2 and -2.6 million USD2019 with RS2) when evaluating them with the standard CBA.

In Morava, the RS1 estimations show a similar result (around -41 million USD2019), whether the benefits-costs difference was estimated with standard or the extended CBA. The RS2 instead shows higher benefits than costs (by 716,000 USD2019) when applying the extended CBA methodology.



	Begecka Jama	Bistret	Krka	Morava
Difference - Extended CBA (RS2)	-1,375,404	-43,437,236	509,662	716,339
Difference - Standard CBA (RS2)	-33,870,069	-102,634,585	-2,587,323	-52,596,396
Difference - Extended CBA (RS1)	24,151,910	-17,224,128	19,879,128	-41,329,501
Difference - Standard CBA (RS1)	-1,476,003	-30,803,317	-1,570,537	-41,156,013

Benefits - Costs [USD2019]

Figure 16. Difference between discounted benefits and discounted costs in all four pilot areas.

Figure 17 shows that the results of the benefit-cost ratios (BCR) of the extended CBA (i.e. considering all ESS) of the restoration measures RS1 and RS2 are always higher than the BCR of the standard CBA (i.e. considering flood mitigation as only ESS).

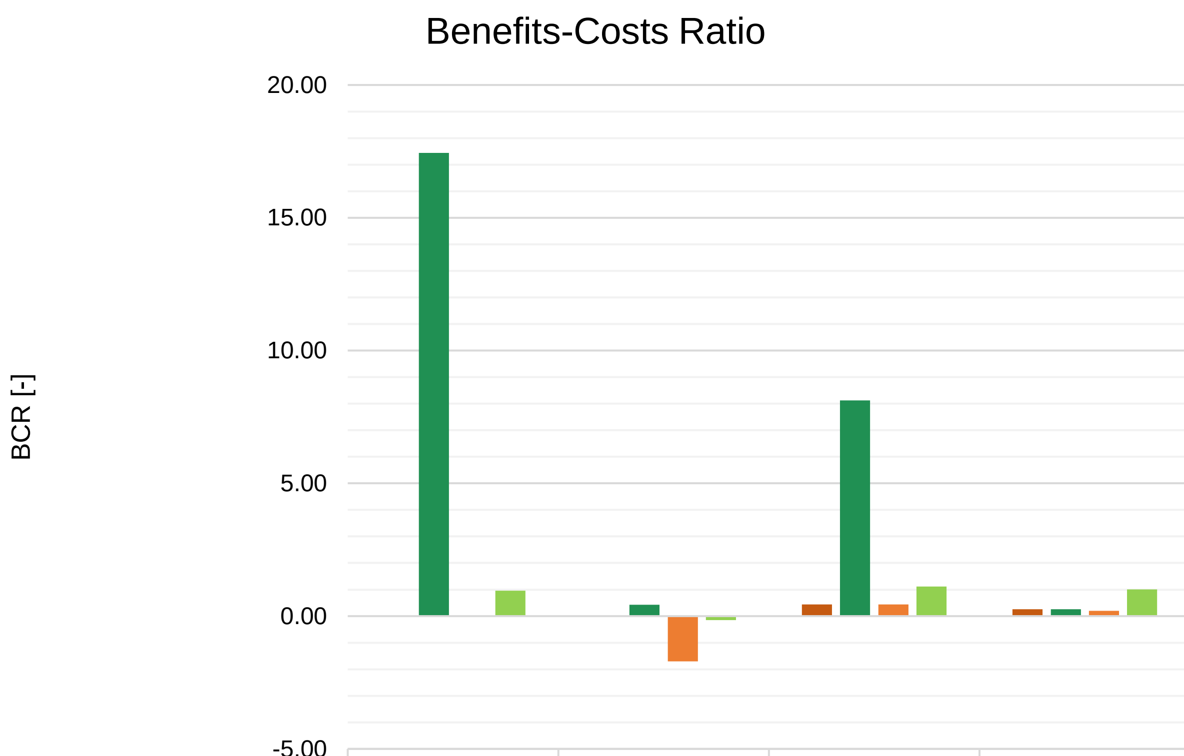
In Begecka Jama, both restoration measures lead to a BCR approximately equal (RS2) or higher (RS1) than 1, when using an extended CBA. The standard BCR shows instead results close to zero for both restoration scenarios.

In Krka, both restoration measures show extended BCR higher than 1, being the BCR of RS1much higher than the BCR of RS2, also due to the higher costs of the RS2. The standard BCR is instead 0.4

for both restoration scenarios, meaning that the discounted benefits in terms of flood risk reduction are equal to 40% of the discounted costs.

In Morava, the only BCR higher than the threshold (1) corresponds to the scenario RS2 calculated with the extended CBA method. All other configurations show a BCR between 0.2 and 0.3.

A divergent result than all other pilot areas is shown in Bistret, where the extended BCR does not reach a value close to 1. In any way (standard or extended), since the total benefits are negative, the restoration measures do not seem to be profitable, although the BCR for RS1 is promising (0.43).



	Begecka Jama	Bistret	Krka	Morava
BCR (RS1) - Standard CBA	-0.01	-0.02	0.44	0.26
BCR (RS1) - Extended CBA	17.45	0.43	8.13	0.26
BCR (RS2) - Standard CBA	0.00	-1.70	0.43	0.20
BCR (RS2) - Extended CBA	0.96	-0.14	1.11	1.01

Figure 17. Benefit-cost ratio (BCR) between discounted benefits and discounted costs in all four pilot areas.

6. Discussion

Adapted from Perosa et al. (2021b)

6.1 Analysis of singular ESS groups

In terms of carbon storage, all four pilot areas benefit from the restoration measures RS2, mainly due to the increase of carbon biomass above ground and from organic soil. The only two cases, where a carbon stocks' gain was not estimated, are RS1 in Bistret (with carbon stock losses) and RS1 in Morava (with no changes). We observed that for RS2 the larger the study area's size, the higher the absolute value of this ESS. However, we consider carbon storage ESS value as an expression of the natural capital, and not as an ESS, from which beneficiaries can get annual revenue from the floodplain. Therefore, we did not include this value in the total added ESS value of the NBS.

In terms of GHGs fluxes, results are heterogeneous among the pilot areas. For example, the estimation of the disturbances in tree-dominated areas in Krka for RS2 has a strong negative effect on the total, being it at around -35,000 USD^{2019}/yr. In general, the assumptions made for carbon stock losses have a great influence on the total GHGs balance. The uncertainty in tree disturbances is added to the ones of the ICCP Tier 1 method, which is a standard very useful tool but which is also highly sensitive to the input data chosen. Therefore, in case time and resources would be available, we would have chosen a more accurate method (e.g. including field measurements), as suggested by TESSA.

The value of the NBS in terms of flood risk mitigation is noticeable for all pilot areas mainly in the absolute value. The results are comparable to the results of Peh et al. (2014), who found the net flood mitigation of a wetland restoration of 23,075 USD/yr. This result is not confirmed in Bistret, where the flood risk increases in both RS1 and RS2. However, when looking at the avoided flood risk maps, these differences are low (if not even negligible), because the difference in water level (used as input data) is smaller than one meter. Also, the flood risk estimation is highly affected by the stepwise damage function chosen for the estimation and by which land uses are recognized as damage-prone by the damage function type itself (e.g. the Begecka Jama pilot area did not include any residential land uses). As a result, the higher value for Morava is shown to be a factor of the size of the pilot area, more than the effectiveness of the measure itself.

The output of cultivated goods added ESS value is for three pilot areas (Begecka Jama, Krka, and Morava) always null or negative, as expected, since in all four pilot areas the area available for agriculture or livestock would decrease in in case of a floodplain restoration. In comparison to other NBS studies (Merriman et al., 2018; Peh et al., 2014; Birch et al., 2014; Liu et al., 2017; Calvo Robledo et al., 2020; Peh et al., 2016; MacDonald et al., 2017), most presented losses of cultivated goods values due to land use change are much smaller, because the decrease in agriculture or livestock suitable area is also quite low. Moreover, in Bistret, the small size of agricultural land use losses and the expected increase in fish provisioning allows an increase of cultivated goods ESS values, due to the restoration measures. This is an encouraging output of the presented NBS, because stakeholders, especially in European countries, often associate floodplain with high losses in terms of agricultural production.

The accuracy of the estimations of cultivated goods depends on the quality of the data on cropland area and yields provided by the EarthStat dataset (Monfreda et al., 2008). This has a cell grid resolution of 0.0833 degrees, corresponding to a minimum of two and a maximum of nine cell grids. The availability of local data, e.g. through interviews, could probably increase the accuracy of this estimation. However, for a rapid assessment for decision-makers, we consider sufficient the mixed approach used in this study. We used input from the stakeholders to derive the most important crop types and input from publicly available sources, to get the country-specific market prices.

Regarding nature-based recreation services, we found the results on the consumer surplus to be reliable and comparable to previous studies of nature-based recreation (Merriman et al., 2018; Peh et al., 2014; Blaen et al., 2016; Birch et al., 2014; Liu et al., 2017; Peh et al., 2016; MacDonald et al., 2017; Soe Zin et al., 2019), where the net value of restoration was found to be between around 60,000 USD/yr (MacDonald et al., 2017) and more than 4 million USD/yr. In our case, the highest value was found for the Krka area, which could be explained by the high range of nature-based activities offered in the area and including the city Kostanjevica na Krki, a main Slovenian tourist attraction close to the capital city Ljubljana. Similarly, Begecka Jama is located in a strategic position, reachable in less than two hours' drive from two big cities (Novi Sad and Belgrade) and its surplus value is almost as high as Krka's. The lowest value of the consumer surplus in Morava might have been affected by the presence of so many other touristic attractions in proximity that could compete with each other. However, these values were calculated without considering the potential increase of mosquitos' presence, which could reduce the recreational amusement in the summer months. Additionally, our study assumed that the areas would remain easily accessible after the restoration measure would be implemented.

The final ESS value of nature-based recreation is strongly influenced by the number of visits that take place annually, a value which is difficult to estimate since areas in proximity are also natural areas. Nevertheless, the interviewed people showed a higher visitation rate, in case the NBS would be implemented. Also, to increase the precision level, the number of interviews might be increased, although, according to some methods (e.g. published tables in Israel, 1992), even for a population size higher than 100,000, the sample size for 10% precision would be still 100. We consider the online interviews valuable for our purposes. The age range of the responses shown in the histogram of Figure 9 proves that the use of online surveys did not necessarily exclude older generations, because Facebook and Instagram are not anymore only an instrument of younger generations. The Pew Research Center (2019) showed that U.S. Boomers (Born 1946-64) and Silents (Born 1945 and earlier) have both increased their Facebook use between 2015 and 2019 from 43% to 60% and from 22% to 37% respectively. However, we are aware that real-person interviews might have given different results.

6.2 Main Outputs

Taking into account six ESS, floodplain restoration is bringing added monetary value for all pilot areas that we considered. A surprising result is that the total increase of ESS due to the "optimistic" restoration scenarios in the Krka pilot area is much smaller in comparison to Begecka Jama and Morava and that in Bistret the ESS total value would even decrease in the case of RS2.

It is also interesting to note that, as expected, the restoration projects have a different impact on different types of services. The provisioning ESS (here represented by the cultivated goods) are decreasing in three out of four pilot areas, 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 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).

The information acquired during the stakeholder workshops was of great help to collect the necessary information about the areas and to map the ESS. The results of these workshops were used as input data for the ESS assessment with TESSA's methodologies. Although 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), we were able to bring together different views. This is because the stakeholders' representation was a mixture of local and national public authorities, sectoral agencies, NGOs, and international organizations, and in the case of Krka, even the general public. Nevertheless, a broader consultation may have described and judged the ESS differently (Merriman et al., 2018).

Looking at the effect of the singular ESS types into the sum of benefits, the most affecting ESS type varies according to the pilot area. In Bistret, the biggest influence is given by the ESS losses in terms of flood risk increase (RS2) or by the cultivated goods ESS (RS1). In Begecka Jama and Krka, the most affecting ESS is recreation, namely the nature-based recreational activities, while in Morava, GHGs flux sequestration has the highest weight, followed by nature-based recreation benefits. This behavior is probably due on the one hand to the fact that GHGs sequestration was estimated based on the surface area, which is the highest for Morava. Nature-based recreation ESS values are site-specific and depend on social behaviors rather than the size of the study area and are therefore not necessarily proportional. On the other hand, the nutrients retention services showed the lowest effect of this NBS's benefits in all pilot areas, besides Bistret. This could be affected by the ESS value transfer or by the approximate method used to estimate the amount of retained nitrogen. To our knowledge, no other publications reported the results on nutrients retention with TESSA. In our case, the floodplain restoration NBS cannot be justified for merely flood risk purposes, especially in Begecka Jama, where the flood mitigation service is slightly decreasing due to the restoration measure. However, flood mitigation still brings Krka's second and Morava's third-highest benefit contribution to the total services' improvement, but the second contribution in terms of losses in Bistret for RS2.

6.3 Quality of the Methodological Approach for Ecosystem Services Assessment

Geographic information capacity plays 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 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 a clear advantage both over the mere mapping of the floodplain's services and over other more time-demanding (e.g. InVEST) software.

TESSA is a helpful tool. The guidelines gave a clear overview of the necessary steps to follow for a quick ESS estimation in the study 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.

Although we consider the results of TESSA's application useful for a preliminary evaluation of NBS, 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 study 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 also encountered difficulties in estimating harvested wild goods, due to the high demand for data. 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 ES. 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. 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.

Moreover, 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 value of cultural ESS and pollination ESS was 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 study 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.

Besides the above-mentioned phenomena, several other steps of our work are affected by uncertainty, such as the application of the benefit-transfer function, the fit of the Poisson distribution to estimate the visitation rates as a function of the travel costs, and the timeframe used for the monetary values. Herein, we presented a first attempt of error estimation. However, dealing with many variables for different ES, 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).

Moreover, to describe the uncertainty associated with our ESS estimates, we followed TESSA's recommendations and categorized the confidence of the results, choosing among “high”, “medium”, or "low". Based on these standards given by TESSA, we rated the estimation confidence level of flood mitigation ESS and nature-based recreation ESS as "high", that of carbon storage and the GHGs flux services as "moderate", and the confidence level of cultivated goods and nutrients retention services as "low". Therefore, decision-makers should remember the presence of uncertainty, when using these results for decision-making.

6.4 Comparison of Discounted Costs, Standard Benefits, and Extended Benefits

By analyzing the results of the discounted benefits and costs presented in Section 5.8, we should be able to judge about the more and less profitable floodplain restoration scenarios hypothesized for the pilot areas.

In the case of Begecka Jama, the standard CBA misses recognizing 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 at the BCR. These parameters predict better overall restoration effects for the RS1 scenario, due to a positive BC-difference and a BCR of around 17. If the standard CBA results were to be used, RS1 would still be the preferable scenario between the two restoration measures, but it would not be shown as profitable (BCR<1 and BC-difference < 0).

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. The results on BC-differences and BCR suggest that the more suitable restoration measure would be the realistic one (RS1), although our results cannot prove its profitability when comparing that scenario with the current state.

Similar to Begecka Jama, the Krka pilot area clearly shows different results when using the standard or the extended CBA method. Here, the highest profitability would be provided by the RS1 scenario, when including the ecosystem services in the estimation, with a BCR of 8 and a BC-difference of almost 20 million USD^{2019}. When omitting ecosystem services from the equation, the difference between the two restoration scenarios is not as marked anymore and the floodplain restoration loses its profitability advantage (BCR<1 and BC-difference < 0).

In Morava, when considering the extended CBA, the preferable scenario tends to be RS2, according to its BCR (>1), its maximum annual added value (3.1 million USD^{2019}/yr). If we only considered the benefits derived from avoided risk, RS1 is the preferable restoration measure, although it would not be profitable (BCR<1 and BC-difference < 0).

When examining these results and suggesting which scenarios should be implemented, we should remember that some factors could substantially modify the results. First, the costs and benefits values are influenced by the parameters used for discounting (Table 10). 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.

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.

An important recognition of the results of this analysis is 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.

7. Conclusions

Adapted from Perosa et al. (2021b)

We estimated the benefits of floodplain restoration in terms of monetized ecosystem services in four pilot areas of the Danube catchment, by then including these results in an extended cost-benefit analysis. The conclusions of the research are threefold. We estimated the added value of the benefits of river and floodplain restoration to test the quality and effectiveness of the scenarios. We showed that the planning of NBS for flood risk management should not only use standard methods (e.g. hydrodynamic modeling) to support decision-making, but also assess ESS 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, which could be considered by TESSA developers to be included in a new version of the toolkit and by decision-makers for a broader knowledge on the consequences of floodplain restoration.

We estimated a maximum total gain of ESS of approximately 1.5 million USD^{2019}/yr in Begecka Jama (RS2), 600,000 USD^{2019}/yr in Bistret (RS1), 1.1 million USD^{2019}/yr in Krka (RS1), and 3.1 million USD^{2019}/yr in Morava (RS2). The results are mainly affected by GHG fluxes, changes in nature-based recreation, and cultivated goods services. However, we have shown that the tested NBS will only weakly affect the retention of nutrients in all pilot areas, besides Bistret. We also observed a diverse effect of the NBS on flood mitigation among the case studies. Although we did not find that floodplain restoration NBS can be justified for flood mitigation only, we remind that this output is only valid for these specific study areas and that NBS remain a flexible and resilient way to address natural hazards (Acharya et al., 2020; Faivre et al., 2017).

As a consequence of the ESS estimations, the extended CBA justifies the implementation of both (RS1 and RS2) floodplain restoration measures in Begecka Jama and Krka, and one in Morava (RS2). In disagreement with these conclusions, all these scenarios would not be categorized as profitable, if evaluated with a standard CBA. Besides, the extended CBA might support the “realistic” restoration measure (RS1) in Bistret, although additional funding should be considered to cover the not fully profitable investment.

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 benefits of NBS, floodplain restoration measures would have much lower chances of being accepted by decision-makers and stakeholders.

ESS assessment can be useful for decision-makers to locate where to build or restore ecosystems (Krol et al., 2016). Policymakers 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.). Moreover, scientists should study the effects of upscaling local-scale methods to the national (or river basin) extent, especially in case more floodplain restoration measures would be implemented at the same time (e.g. nature-based recreation). We suggest that monitoring is done, in case restoration measures would be implemented, to confirm or discard the ESS assessment's results. A high number of factors influence the floodplain ecosystem and the phenomena taking place in it. Therefore, we should make sure that the assumptions used do not invalidate the ESS assessments.

Although some progress has been made using our methodology, this approach, based on a toolkit for rapid execution, assesses only a part of all ESS potentially provided by floodplains. In addition, an improvement of the interpretation of the results might be given by analyzing the results' uncertainties. Further, more modeling could be implemented to get a more detailed estimation of some ESS (e.g. of water quality).

We finally call for better inclusion of ESS assessment in the Danube River Basin Management Plans, for not only improving ESS themselves but also because ESS improvement intersects with the achievement and monitoring of the Sustainable Development Goals. ESS assessment would act for different purposes, such as to encourage a sustained, inclusive and sustainable economic growth (Goal 8) and to facilitate sustainable management of water (Goal 6) and terrestrial ecosystems (Goal 15) (United Nations General Assembly, 2015).

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Annex A1. Habitat Types according to Scenarios

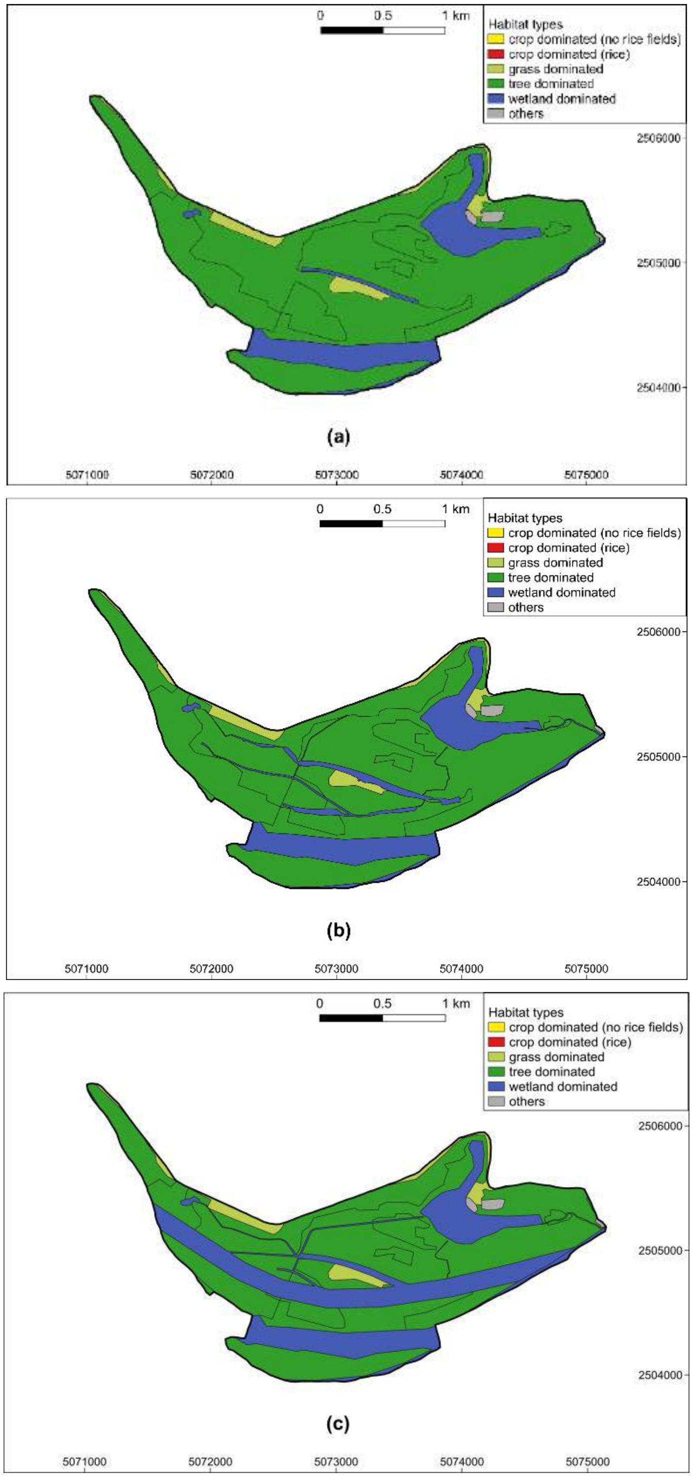


Figure A1.1. Habitat types of Begecka Jama for current state (a) and restoration scenarios RS1 (b) and RS2 (c)

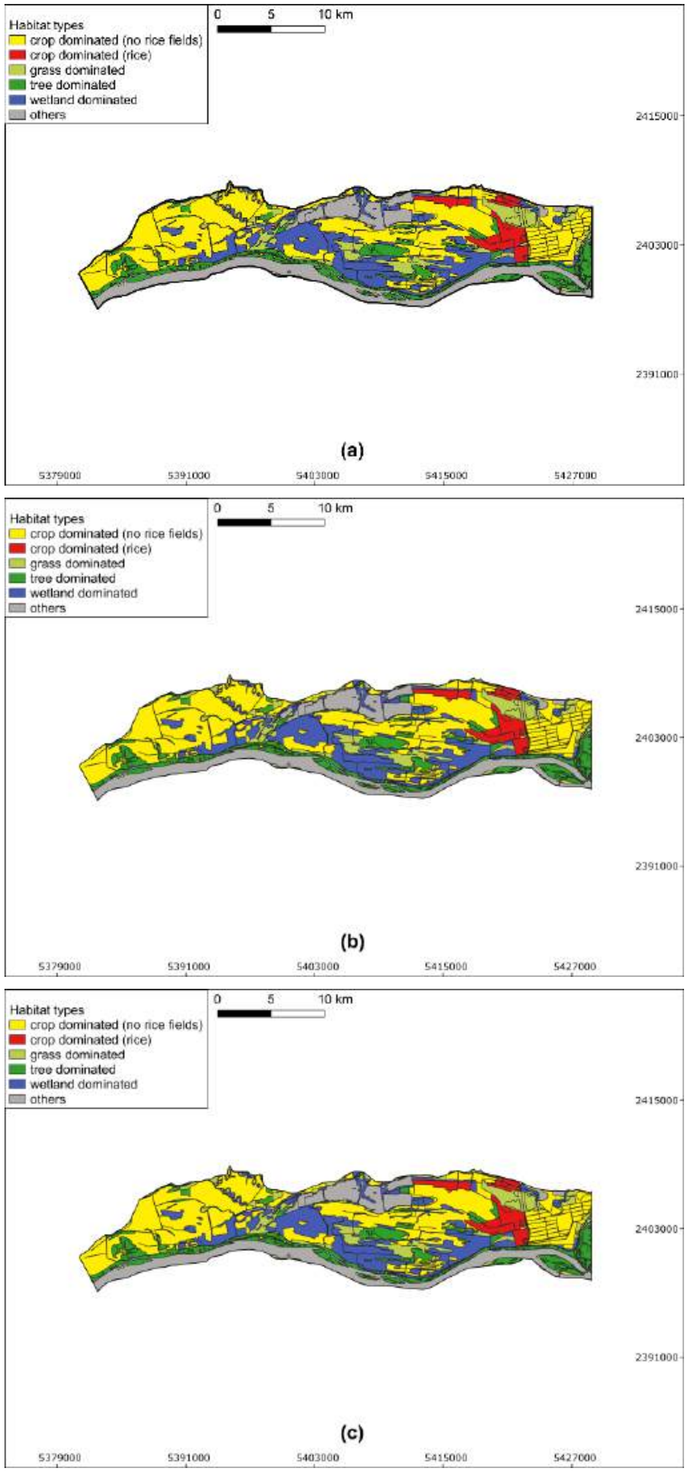


Figure A1.2. Habitat types of Begecka Jama for current state (a) and restoration scenarios RS1 (b) and RS2 (c)

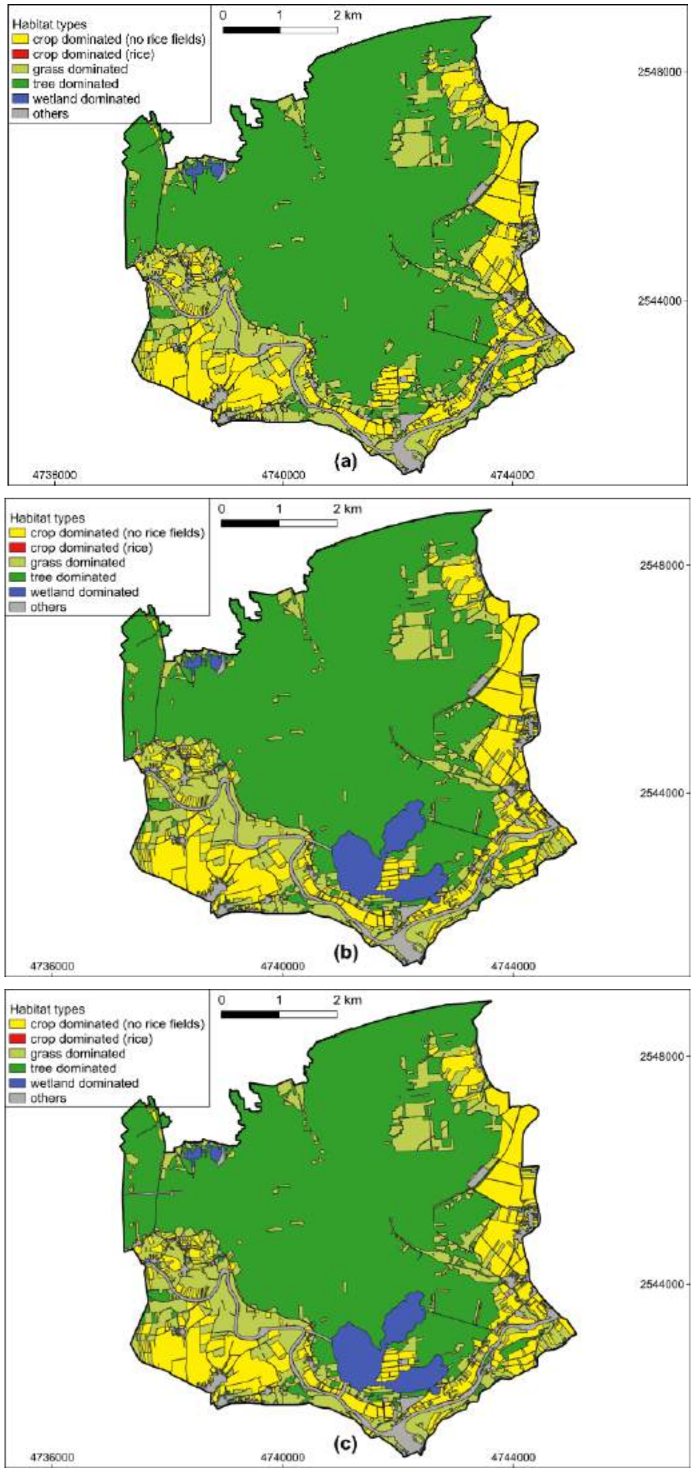


Figure A1.3. Habitat types of Begecka Jama for current state (a) and restoration scenarios RS1 (b) and RS2 (c)

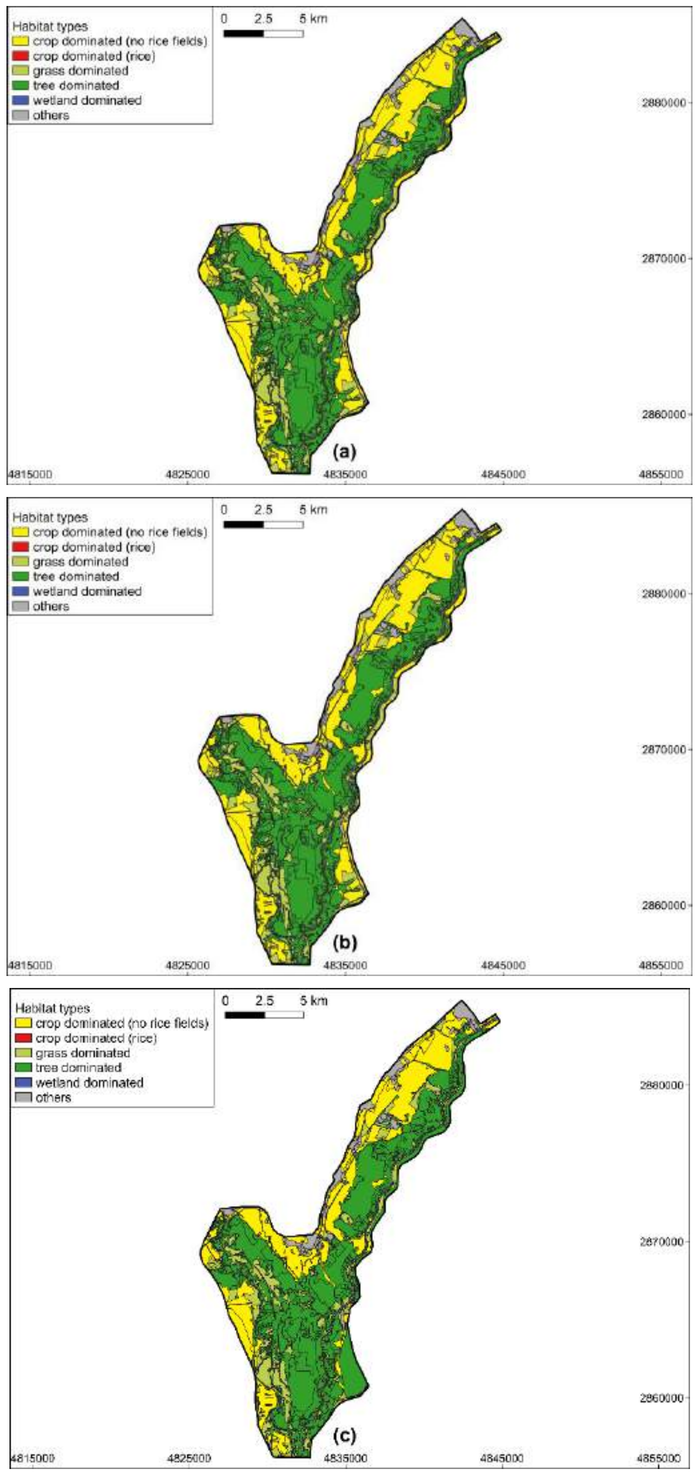


Figure A1.4. Habitat types of Begecka Jama for current state (a) and restoration scenarios RS1 (b) and RS2 (c)

Annex A2. Additional studies on the assessment of ecosystem services in the Bistret (RO) pilot area and on the extended cost-benefit-analysis in the Middle Tisza (HU) pilot area

The following documents ("Report on mapping and assessment of the ecosystem services from Bistreț pilot site") and ("Hungary: Tisza Pilot CBA").

The first one shows the results of the ecosystem services assessment in Bistret and represents the results of a parallel work that was conducted by Dr. Mihai Adamescu on the Bistret pilot area.

The second one shows the results of the extended cost-benefit analysis in Middle Tisza pilot area, the fifth pilot area of the Danube Floodplain Project. The document was prepared by András Kis and Gábor Ungvári from the Regional Centre for Energy Policy Research (REKK). The case study followed the methodology that the Hungarian project partners developed for Work package 4.3 and tried to assess what role the extended CBA analysis would fulfill in the planning phase of an integrated flood risk-mitigating intervention that aims to give more room for the river. Therefore, the extended CBA analysis was incorporated into a decision flow, where the wider sustainability aspects, the social-economic aspects, and the issues of the directly affected stakeholders are all considered.

Report on mapping and assessment the ecosystem services from Bistreț pilot site

The report is part of the analysis done by Dr. Mihai ADAMESCU as a contribution to deliverable 4.2.3 and 4.3.1. The results are input to the pre-feasibility study for Bistreț pilot site (deliverable 4.4.1)

TABLE OF CONTENTS

ABBREVIATIONS

BISE	Biodiversity Information System for Europe
CICES	Common International Classification of Ecosystem Services
CLC	Corine Land Cover
ES	Ecosystem services
GIS	Geographical Information Systems
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
TEV	Total Economic Value
TEEB	The Economics of Ecosystems and Biodiversity

1 INTRODUCTION

A detailed analysis of the Bistreț pilot area was conducted from the perspective of ecosystem evolution related to the possible restoration scenario. Based on existing literature data and relevant documents like management plans for Natura 2000 sites, information about biodiversity and ecosystems in the pilot area Bistret has been be provided, focusing especially on typical wetland biodiversity and how biodiversity / ecosystems will evolve after implementing restoration measures (this component contributing to the biodiversity / ecosystem assessment in pilot area and habitat modeling - deliverable 4.2.3). The results are presented in the chapters 3.6 and 3.7 of the report and the maps of ecosystems and ecosystems services in different scenario in the form of GIS / shape files. The contribution to the deliverable 4.3 (Cost-benefit analysis on pilot areas integrating ecosystem services) and 4.4.1 (pre-feasibility study for Bistreț pilot site) are presented under the chapters 3.6 (monetary valuation) based on the activity 4.2 (Assessment of stakeholders, ecosystem services, biodiversity and measures in the selected pilot areas).

1.1 GENERAL CONTEXT

Pre-1990 agricultural area expansion programs have reduced the Danube floodplain area by 75% in the upstream area, 79% downstream (Middle Danube and Lower Danube) and 35% in the Danube Delta by applying hydrotechnical works for wetland drainage. On top of this, protection against floods of agricultural lands and new localities that appeared, was achieved by building defense dams along the Danube, and land improvement works (irrigation systems, drainage systems). All the dams, drainage and drainage channels built have led to changes in the hydrological regime of the Danube River and implicitly of the existing ecosystems types, which has led to a sharp decline in biodiversity (at all levels - from specific diversity to ecosystem diversity) with strong impact on the quantity and quality of ecosystem services generated by these systems and with a strong impact on the well-being of different communities in the floodplain areas. Due to the decrease in ecosystem services (for example the loss of water retention capacity) the number of flooding events increased with high negative impact on the socio-economic sector. Thus, in the 2000s, Europe suffered floods with a major impact on the floodplain economy and local communities.

Considering the international context of concern regarding the accelerated loss of biodiversity and it's negative impact on the society and economy, the concepts of ecosystem services mapping and assessment starts to evolve. This report, done under the project "Danube Floodplain - Reducing flood risks by restoration of the Danube floodplain and tributary rivers" is presenting the results of the mapping and assessment of the ecosystem services done for Bistreț pilot area based on the perceptions of local inhabitants towards local biodiversity and what nature is offering.

1.2 AIM AND OBJECTIVES OF THE REPORT

In order to fulfil the requirements described by the Terms of Reference this report is following each objective with specific actions:

- Objective 1. Assessment of biodiversity in pilot areas including the creation of a database on biodiversity in the pilot area and habitat / ecosystems modeling / evolution. The relevant scientific literature refering to the mapping and assessmen of ecosystem services and Managment plan for Natura 2000 site Coridorul Jiului have been analysed and necesary information, conclusions and methods have been extracted (and applyed) to understand the status of biodiversity / ecosystems and connected services and assess and map their evolution in diferent restoraiton scenario.

- Objective 2. Carrying out a cost-benefit analysis applied to the Bistreț area including ecosystem services, stakeholders and biodiversity. The report is providing an analysis of speficic monetary evaluation methods useful for the extended cost-benefit analysis in Bistreț area including the results of the valuation of the ecosystem services.

The both objectives, together with the obtained results are contributing to a broader understating of the socio-economic impact and co-benefits generated by the technical solutions identified under the pre-feasibility study.

2 METHODOLOGY

2.1 GENERAL APPROACH

A review of the national and international research on the assessment of ecosystem services reveals a very wide variety of methods and techniques, including a number of complex, relatively costly and time-consuming processes. Furthermore, this field is at an incipient stage in its development, therefore many of the existing methodologies are divergent or will produce radically different results. Even though it is a rather difficult concept to understand, the placing it within the efforts for mobilising various social partners in the field of environmental protection might bring about considerable strengthening of social support for this aim. The use of the concept of ecosystem services is helping to outline the significant benefits that ecosystems (natural, semi-natural, anthropized) supply to the human society. On the other hand, the term of ecosystem services, and especially the monetary assessment of ecosystem services must be used with precaution, only after thoroughly understanding the consequences of losing biodiversity upon the functioning of ecological systems.

Monetary valuation of ecosystem services often tends to concentrate on a small number of ES and attributed monetary values remain often only approximations depending on the method used. The great majority of the population is not aware of many of the ecosystem services, and takes them as a given "fact" of nature. These ecosystem services are supplied by natural and semi-natural systems, without the society "paying" in any way for such provision. One example in this sense is the supply of drinkable water. Most of the times, it's not the water itself that is paid for, but only the cost of transportation, and some other costs in certain instances (such as costs with water purification). In very few instances there is payment for "water" as a resource. Moreover, the society is not even willing to accept a "price" for certain ecosystem services that, at their best, are deemed to be free of charge services. In a world where decisions are made especially based on economic criteria, we do need to include the services that nature is supplying into the decision-making process. At the same time, we need to recognise, on one hand, the high level of complexity of ecosystems (of nature in general), and on the other hand the need to identify some elements for argumentation, in order to advocate for "nature conservation". The system that emphasises monetary aspects greatly simplifies the argumentation needed and, although not always beneficial, can, to some extent, contribute to building an understanding of the fact that ecosystems and conservation areas (irrespective of how they are called: natural parks, national parks, Natura 2000 areas or biosphere reservations) have a fundamental role in sustaining life in general and the human society as well, at the same time ensuring the capacity of natural systems to adapt and evolve.

Excessive simplification of the natural system for the purpose of emphasising certain ecosystem services to the detriment of others (increasing the capacity of ecosystems to supply production services to the detriment of adjustment or cultural services, for instance) bears dramatic consequences upon the human society and the biodiversity and operation of ecosystems in general. Most of the times, failure to understand the consequences of losing biodiversity upon ecological systems and, as a result, upon ecosystem services, is the main scientific and managerial constraint to reducing loss of biodiversity.

What is missing most of the times is the tools to guide decision-makers, so that ecosystems, on one hand, supply multiple ecosystem services and, on the other hand, enable adaptation to present and future environmental changes (including adaptation to climate change), thus maintaining the systems' capacity to evolve. A number of examples could contribute to building a better understanding of how various ecosystems supply ecosystem services, but also to understanding how the "amount" and the "quality" of the services supplied depend on the complexity of the ecosystems and on compounds of ecosystems.

2.2 ECOSYSTEMS IDENTIFICATION METHODOLOGY

Ecosystem maps (figure 2 – figure 4) for the Bistret area, used in this study, was done based Corine Land Cover land use/land cover maps for 1990 and 2018 (CLC 1990, CLC 2018) for the current landscape configuration. To identify ecosystem configuration prior river embankment and wetland area conversion towards agricultural exploitations historical topographic maps of the year 1900 were digitized and harmonized in terms of nomenclature with Corine Land Cover in order to assess land-use changes.

Ecosystems have been identified for the entire area. The map was created using the MAES (Mapping and Assessment of Ecosystems and their Services) methodology, through which the land cover classes were merged and transformed into Ecosystem Types, according to the table below.

Table 1 Land use land cover classes transformed in ecosystem types

CLC Level 1	CLC Level 2	CLC Level 3	Ecoystem types
1. Artificial surfaces	**1.1. Urban fabric**	1.1.2. Discontinuous urban fabric	Urban
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units	
2. Agricultural areas	**2.1. Arable land**	2.1.1. Non-irrigated arable land	Agricultural areas
		2.1.3. Rice fields	
	2.2. Permanent crops	2.2.1. Vineyards	
		2.2.2. Fruit trees and berry plantations	
	2.3. Pastures	2.3.1. Pastures	Pastures
	2.4. Heterogeneous agricultural areas	2.4.2. Complex cultivation patterns	Agricultural areas
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation	
3. Forest and semi natural areas	**3.1. Forests**	3.1.1. Broad-leaved forest	Forests
	3.2. Scrub and/or herbaceous vegetation associations	3.2.1. Natural grasslands	Pastures
		3.2.4. Transitional woodland-shrub	Forests
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, sands	Beaches
4. Wetlands	**4.1. Inland wetlands**	4.1.1. Inland marshes	Wetlands
5. Water bodies	**5.1. Inland waters**	5.1.1. Water courses	Water courses
		5.1.2. Water bodies	Water bodies

2.3 Ecosystem services identification methodology

The benefits that humans derive from nature in the form of goods and services provided by natural and semi-natural ecosystems are known generically as "ecosystem services" (TEEB

2010). Ecosystem services are grouped into several broad categories, depending on different research projects or assessments carried out by expert groups (eg MA 2005, TEEB 2010, MAES, CICES, Potschin and Haines-Young 2016). In general, they refer to support services and the so-called final services - provisioning, regulation and maintenance, and cultural values:

- Support services are those services that create the necessary conditions for the provision of all other ecosystem services (eg: the provision of substrate for biological diversity and adequate space for human activities, ensuring abiotic heterogeneity);
- Provisioning services are represented by the ability of ecosystems to provide different resources (eg: food, fiber, fuel, drinking water);
- Regulation and maintenance services are determined by the ability of ecosystems to control natural processes (eg, regulation of climate, water quality and quantity);
- Cultural services represent the non-material benefits offered by ecosystems (eg: the aesthetic value of the landscape, recreational spaces).

The development of socio-economic systems is strictly dependent on biological and physical infrastructure, the existence of resources and services provided by natural and semi-natural ecosystems.

Ecosystem services have a strong social dimension. Even if they have an objective existence (they are provided independently of the existence of a social community that recognizes their existence and appreciates their usefulness) ecosystem services are socially defined in the sense that society is the one that recognizes, evaluates and establishes the importance of externalities provided by ecosystems. A local and regional approach is needed, providing the basics needed to identify ecosystems providing ecosystem services, as well as an analysis of stakeholders' perceptions of ecosystem services, as they represent the benefits that humans derive from nature in the form of goods and services.

The decision to allocate the natural resources must reflect satisfactory opportunities for the various alternatives for using ecosystem services. The non-assignment of values, or the underestimation of ecosystem services attracts a weakening of responsibility in the process of capitalizing on ecosystem services, because their share in total user efforts will be undersized (when an item of expenditure has a small share in total expenditure, does not trigger interest in rationalizing its consumption). Also, to diagnose the efficiency of a project, of an activity, it must take into account the social cost, respectively the private cost increased by the external environmental costs (negative environmental externalities: degradation of biodiversity, air quality, water, landscape, etc.).

The ecosystem service assessment methodology used in this case is based around two central elements that allow for application of inductive procedures meant to pick out the monetary value of the key ecosystem services:

1. *Establishing a reference system* by calculating a relevance coefficient of the ecosystem services supplied by a certain ecosystem or compound of ecosystems. In practical terms, this approach implies ranking the importance of various ecosystem services, but especially calculating the exact distance between the different services depending on their relevance, in the way in which the stakeholders define it at a certain moment in time. The existence of this reference system is essential for inferring the monetary value of a service from the monetary value of another ecosystem service.

2. *Selecting a reference ecosystem service and measuring its monetary value*. In practical terms, one service is picked out of the total of ecosystem services, for which the monetary value is measured and which will be used as a benchmark for inferring (based on relevance coefficients) the monetary value of all the other services.

The identification and description of ecosystem services was based on the "cascade model" for analyzing the generation of environmental services and evaluating them by highlighting the links between biophysical aspects and human well-being (Potschin and Haines-Young 2011) (Figure 1).

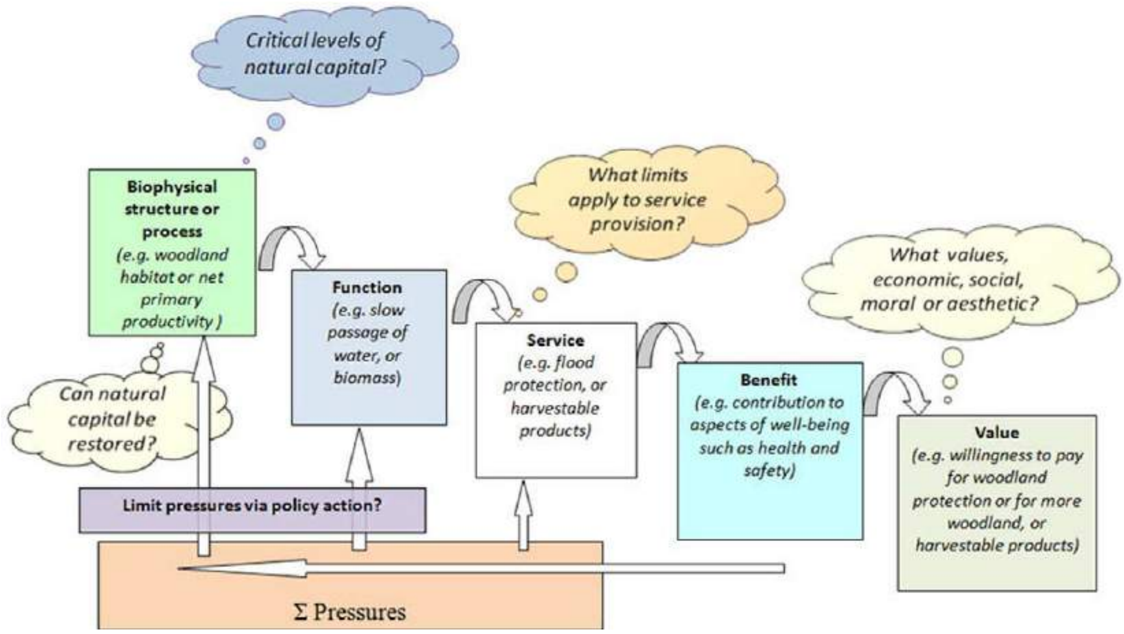


Figure 1 The cascade model of analysis and evaluation of environmental services by ecosystems (Potschin şi Haines-Young 2011)

The Common International Classification of Ecosystem Services (CICES) typology for ecosystem services was used, as recommended by the Member States of the European Union at the European Working Group on Ecosystem Mapping and Assessment (MAES). The main types of ecosystems were identified using existing geo-relational databases on land cover (Copernicus CLC), as detailed in the previous section.

The mapping of potential final ecosystem services (assessment of the overall bio-physical state of ecosystems) was done by using a relationship matrix linking the main types of ecosystems with the ecosystem services (Burkhard et al. 2009, 2014), adapted to the specific area.

Determining the value of ecosystem services is based on methods and techniques of revealing / expressing preferences. In this study, assuming the social dimension of ecosystem services, the methodology of identification and ranking of ecosystem services described in the Methodological Guide for rapid assessment of ecosystem services in protected areas in Romania was used (Adamescu et al. 2016), starting from three fundamental methodological principles:

1. *Participatory approach* - identifying and assessing the importance of ecosystem services must take into account the mosaic of value systems of local communities and capture not the position of an expert but the position of all local and regional stakeholders;

2. *Inclusive approach* based on mobilizing representatives of all interest groups at local and regional level. The evaluation of ecosystem services thus requires a process of prior segmentation of stakeholders and their co-optation in the process of identifying and prioritizing social services;
3. *Deliberative approach* focused on public / group discussion of ecosystem services. The deliberative approach has a multiple effect at individual and group level contributing to:
   - awareness of differences in perception regarding the number and importance of ecosystem services;
   - deepening the individual understanding regarding the multitude of ecosystem services and their importance;
   - building a common, negotiated agreement on the most important ecosystem services.

In this project, the identification and ranking of ecosystem services was based on the use of several questionnaires addressed to stakeholders. Two distinct methods were used to identify and evaluate the services in the Danube floodplain, and more particularly in the Bistret area. The first method aims to identify ecosystem services while the second aims to rank the most important ecosystem services:

1. Methods for identifying ecosystem services: the method of sociological survey. A sociological questionnaire containing a list of 29 ecosystem services was used
2. Methods of ranking ecosystem services: the method of comparison by pairs. For a rigorous analysis of the 20 most important ecosystem services as indicated by the voting method.

Identification of trade-offs and synergies between ecosystem services by using of FCM - fuzzy cognitive map. Fuzzy Cognitive Map (FCM) is a suitable tool for highlighting trade-off relations and / or for highlighting synergies between ecological services, because:

i) they allow a mix of qualitative and quantitative approaches,
ii) they allow the inclusion of multiple and diverse sources to overcome the limitations that become obvious when we work only with the opinions of experts.

In addition, such an approach considers multivariate interactions that lead to nonlinearities but also allow a qualitative analysis including explicit modeling.

Fuzzy Cognitive Maps are actually representations of directed graphs that consist of nodes, or concepts, interconnected by links that show the direction of influence between them. A positive (or negative) connection indicates the interrelation of concepts A and B as well as the influence exerted (the connection between concepts - A increases or decreases concept B). The concepts are described by the model developer and may contain any kind of representation (including concepts such as ecosystem services). FCMs are based on causal cognitive mapping, which provides an effective way to generate, capture and communicate causal knowledge and helps respondents become more aware of their own mental patterns. Maps (such as fuzzy cognitive mapping) can be based on interviews, text analysis or group discussions and can be easily modified or extended by adding new concepts and / or relationships or by changing the relative weights assigned to causal links.

2.4 LIMITATIONS AND CONSTRAINTS

A series of limitation and constrains hindered with the identification and assessment of ecosystem services in the project area. For most of them it was found good solutions that have been implemented so that the results to be in line with the requirements under the terms of reference. The first was that no prior data were available concerning the investigated area. A second more important constrain was the impossibility to perform extensive field trips to check more thoroughly some of the assumptions (ecosystem identification large stakeholder gathering due to covid pandemic restrictions). Other constrains (more theoretical) have already being addressed.

3 RESULTS

3.1 IDENTIFICATION OF MAJOR ECOSYSTEM TYPES IN THE BISTRET AREA

According to the initiative "The Economics of Ecosystems and Biodiversity" (TEEB, 2010) which aims to assess the costs of biodiversity loss and associated decline in global ecosystem services, ecosystems are the basis of life and all human activities (Miron, 2019). The goods and services they provide are vital for maintaining well-being, as well as for social and economic development (Europa.eu, 2010), examples being food, water, timber, air purification, soil formation and pollination.

Ecosystem services maps are useful for spatial prioritization and problem identification, especially in terms of synergies and trade-offs between different ecosystem services and between ecosystem services and biodiversity (BISE, 2020). Moreover, maps can be used as a communication tool to initiate discussions with stakeholders, visualize the locations where valuable ecosystem services are produced or used, and explain the relevance of ecosystem services to the general public (BISE, 2020).

Land cover analysis (figure 2 – figure 4) show the land cover spatial distribution transition from the reference state of the Bistret ecosystem complexes to the present configuration of the landscape in the study area. Land cover analysis for the reference state revealed 6 distinct classes: water bodies (22%), agricultural areas (12%), water courses (7%), forests (6%), wetlands (51%) and urban areas (2%).

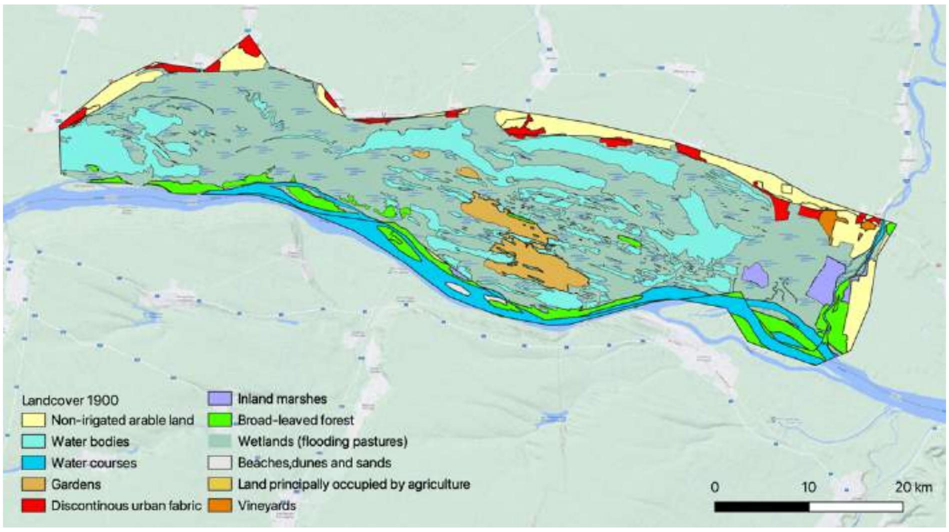


Figure 2 Bistret case study area landcover for the reference state

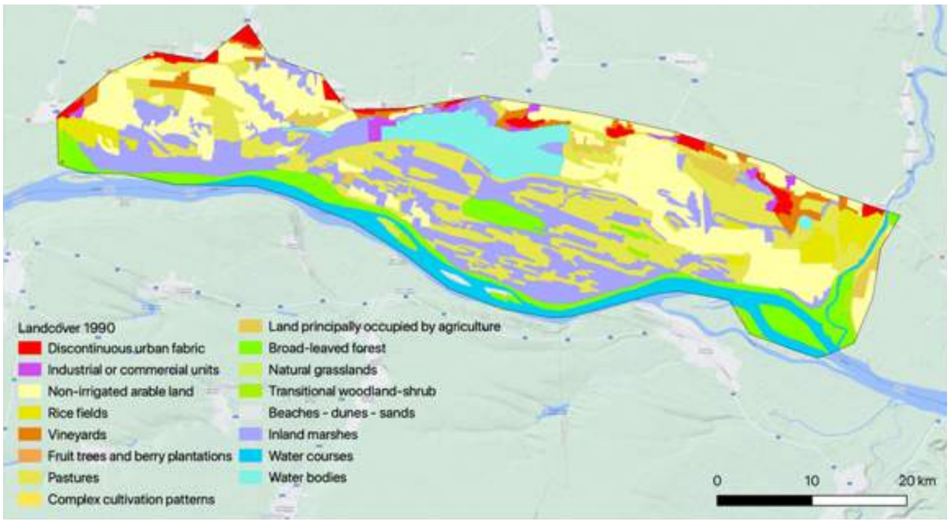


Figure 3 Bistret case study area landcover for the year 1990

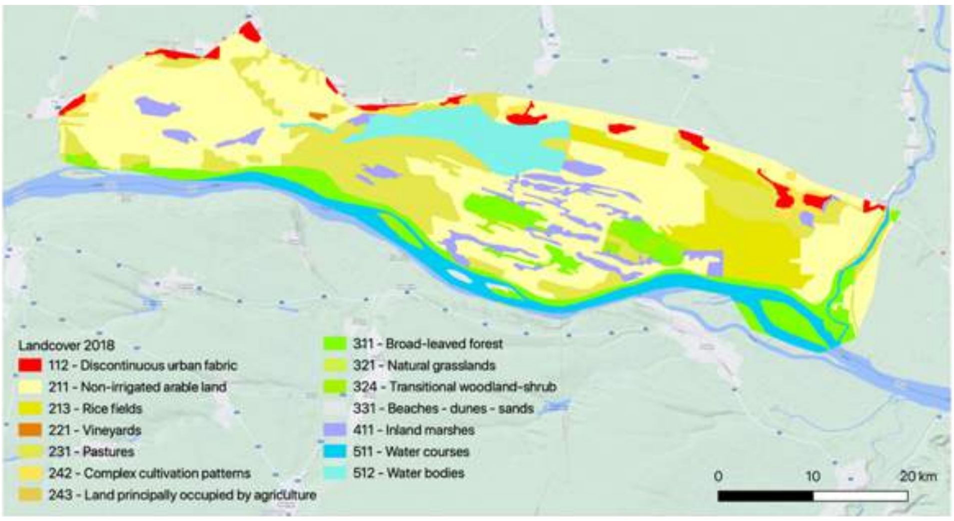


Figure 4 Bistret case study area landcover for the current ecosystem state

During the 1960s based on limited knowledge and understanding of ecosystem functioning the entire Danube floodplain suffered river embankment and land reclamation, that caused the conversion of natural wetland ecosystems towards agricultural land. As such in the current landscape configuration the dominant ecosystem type is represented by agricultural areas (51%), pastures (17%), forests (11%), wetlands (6%), water courses (7%), water bodies (6%), urban areas (3%). Land use/land cover dynamics for the three identified periods of time is presented in table 2 and figure 5.

Table 2 Bistret case study ecosystem area (ha) for each period

Land cover area (ha)	1900	1990	2018
Urban areas	815	1186	840
Agricultural areas	4302	11051	18898
Pastures (floodplain wetlands)	18566	8429	6093
Forest	2083	3375	4064
Wetlands	522	8127	2066
Water courses	2654	2749	2732
Water bodies	8045	2063	2289
Beaches	69	76	74
Total surface	**37056**	**37056**	**37056**

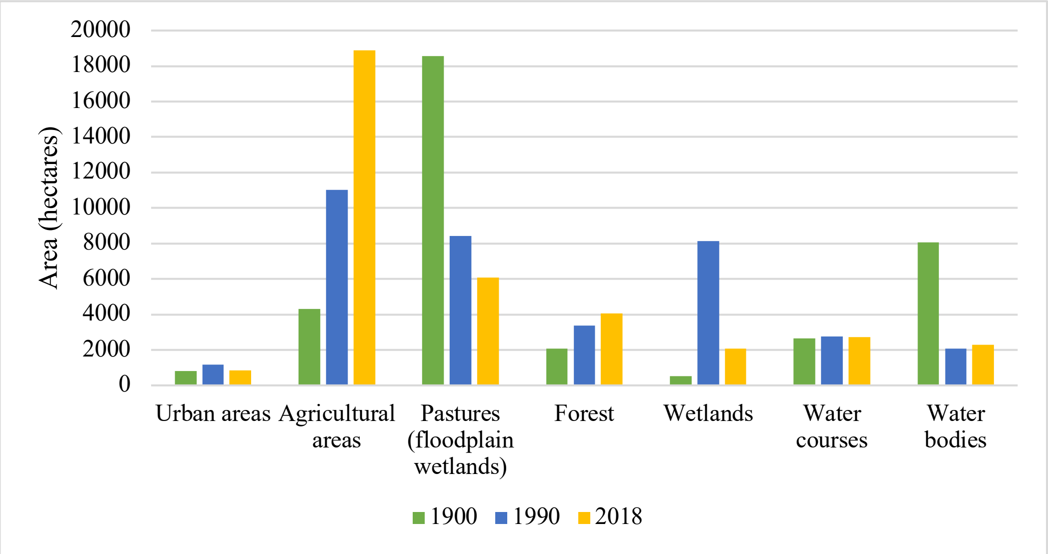


Figure 5 Land cover dynamics in the Bistret area

3.2 ECOSYSTEM SERVICES IDENTIFICATION IN BISTREȚ CASE STUDY AREA

Ecosystem services bio-physical mapping using a simple matrix (Burkhard et al. 2017) links ecosystem services to land cover by generating maps of the ecosystem services potential supply. Mapping and modeling of ecosystem functions provides the opportunity to reveal spatial heterogeneity in the quantity and quality of ecosystem services provided. The methodology consists in correlating land-use / land-cover data with the ecosystem services identified as relevant. At the intersection between land-cover and the ecosystem services a score on scale between 0 and 5 is provided depending on the capacity of each class to provide the respective service (0 - without relevant capacity, 1- small capacity, 2- relevant capacity, 3- medium capacity, 4 - high capacity, 5- very high capacity). The obtained values are those that allow the evaluation of ecological services for each category of land cover.

The potential final ecosystem services according to the CICES classification at the level of the study area and the intensity of the relationship between the ecosystem services and landcover type (the scale from 0 for less intense to 5 the most intense) are presented under the table 3.

Table 3 Classifying ecosystem services

Section	Division	Group	Class	Landcover type													
				112	211	213	221	231	242	243	311	321	324	331	411	511	512
				Discontinuous urban fabric	Non-irrigated arable land	Rice fields	Vineyards	Pastures	Complex cultivation patterns	Land principally occupied by agriculture	Broad-leaved forest	Natural grasslands	Transitional woodland-shrub	Beaches, dunes, sands	Inland marshes	Water courses	Water bodies
Provisioning	Nutrition	Biomass	Cultivated crops	1	5	5	4	0	4	4	0	0	0	0	0	0	0
Provisioning	Nutrition	Biomass	Domestic animals	1	2	0	0	5	1	3	0	3	0	0	0	0	0
Provisioning	Nutrition	Biomass	Wild plants	0	0	0	0	3	2	3	5	5	3	0	0	4	0
Provisioning	Nutrition	Biomass	Wild animals	0	1	2	0	3	2	1	5	4	2	0	2	3	2
Provisioning	Nutrition	Biomass	Plants and algae from in-situ aquaculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Provisioning	Nutrition	Biomass	Animals from in-situ aquaculture	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Provisioning	Nutrition	Water	Surface water for drinking	0	0	0	0	2	0	0	2	3	2	0	2	4	4
Provisioning	Nutrition	Water	Ground water for drinking	2	0	0	0	0	0	1	3	2	2	0	2	3	2

Provisioning	**Materials**	**Biomass**	**Fibres, plants, animals, and other materials for direct use or processing (excluding genetic materials)**	0	5	5	4	2	4	4	4	2	2	0	0	4	0
Provisioning	**Materials**	**Biomass**	**Materials from plants, algae and animals for agricultural use**	0	5	0	0	0	4	4	0	0	0	0	0	0	0
Provisioning	**Materials**	**Biomass**	**Genetic material**	0	2	2	4	4	3	3	5	1	3	0	0	1	0
Provisioning	**Materials**	**Water**	**Surface water used for other than drinking**	0	0	0	0	0	0	2	1	1	1	0	2	3	2
Provisioning	**Materials**	**Water**	**Ground water used for other than drinking**	0	0	0	0	0	0	2	2	1	1	0	2	3	2
Provisioning	**Energy**	**Biomass based energy**	**Plant based resources**	1	5	0	4	2	4	5	5	0	3	1	0	0	0
Provisioning	**Energy**	**Biomass based energy**	**Animal based resources**	0	2	0	0	3	1	4	1	0	2	0	0	0	0
Provisioning	**Energy**	**Biomass based energy**	**Animal based energy**	0	0	0	0	5	1	3	0	0	0	0	0	0	0
Regulation and maintenance	**Mediation of waste, toxics and other nuisances by non-living processes**	**Mediation by biota**	**Bio-remediation by micro-organisms, algae, plants, and animals**	0	0	3	3	4	4	2	3	4	2	1	2	3	2

Regulation and maintenance	**Mediation of waste, toxics and other nuisances by non-living processes**	**Mediation by biota**	**Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals**	0	0	3	3	4	3	2	3	4	2	1	2	3	2
Regulation and maintenance	**Mediation of waste, toxics and other nuisances by non-living processes**	**Mediation by ecosystems**	**Filtration/sequestration/storage/accumulation by ecosystems**	0	0	3	3	4	3	2	4	4	2	1	2	3	2
Regulation and maintenance	**Mediation of waste, toxics and other nuisances by non-living processes**	**Mediation by ecosystems**	**Dilution by athmosphere**	0	0	0	0	3	3	2	4	4	2	1	2	3	2
Regulation and maintenance	**Mediation of waste, toxics and other nuisances by non-living processes**	**Mediation by ecosystems**	**Mediation of smell/noise/visual impacts**	0	0	2	3	4	2	2	4	3	2	1	2	2	2
Regulation and maintenance	**Regulation of baseline flows and extreme events**	**Mass flows**	**Stabilisation and control of erosion rates**	0	1	0	3	4	2	1	5	5	3	0	2	3	2

Regulation and maintenance	**Regulation of baseline flows and extreme events**	**Mass flows**	**Buffering and attenuation of mass flows**	0	0	3	2	3	3	1	4	3	3	1	4	3	4
Regulation and maintenance	**Regulation of baseline flows and extreme events**	**Liquid flows**	**Hydrological cycle and water flow maintenance**	0	0	3	3	2	3	3	4	1	2	0	5	3	5
Regulation and maintenance	**Regulation of baseline flows and extreme events**	**Liquid flows**	**Flood protection**	0	1	1	1	2	2	2	4	2	2	3	5	2	5
Regulation and maintenance	**Regulation of baseline flows and extreme events**	**Gas flows**	**Storm protection**	0	0	0	1	2	1	2	4	1	2	1	5	2	5
Regulation and maintenance	**Regulation of baseline flows and extreme events**	**Atmospheric composition and conditions**	**Regulation of temperature and humidity, including ventilation and transpiration**	0	0	2	2	2	2	2	4	4	2	0	2	0	2
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Lifecycle maintenance, habitat and gene pool protection**	**Pollination**	0	0	0	2	5	2	4	5	4	3	0	0	1	0
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Lifecycle maintenance, habitat and gene pool protection**	**Maintaining nursery populations and habitats**	0	2	3	0	3	2	4	4	5	4	3	1	3	1
Regulation and maintenance	**Maintenance of physical,**	**Pest and disease control**	**Pest control**	0	2	3	3	4	3	3	4	3	3	0	0	3	0

	chemical, abiotic conditions																
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Pest and disease control**	**Disease control**	0	2	2	3	4	3	3	4	3	3	0	0	2	0
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Regulation of soil quality**	**Weathering processes**	0	0	0	0	1	2	3	4	2	2	0	0	0	0
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Regulation of soil quality**	**Decomposition and fixing processes**	0	0	1	2	2	2	3	4	3	2	0	0	4	0
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Water conditions**	**Chemical condition of freshwaters**	0	0	1	2	4	2	2	5	2	2	1	2	4	2
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Water conditions**	**Chemical condition of saltwaters**	0	0	0	0	0	2	2	0	0	0	0	0	4	0
Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Atmospheric composition and conditions**	**Global climate regulation by reduction of greenhouse gas concentrations**	0	0	0	0	1	0	1	4	2	2	0	1	2	1

Regulation and maintenance	**Maintenance of physical, chemical, abiotic conditions**	**Atmospheric composition and conditions**	**Micro and regional climate regulation &Ventilation and transpiration**	0	2	3	2	3	2	2	5	2	3	0	3	3	3
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Physical and experiential interactions with natural environment**	**Experiential use of plants, animals and land-/seascapes in different environmental settings**	3	1	1	2	5	2	2	5	3	3	5	1	4	1
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Physical and experiential interactions with natural environment**	**Physical use of land-/seascapes in different environmental settings**	3	1	1	2	4	2	2	5	3	3	5	2	4	2
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on**	**Intellectual and representative interactions with natural environment**	**Scientific**	1	2	2	2	2	2	2	5	5	3	2	1	4	1

	presence in the environmental setting																
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Intellectual and representative interactions with natural environment**	**Educational**	1	2	2	2	2	2	2	5	5	3	2	1	4	1
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Intellectual and representative interactions with natural environment**	**Heritage, cultural**	3	3	2	2	4	2	2	5	4	3	2	0	4	0
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Intellectual and representative interactions with natural environment**	**Entertainment**	5	0	0	0	2	0	2	5	3	2	5	2	4	2

Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Intellectual and representative interactions with natural environment**	**Aesthetic**	3	1	1	2	4	1	2	5	4	4	4	2	4	2
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Spiritual, symbolic and other interactions with natural environment**	**Symbolic**	3	0	0	3	3	1	0	3	4	2	1	0	4	0
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Spiritual, symbolic and other interactions with natural environment**	**Sacred and/or religious**	4	0	0	1	0	0	1	5	1	0	0	0	4	0
Cultural	**Direct, in-situ and outdoor interactio**	**Other biotic characteristics that have a**	**Existence**	2	1	0	2	3	1	3	5	3	3	2	0	3	0

	ns with living systems that depend on presence in the environmental setting	**non-use value**															
Cultural	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Other biotic characteristics that have a non-use value**	**Bequest**	2	2	0	3	3	1	3	5	3	3	4	0	3	0

Ecosystem services spatial distribution was mapped for the three selected time periods (figure 7 – to figure 15) for provisioning, regulating and cultural services. The landscape configuration in the reference state comes with a lower value for the provisioning services when compared with the other analyzed periods, but high values of regulating and cultural services. In the following periods year 1990 and 2018 (current landscape configuration), even if the provisioning services values are higher a drastic decrease for the regulating and cultural services can be observed (figure 6).

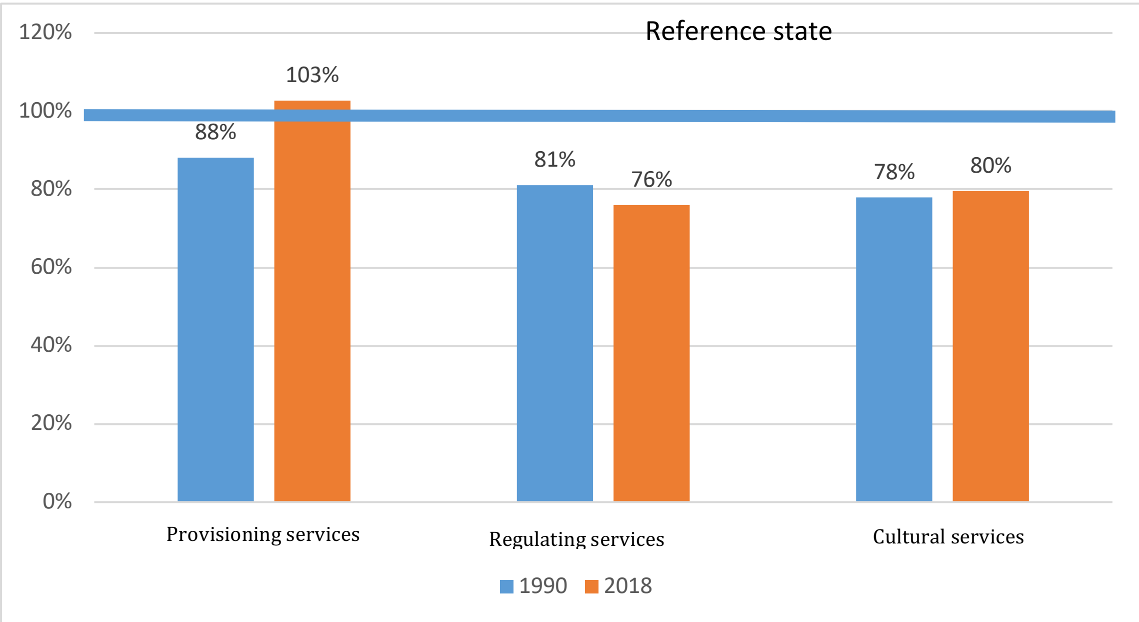


Figure 6 Ecosystem service potential as compared with the refence state (1900)

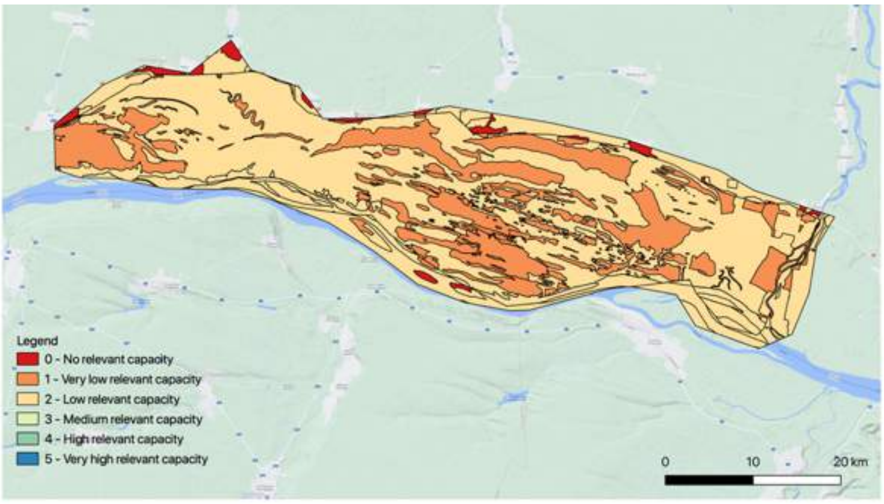


Figure 7 Provisioning services spatial distribution for the reference state of the ecosystems

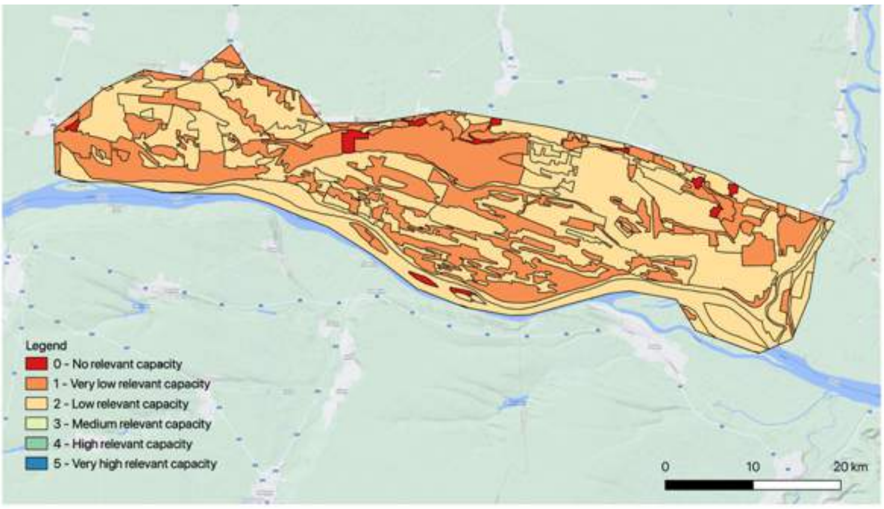


Figure 8 Provisioning services spatial distribution for the year 1990

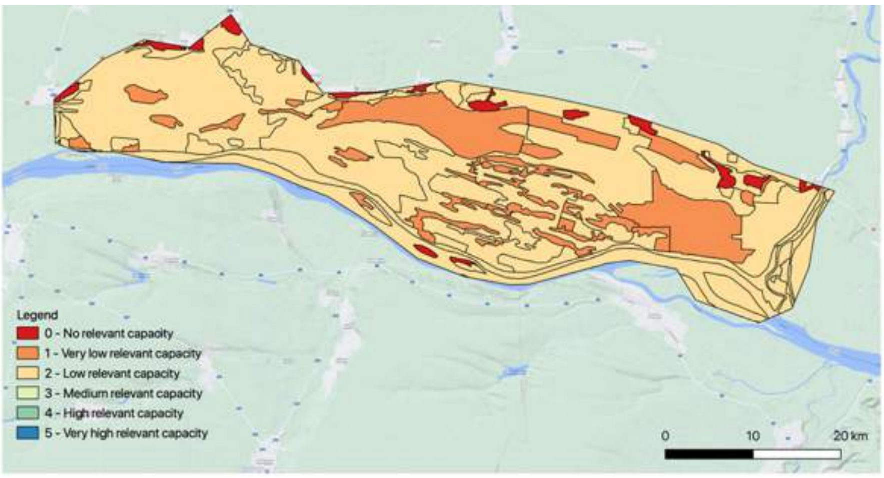


Figure 9 Provisioning services spatial distribution for the current state of the ecosystem

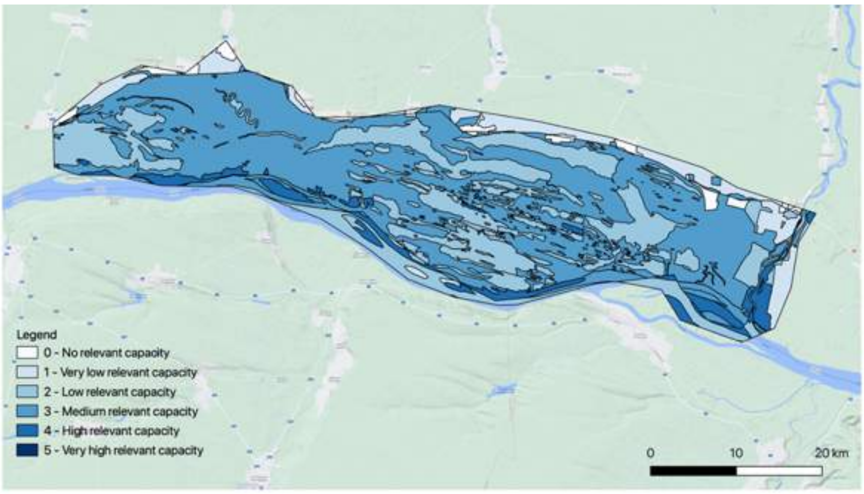


Figure 10 Regulating services spatial distribution for the reference state of the ecosystems

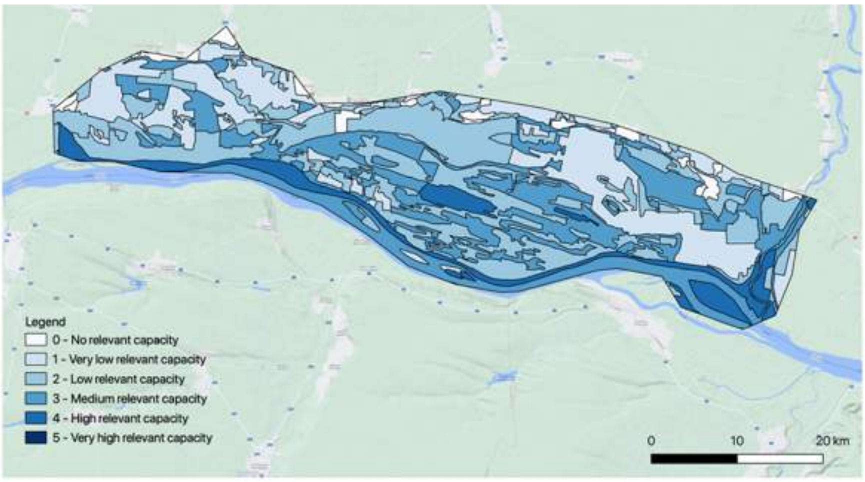


Figure 11 Regulating services spatial distribution for the year 1990

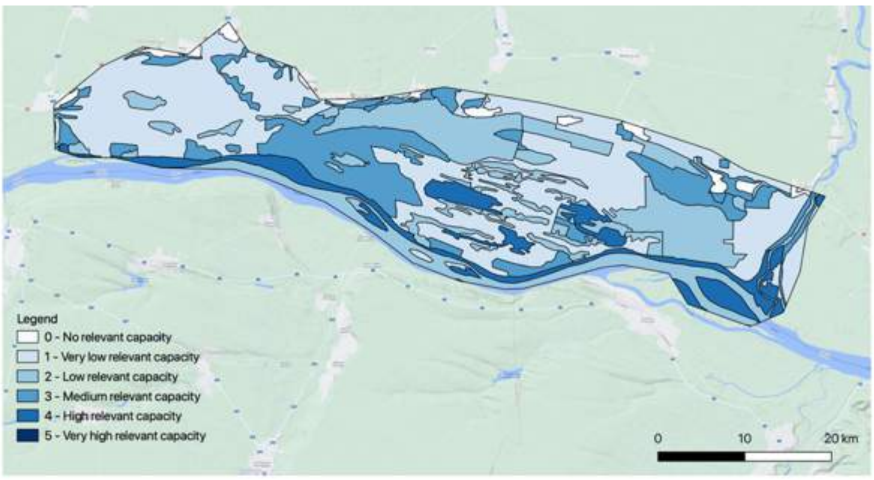


Figure 12 Regulating services spatial distribution for the current state of the ecosystem

Figure 13 Cultural services spatial distribution for the reference state of the ecosystems

Figure 14 Cultural services spatial distribution for the year 1990

Figure 15 Cultural services spatial distribution for the current state of the ecosystem

3.3 Social perception on ecosystem services

The social definition of an ecosystem service does not imply a social unanimity in terms of awareness and recognition of the existence of that service. A segmentation of social actors according to their relevance to environmental objectives allows an identification of the most important actors at which it is necessary to raise awareness of ecosystem services concepts and to determine a favorable attitude towards them: local actors (people living inside or the proximity of natural areas or those that operate within them) and policy makers (institutional actors responsible for developing and implementing environmental protection policies).

It is society that determines the degree of importance for a particular ecosystem service in a specific context. The diversity of the attitudinal value systems of the social actors makes the same service to be appreciated differently by different actors. The importance of ecosystem services is defined exclusively socially by reference to the value attitude system of those who evaluate them. From this perspective, the importance of ecosystem services varies not only from one actor to another but also over time in the case of the same actor. Moreover, depending on the value attitude system and the interests of social actors, what appears as a service for some actors can be defined as a disservice for other social actors.

In order to capture the knowledge and attitudes of social actors regarding the value of ecosystem services in the studied area, questioning session was organized with the inhabitants of Bistreț pilot area. The questionnaire for the assessment of ecosystem services was a necessary step to conduct the assessment study of the services provided by the ecosystems in the target area in the study compared to the needs / requirements of society. The socio-demographic data of the participants in the questionnaires are presented in the table 4.

Table 4 Socio-demographic data of the participants

		Local
Number of respondents sociological survey		9
Gender	Male	78%
	Female	22%

	Not answering	0%
Average age of respondents		35 years
Last school graduated	Highschool	-%
	University	-%
	I prefer not to answer	-%
They own properties inside the investigated area	Yes	-%
	No	-%

3.4 IDENTIFICATION AND HIERARCHY OF ECOSYSTEM SERVICES IN THE STUDY AREA

1. Services identified by members of the local community and by decision-makers at the local level through the sociological survey

From Table 5 it can be seen that the members of the local community identified to a large extent the main existing services at the level of the studied area. Basically, there was a consensus for many of them, almost all of them identifying mainly production, cultural and regulatory ecosystem services and to a lesser extent support. Being a complex area in terms of benefits provided, with many habitats and species of flora and fauna, the participants in the questionnaires identified a high number of ecosystem services. Among the services presented through the questionnaire, a small number was not identified at the level of the investigated area, stating either that it does not exist or that I do not know if it exists. These are the existence of industrial plants, salt or other mineral resources usable in food, plant materials used as biofuels.

Table 5 Percentage of participants who identified ecosystem services

Identified ecosystem services			
Benefits related to human nutrition	**Yes**	**No**	**I don't know**
Cereals / vegetables obtained by using the agricultural land on the site	**100%**	**%**	
Fruits from orchards / fruit trees inside the site	**100%**	**%**	**%**
Berries	**-%**		
Mushrooms	**-**		
Aromatic and medicinal plants	**-**		

Identified ecosystem services			
Hunting	100%		
Sources of drinking water for the population	100%		
Fish	100%		
Salt or other mineral resources usable in food			
Animal husbandry benefits	Yes	No	I don't know
Grazing areas for animals	100%		
Hay	100%		
Beekeeping (using existing flora)	80%		
Water for animals			
Food resources for other domestic animals			
Natural resources used in economic activity	Yes	No	I don't know
Wood resources for heating	100%		
Wood for the wood industry - processing			
Industrial plants (hemp and other industrially exploited plants for fiber and cellulose)			
Other raw materials used in the pharmaceutical industry or other industries			
Water resources used for irrigation, domestic or industrial use	100%		
Construction materials: sand, aggregates, stone			
Other surface or underground mineral ores / deposits			
Resources with energy value	Yes	No	I don't know
Energy production (wind, hydropower, solar, etc.)			
Coal, oil or natural gas deposits			
Plant materials used as biofuels			
Environmental benefits	Yes	No	I don't know
The site contributes to the reduction of air pollution at local / regional level		80%	20%
The site contributes to improving the quality of the soil locally	40%	60%	

Identified ecosystem services			
The vegetation of the site contributes to the reduction of noises, unpleasant smells and to the improvement of the landscape (forest curtains)			100%
The site helps protect the area from flooding	80%	20%	
The vegetation on the site offers forest curtains to protect agricultural lands, roads / households from strong winds, snow, etc.	70%		30%
The site offers protection for crops / households through landforms (hills, terraces, etc.)	100%		
The site helps to protect the land from erosion and landslides	40%		60%
The site contributes to improving the conservation of some species of animals / birds / etc.	80%	20%	
Tourist and symbolic value	Yes	No	I don't know
The site contributes to attracting tourists to the area	80%	20%	
In the site there are objectives of cultural - historical interest		20%	80%
In the site there are places / objectives with religious / sacred significance	30%		70%
In the site there are natural objectives (relief forms) with a unique character	100%		
In the site there are species of plants or animals whose conservation is important	20%		80%
The site includes a series of spectacular landscapes	80%		20%
General ecological value	Yes	No	I don't know
The site contributes to the conservation of ecosystems and the protection of biodiversity	70%		30%

2. The most important 11 services resulting from the ranking on a scale from 1 to 10, depending on the importance, provided by members of the local community and decision makers at the local level. The method used was also the sociological survey. The services mentioned by at least one third of the respondents were taken into account.

As the investigated area provides many ecosystem services, we further present the top 11 services assessed locally on a scale of 1 to 10 (Table 6). It can be seen that the most important ecosystem services resulting from local assessment are related to fishing, attracting tourists, crop production, water for irrigation, Landscape aesthetics etc.

Table 6 Evaluation of ecosystem services by assigning a grade from 1 to 10 to standardized items (arithmetic mean of grades obtained) (total voting system)

No.crt	Ecosystem service	Average
1	Fish	10
2	Tourism	8
3	Crops	6
4	Water for irrigations	5
5	Landscape aesthetics	5
6	Animal husbandry	3
7	Local identity	2
8	Flood protection	2
9	Bee keeping	1
10	Timber for fire	1
11	Pastures	1

3. Peer ranking method as a tool to identify and rank the ES. The most important services resulting from the group vote were used in a random order.

Participants in the two workshops were asked to rank in pairs each of the 11 ecosystem services that were considered important following the group discussion (Table 7). It can be seen that this method changes the hierarchy of the importance of ecosystem services, validating the thesis of the relative importance of ecosystem services.

Table 7 The most important ecosystem services ranked by the method of voting in pairs

Hierarchy	Local workshop
S10_Timber for fire	57
S1_Fish	36
S2_Tourism	32
S3_Crops	26

S5_Landscape	23
S4_Water for irrigations	20
S6_Animal husbandry	20
S7_Local identity (brand)	14
S8_Flood protection	13
S9_Bee keeping	3

3.5 IDENTIFICATION OF TRADE-OFFS AND SYNERGIES BETWEEN ECOSYSTEM SERVICES (USE OF FCM-FUZZY COGNITIVE MAP)

Modeling using directional graphs is increasingly used both to represent the complexities of social networks but also by other sciences. It has recently begun of concern to map the links between different ecosystem services. This in fact allows us to highlight the positive links (synergies) but also the negative relationships (trade-offs) between different ecosystem services. In this study we opted for the development of the network together with local actors by involving them in the interactive creation of the connectivity map between ecosystem services (figure 16).

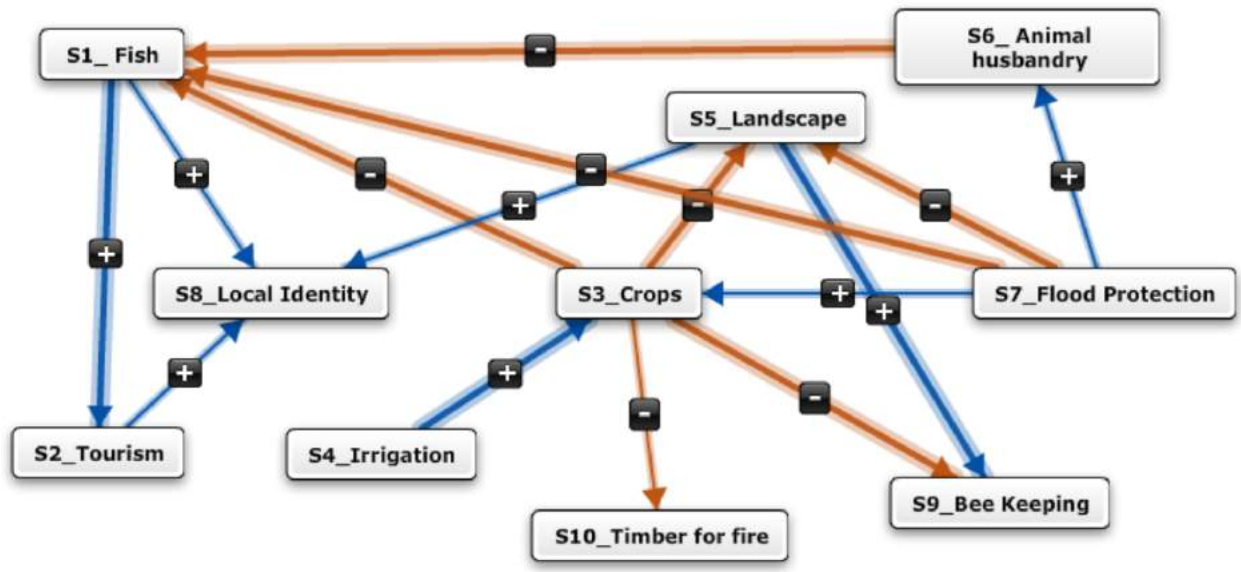


Figure 16 Identification of ecosystem services and the relationships between them

For this, the 10 most important ecosystem services identified by local actors were selected (those that have interests in use on the one hand, but also in conservation or rather in their sustainable use). The characteristic elements are presented in table 9:

Table 8 The main features of FCM

Number of Concepts	**10**	
Number of Connections	**15**	
Density	**0.15**	
Number of Connections / Components	**0.67**	
Driver Components		
	S9_Bee Keeping	**2**
	S8_Local Identity	**1.5**
	S10_Timber for fire	**0.5**
Receiver Components		
	S7_Flood Protection	**3**
	S4_Irrigation	**1**
Number of Ordinary	**5**	
Complexity Score	**0.67**	
Highest Centrality Variables		
	S3_Crops	**5**
	S1_ Fish	**4.5**
	S5_Landscape	**3.5**

	S7_Flood Protection	3
	S9_Bee Keeping	2
	S2_Tourism	1.5
	S8_Local Identity	1.5
	S6_ Animal husbandry	1.5
	S4_Irrigation	1
	S10_Timber for fire	0.5
OutDegree Values		
	S1_ Fish	3
	S5_Landscape	2
	S9_Bee Keeping	2
	S8_Local Identity	1.5
	S3_Crops	1.5
	S2_Tourism	1
	S10_Timber for fire	0.5
	S6_ Animal husbandry	0.5
	S4_Irrigation	0
	S7_Flood Protection	0
InDegree Values		
	S3_Crops	3.5
	S7_Flood Protection	3
	S1_ Fish	1.5
	S5_Landscape	1.5
	S4_Irrigation	1
	S6_ Animal husbandry	1

	S2_Tourism	**0.5**
	S8_Local Identity	**0**
	S9_Bee Keeping	**0**
	S10_Timber for fire	**0**

Number of identified connections 15. The central component is that of Crops, to this is added the forestry component: timber for fire (or better the management of the forest ecosystems) which is very important for the local community, in the sense that it is identified by them as having a negative impact most often on other ecosystem services (biodiversity conservation, tourism, air quality, etc.).

3.6 MONETARY VALUATION

The economic evaluation of ecosystem services, in acceptable conditions of reliability, implies an effort to define them, respectively to establish the content, so that it is possible to compare with the matrix of human needs and express the cardinal and / or ordinal utility / satisfaction.

Even if there are concerns in achievements of standardization of the ecosystem services matrix, the understanding and evaluation of user / consumer behavior must have as a starting point the individual and collective perception of the relationship between different components of natural capital and human needs; of course, decision-making communication needs to ensure the conversion of individual and collective perceptions of ecosystem services into standardized language. The above emphasis has a special role, because the determination of the value of ecosystem services is based on methods and techniques of revealing / expressing preferences, which induces an important subjective dimension that may affect the need to objectify the decision-making act. The assessment of the services provided by the protected natural areas covered by the project and their support capacity compared to the needs / requirements of the human society requires understanding and assessment of user / consumer behavior, given that needs refer to a threshold of available services needed by the user, while the requirement depends on its ability to purchase services.

Some ecosystem services are direct services (e.g. aesthetic value of forests, recreation, raw materials for construction, artisanal production and firewood) and others are indirect ecosystem services (soil erosion control, nutrient storage capacity, carbon, etc.). Similarly, there are some services for which there is no developed market yet (such as services related to nutrient storage, or soil erosion control) but for which a market could be developed in the future (just as markets have been created for trading CO2).

For the evaluation of ecosystem services, it is necessary to classify them using different classification systems (MA, TEEB, and IPBES). As mentioned in this paper, the CICES (Common International Classification of Ecosystem Services) was used as a classification system. This system funded on the notion of evaluation of ecosystem services based on the Total Economic Value of ecosystem services (TEV). The value of ecosystem services is calculated by summing two major components: the value of use and the value of non-use. The structure of the two components is detailed in Figure 17.

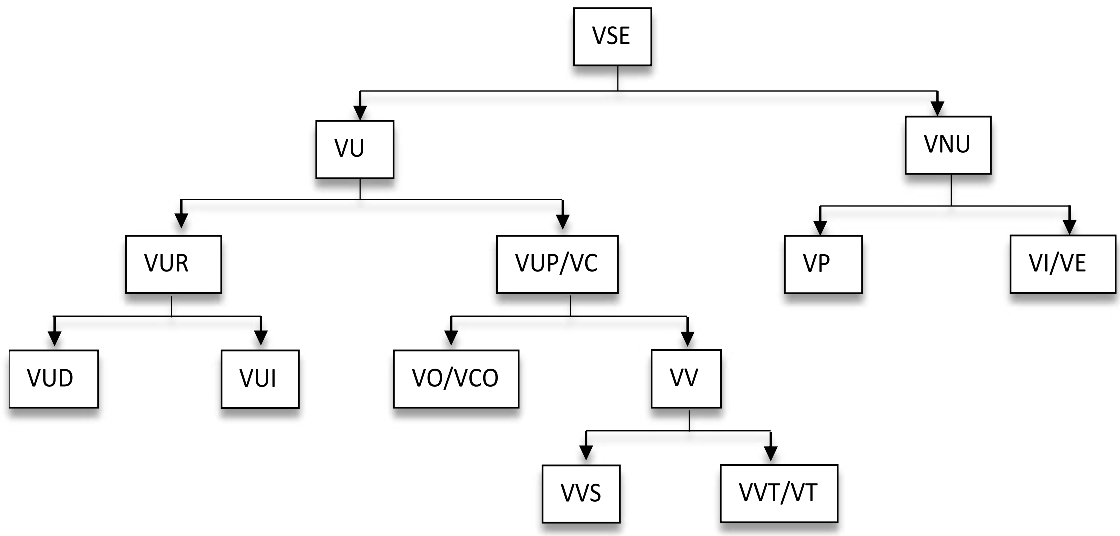


Figure 17 The value structure of ecosystem services

Where:

VSE: the ecosystem services value

VU: use value

VUR: real use value

VUD: direct use value

VUI: indirect use value

VUP/VC: potential use value/conservation value

VO/VCO: optional value/ quasi optional value

VV: neighborhood value

VVS: spatial neighborhood value

VVT/VT: temporal neighborhood value / testamentary value

VNU: non-use value

VP: preservation value

VI/VE: intrinsic value /existential value

The use and non-use value of ecosystem services are the two components of the total value of ecosystem services, whose importance is given by the level and intensity at which they can be perceived as a result of formal and informal knowledge, differentiated by space and time scale. Therefore, the value of use reflects the direct and indirect relationships between ecosystem services and the various users, relationships that significantly influence their capitalization mechanism, based on economic, social and ecological reasoning. (When the objective capitalization mechanism deviates from such reasoning, it is necessary to promote specific institutional measures).

Apparently, the use value does not take the time frame into consideration (it is expressed by the user “here and now”) but, from the perspective of the knowledge process, which is currently part of the non-use value, in a closer or further perspective, it could become use value. Taking into account the arguments in favor of the monetary evaluation approach of ecosystem services, the use value, will be reflected in the performance indicators of socio-economic systems (components of socio-ecological complexes), will stimulate concerns for rational capitalization of the natural environment.

The solution adopted to determine the value of ecosystem services in the Bistreț area is a mix of methods, techniques, assumptions, which allowed us to establish the profile of area, but also the transition from the ordinal utility of ecosystem services to their value; the mix being subsumed to the hypothetical market method, the technique based on choice modeling, as a methodological expression of the theory of random utility.

In this approach the problems to be solved were:

- aggregation of ordinal utilities at the local level, with those at the regional level;
- determining the user's surplus, a component of the value in use, together with the market value.

Ordinal utilities at the local level were standardized and weighted with those at the regional level, and the coefficients of ecosystem services directly related to the main local economic activities were adjusted according to the relationship between dominant economic activities in the area and ecosystem services identified in the workshops.

To determine the user surplus, a component of the value in use, together with the market value, a family of demand functions was taken into account, with the help of which the average level of the ratio between the user surplus and the market value was determined.

1. Ensuring the structural comparability of ecosystem service portfolios identified and retained for evaluation at local and regional level

To unify the local lists of identified ecosystem services (identified services are mentioned according to the names given by participants) with the other ecosystem services relevant for the regional level and retained for evaluation, it was adopted the proportionality rule, based on the basic reasoning of assessing the importance of ecosystem services by users, respectively comparing ecosystem services not only with their needs (in the identification process), but also between them.

Accepting and starting from this hypothesis we went through the following sub-steps:

- establishing a *reference* ecosystem service among the first ecosystem services in the local rankings, based on the frequency of options, in the case under consideration being "timber for fire"
- establishing the share of options for ecosystem services on one list and which are not on the other list, by reference to the frequency of options for the common service (these shares have the status of equivalence coefficients)
- multiplying the equivalence coefficients for the services in question by the frequency of the options for the common service on the other list, obtaining the fervor of the options for them.

2. Hierarchy of ecosystem services identified by users and retained for evaluation

For this purpose, the DELPHI method was used, the binary comparison technique, going through the following sub-steps: priority given to each ecosystem service compared to other ecosystem services, establishing the frequency with which each service was preferred by each user / group of users to other ecosystem services and determining the share of the frequency (n) with which each user (group of users) was preferred in the total number of value judgments.

Within each working group / workshop participants compared the two benefits / services provided by the area concerned and chose the service considered most important, completing the Comparative Analysis Form of the importance of the services / benefits provided.

3. Determination of the importance coefficients for the services subject to evaluation

Significance coefficients are calculated by relating the absolute frequency of each ecosystem service to the total number of options expressed. Ordinal utilities at the local level were standardized and weighted with those at the regional level, and the coefficients of ecosystem services directly related to the main local economic activities were adjusted according to the relationship between the dominant economic activities in the area and the ecosystem services identified in the workshops (the coefficients values are presented in table 9).

Table 9 Coeficient values based on the number of choices for first 10 ranked ES by the local stakeholders

Ecosystem services	Number of choices	Coefficient
S10_Timber for fire	57	0.233607
S1_Fish	36	0.147541
S2_Tourism	32	0.131148
S3_Crops	26	0.106557
S5_Landscape	23	0.094262
S4_Water for irrigations	20	0.081967
S6_Animal husbandry	20	0.081967
S7_Local identity (brand)	14	0.057377
S8_Flood protection	13	0.053279
S9_Bee keeping	3	0.012295

The ranking of ecosystem services is done according with their importance for the local economy (based on the economic profile of local communities). The analysis of the prevalence of economic activities shows that the main connections between ecosystem services and the local economy are primarily aimed at logging, fishing, agriculture but also towards tourism, animal husbandry, flood protection and water supply. From this point of view, the higher weighting of ecosystem services related to these economic activities is justified (table 10) in terms of establishing the indicator of relative importance of ecosystem services.

Table 10 Dominant local economic activities and ecosystem services that support the local economy

Dominant economic activities at local level	Supporting ecosystem services for local economy
S10_Timber for fire	**Fire wood provisioning services**

S1_Fish	**Fishing is very important for the local communities as it provides either an increased income or forms the food base for the poor families.**
S2_Tourism	**This is important althow is more like a target than a reality**
S3_Crops	**Production services especially agriculture;**
S5_Landscape	**Nice scenary (linked with tourism)**

4. Identification of the reference ecosystem service

For this, we took into account the assumptions of the application of different methods and techniques for assessing ecosystem services, the main criterion being the reflection of ecosystem service on a functioning market, such as the market of primary and secondary forest ecosystem services. In our study we opted for the service S10_Timber for fire due to at least two reasons:

1) has market value, and
2) was the top choice for many local stakeholders.

5. Determination of the value of the reference ecosystem service, respectively of the potential supply of standing timber

For this purpose, we used the model based on the willingness to pay.

$$\mathbf{SV=MP+CS}$$

SV = service value

MP = market price

CS = consumer surplus

To measure the consumer's surplus, a mathematical calculation was used based on the graphical representation of the relationship between the market value and the consumer's surplus (figure 18).

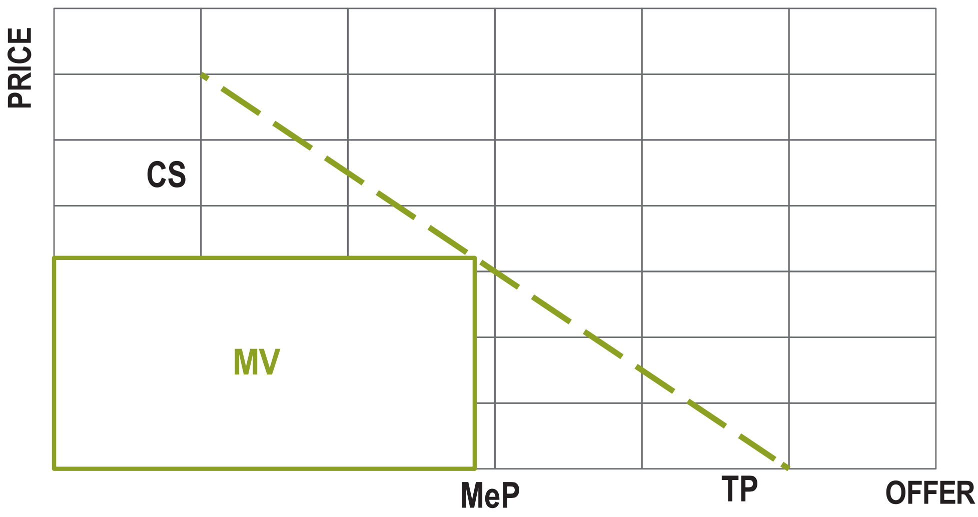


Figure 18 Relationship between market value and consumer surplus

Where: TP = Total provision; MeP = Provision expressed on the market; MP = market price; MV = market value; CS = consumer surplus.

Determination of the use value of the reference ecosystem service “S10_Timber for fire“

Table 11 Value for Timber for fire (the reference ES)

Total offer	**5.6**	**m³/ha/an**
Market offer	**4**	**m³/ha/an**
Market price	**155**	**lei/m³**
Market value	**620**	**lei/ha/an**
Consumer surplus	**775**	**lei/ha/an**
Value of the ES "Timber for fire"	**1395**	**lei/ha/an**

MV = Total offer x Market price (5.6 m³ / ha / year x 155 lei / m³ = 620 lei / ha/ year)

CS = 775 lei (surface area below the demand curve, within the market price)

SV = 620 +775 = 1395 lei / year / hectare

6. Determining the non-use value of the reference ecosystem service

In the case of the non-use value (NUV) of ecosystem services, we will take the following circumstances as a base for model:

- UV = MV+CS

- ESV= UV+NUV

Where: ESV = total value of the ecosystem service; UV = Use value; NUV = Non-Use value; MV = market value; CS = consumer surplus.

- There is a certain relation of influence between the value (of an asset, service) and the price (we reckon that the value cannot be exclusively objective – the theory of work value, or subjective – the theory of usefulness value; however, this does not justify the elimination, from economic thinking, of the notion of value).
- The price, as a tool of the market economy, plays a certain role in rationalising consumption/exploitation of goods, services.

At least in the long run, the size of the price has as a determined element the labor consumption (the cost of generating the product, the service) and / or the utility, respectively the value, regardless of its essence. However, we emphasize that the proximity, in size, between price and value is influenced by multiple factors, a situation that can be explained if we take into account the fact that price is a form of objectification of value, as a result of social recognition of labor consumption and / or utility characteristic to one good / service or another. In conclusion, we consider that the change in the size of the value (this is the value of the ecosystem service) is also reflected in the change in the price.

Continuing the analysis of causal relations, economic thinking, "legislates" the inversely proportional character of the evolution of price and demand associated with a good / service, of course depending on its price elasticity.

Taking into account these two conclusions, the reasoning allows to state the following aspects:

- Adding the value of non-use to the value of use leads to a higher value of the ecological service, imprinting a similar trend to the “market price”;
- The increase of the market price will change as the surplus of the consumer / user (decreases the surplus of the consumer as a result of the increase of the market price);
- To the extent that the decrease of the consumer / user surplus due to the addition of the non-use value, respectively, the price increase, is accepted by him, we appreciate that the “decrease” gives us an order of magnitude of the non-use value.

In order to determine the non-use value of the ecosystem service “S10_Timber for fire” the theoretical aspects presented above were taken into account, and the detail of the calculation is presented in table 12.

Table 12 Detail of the calculation of the use value of the ecosystem service "S10_Timber for fire"

Reference ecosystem service	Timber for fire
Market price (= use value) UV	155
Market price (= use value) UV+ (non-use value) NUV (10%)	170.5
Market price (= use value) UV+ (non-use value) NUV (20%)	186
Market price (= use value) UV+ (non-use value) NUV (30%)	201.5
Consumer surplus, corresponding in use value	775.00
Consumer surplus, corresponding UV +NUV	620.00
Market price (= use value) UV+ (non-use value) NUV (10%)	604.50
Market price (= use value) UV+ (non-use value) NUV (20%)	589.00
Market price (= use value) UV+ (non-use value) NUV (30%)	573.50
Non-Use value for the Reference ES	
Surplus (VU) - Surplus (VU+NUV) 10%	170.50
Surplus (VU) - Surplus (VU+NUV) 20%	186.00
Surplus (VU) - Surplus (VU+NUV) 30%	201.50
Minimal value	170.50

The market price (expressed in lei / m3) is provided by the National Institute of Statistics. It was also used other data sources. The price is nevertheless a minimum based on the available data. The real value is fluctuating between 150 to 300 lei per cubic meter.

7. Determining the value of ecosystem services

The value of the ecosystem services was determined taking into account the value of the reference ecosystem service and the size ratio between the importance coefficients of the other ecosystem services and that of the reference ecosystem service. The results are shown in Table 13.

Table 13 Value of ecosystem services

Ecosystem services	Number of choices	Coefficient	Total minimal value (lei/ha/year)	Minimal use value (lei/ha/year)	Minimal total value (lei/ha/year)
S10_Timber for fire	57	0.23	1565.50	170.50	1395.00
S1_Fish	36	0.15	988.74	107.68	881.05
S2_Tourism	32	0.13	878.88	95.72	783.16
S3_Crops	26	0.11	714.09	77.77	636.32
S5_Landscape	23	0.09	631.69	68.80	562.89
S4_Water for irrigations	20	0.08	549.30	59.82	489.47
S6_Animal husbandry	20	0.08	549.30	59.82	489.47
S7_Local identity (brand)	14	0.06	384.51	41.88	342.63
S8_Flood protection	13	0.05	357.04	38.89	318.16
S9_Bee keeping	3	0.01	82.39	8.97	73.42
Total	**244**	**1.00**	**6701.44**	**729.86**	**5971.58**

The „total" ecosystem value is estimated at around 1381 euro/hectare/year (6701.44 lei / hectare/year), and this is a very conservative figure based only on data from the involved stakeholders. If we are taking into consideration more ecosystem services the total value will increase as much as 50 times. For e.g. Costanza et al. (1997) estimated the values for more ES in wetland and so they reached values of 51093 Euro per hectare and year. Only Nutrient cycling being evaluated at around 21000 euro. Different other ecosystem services could be considered as very important in these types of wetlands (floodplains) but usually they are overlooked by most of the stakeholders being more hidden (or not so visible) to local communities. Different such ecosystem services are mostly under the regulation such as carbon sequestration, nutrient cycling or sediment retention.

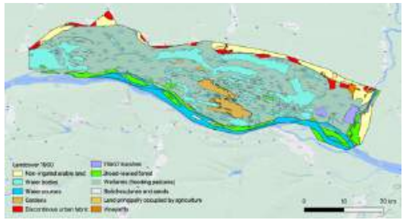
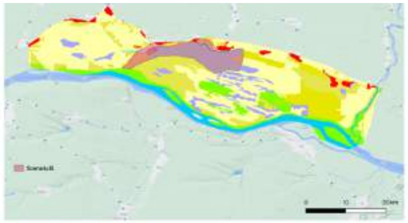
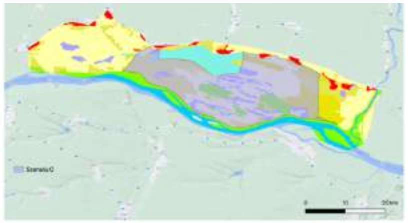
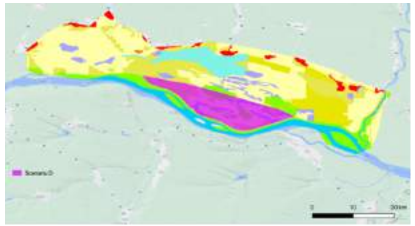
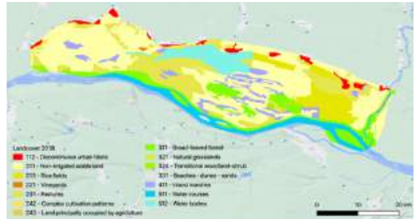
3.7 Proposed restoration scenarios and their ecosystem and acosistem services analysis

The ecosystem services provided by Bistret area were analysed according to five scenarios:

- scenario A – restoration of the former Bistret wetland area to the landscape configuration prior to the wetland conversion
- scenario B – realistic scenario where only Bistret lake area will be increased
- scenario C – most optimistic scenario with restoration of most of the wetland and lake area mainly for water storage at high flows of the Danube
- scenario D – half of wetland area will be restored
- scenario E – business as usual.

Table 14 Land cover area for the five selected scenarios for Bistret area

Land cover area (ha)	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Urban areas	815	840	841	840	840
Agricultural areas	4302	18709	12255	17763	18877
Pastures (floodplain wetland)	0	5393	2304	4735	6093
Forest	2083	4065	2875	3538	4064
Wetlands	522 + 18566 (floodable pastures)	2066	9178	3737	2066
Water courses	2654	2733	2742	2743	2732
Water bodies	8045	3167	6778	3619	2289
Beaches	70	74	74	74	74

Scenario A total restoration / reference	Scenario B Increase of Bistret lake area	Scenario C Restoration of wetland area at high levels of the Danube	Scenario D Partial restoration of the wetland area	Scenario E Business as usual
				
Aim: increase of the whole range of ES Advantages: – increase of cultural services – increase of flood retention capacity – high support for biodiversity How: destroy existing damns and dikes	Aim: increase the provisioning of fish Advantages: – increase of fish accessibility to local population – no of tourists How: relocating a dyke and opening a channel	Aim: increase of cultural and regulating services Advantages: – increase water retention – increase of regulating services – increase of cultural services – biodiversity support – habitat for species How: dike relocation to the north	Aim: increase of cultural and regulating services Advantages: – increase water retention – increase of regulating services – increase of cultural services – biodiversity support – habitat for species How: dike relocation to the north	Aim: agricultural provisioning services Advantages: – provisioning services due to agriculture How: no investments needed The capacity of the system to provide other types of services (regulation and support, cultural) is greatly reduced.

Ecosystem services provided by the Bistret area were evaluated and mapped according to the specific land use / land cover in line with the five different reconstruction scenarios (figure 20). As it can be observed the highest provisioning services capacity is scenario E, followed by B, D, C, A. As for regulating services the highest value is in Scenario A, followed by C, D, B, E. Cultural services have the highest values in Scenario A, followed by C, D, B, E (figure 19 and Table 15).

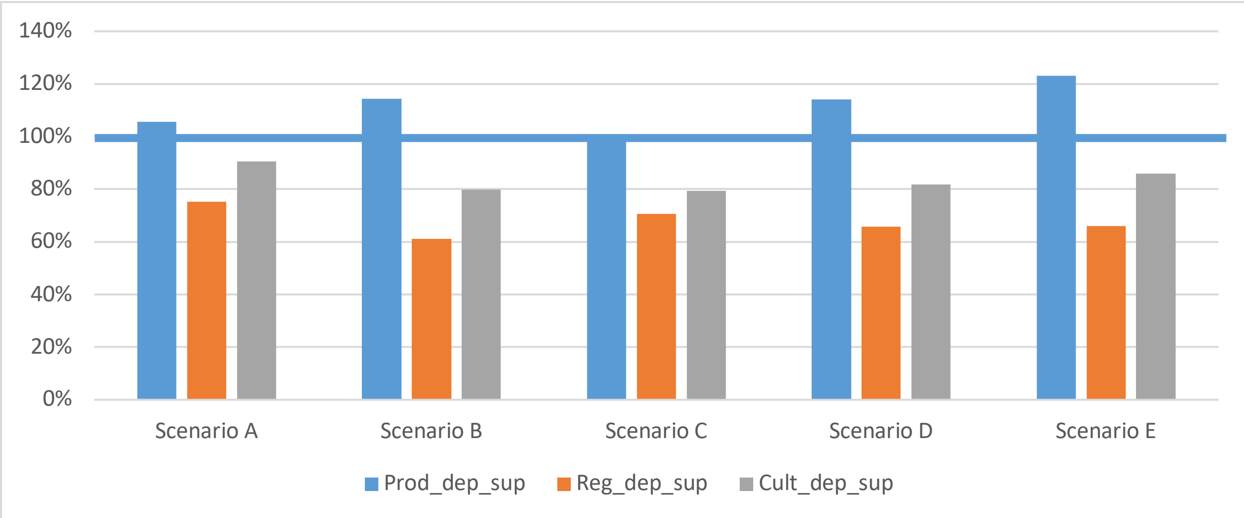


Figure 19 Dynamics of Ecosystem services potential (reference and reconstruction scenarios)

Table 15 Comparation between monetary valuation for scenarios using just wetland reconstructed area and the "conservative" value (1381 euro/year) provided by the stakeholders.

year/scenario	1900 (reference)	Scenario B (realist)	Scenario C (optimist 1)	Scenario D (optimist 2)	Scenario E (business as usual)
wetland area	19,088	2,944	9,178	3,737	2,066
Agricultural area	4,302	18,709	12,255	17,763	18,877
Total value/year based only on	1,006,668	4,377,906	2,867,670	4,156,542.00	4,417,218

agriculture area*					
Total value/year based on wetland	26,360,528	4,065,664	12,674,818	5,160,797	2,853,146
Total value/year	27,367,196	8,443,570	15,542,488	9,317,339	7,270,364

* the monetary value/ha estimated for cereals (market price) in a similar area (also on the Danube floodplain) is 234 euro (the market price does not account for direct and indirect cost related with production) (see Racoviceanu et al, 2021 in press)

Returning the area to the reference state is the most benefic in monetary terms as could be observed in table 16. The scenario C - the most optimist scenario is the one in which the monetary loss is diminished by half as compared with the reference. The added value from the agriculture could not be compared with the multiple ecosystem services that people could obtained in the reference conditions with wetland dominating the landscape.

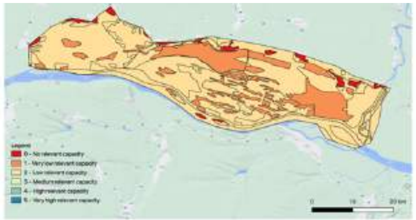
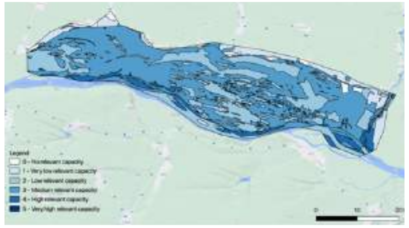
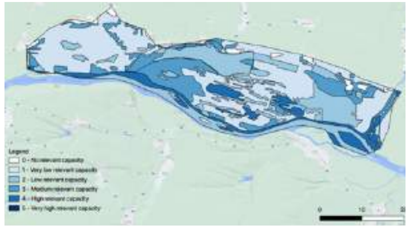
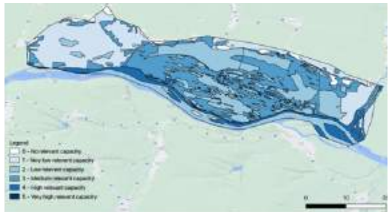
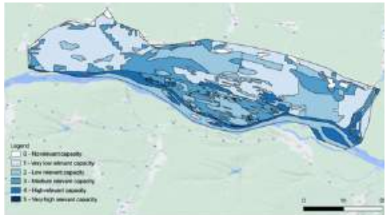
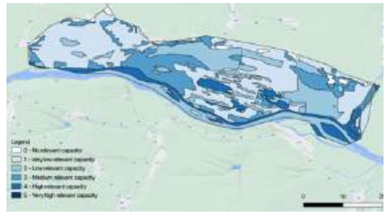
Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
 Provisioning services	 Provisioning services	 Provisioning services	 Provisioning services	 Provisioning services
 Regulating services	 Regulating services	 Regulating services	 Regulating services	 Regulating services
 Cultural services	 Cultural services	 Cultural services	 Cultural services	 Cultural services

Figure 20 Dynamics of Ecosystem services in five scenarios

3.8 CARBON STORAGE CAPACITY UNDER THE RESTORATION SCENARIOS

Besides the tangible ecosystem service provided by natural wetland landscapes previously described in the report, carbon sequestration service provided by wetlands have gained a lot of attention in the last years. Thus, for the Bistreț report, a special chapter is dedicated to highlight the complexity of the topic and to use the theories and methods available at this moment.

Wetlands act as carbon sinks and play a key role in climate regulation. They have been shown to be among the most important, cost-effective and efficient options for sequestering atmospheric CO^2 (Adhikari et al. 2009; Lal 2008; Lane et al. 2016; Mitra et al. 2005; Nahlik and Fennessy 2016; Villa and Bernal 2017; Yu et al. 2012) and have the highest soil carbon (C) density compared to other ecosystems such as forests and grass/shrub-lands (Kayranli et al. 2010; Villa and Bernal 2017; Zeng et al. 2014). With only 5-8% of the total land surface wetland are storing up to 35 % of the total 1500 gigatones of organic carbon stored in soils (Mitsch & Gosselink, 2015).

However, they are highly dynamic ecosystems and accurate determination of the ecosystem services they provide can be challenging and thus the current state of a wetland may not reflect its future trends or conditions (Odum, 1969, Mitsch and Gosselink, 2015, Villa and Bernal 2017).

Carbon stock in wetland ecosystems is comprised of:

1. carbon stock of wetland vegetation,
2. carbon stock of wetland soil,
3. aquatic carbon pool mainly including hydrophyte biomass, water body and deposit carbon stock (Zeng et al. 2014).

Carbon storage capacity and carbon sequestration is undoubtable a crucial ecosystem service provided by natural wetland ecosystems. Wetlands are able to store approximately twice the organic carbon load in comparison to cropland that is not tilled (Euliss et al. 2006), although the flooded wetlands generally sequester carbon dioxide and release methane to the atmosphere (Kayranli et al. 2010). Anyway, increasing wetland spatial extent is important for the increase of carbon amount that can be stored instead of being released in the atmosphere while reducing the amount of GHG.

The carbon storage capacity for the Bistreț case study area was estimated for each scenario present in the previous chapters. The calculations have been done for agriculture areas, wetland areas and water bodies following the three main components in C cycle process:

- carbon sequestration rate tC/t/year;
- primary production of biomass expressed into tC/t/year;
- soil carbon content tC/year.

The used input data are presented in the tables below, followed by the figures with the results for each foreseen scenario in Bistreț.

Table 16 Carbon sequestration rate

Wetland type	Carbon sequestration rate (mean value)	Citation
Permanent freshwater marsh*	143 g C m2 yr−1	Villa and Bernal 2017
Non-forested peatland	20 g C m2 yr−1	Villa and Bernal 2017
Freshwater tree-dominated	186 g C m2 yr−1	Villa and Bernal 2017
Temperate climate wetlands*	89.8 g C m2 yr−1	Villa and Bernal 2017
Temperate peatlands (in sediments)	10-46 g C m2 yr−1	Turunen et al. (2002)
Corn	55 g C m2 yr−1	West and Post 2002
Wheat	74 g C m2 yr−1	West and Post 2002
Crops (unspecified)*	48 g C m2 yr−1	West and Post 2002
*** data used in carbon sequestration under reconstruction scenarios**		

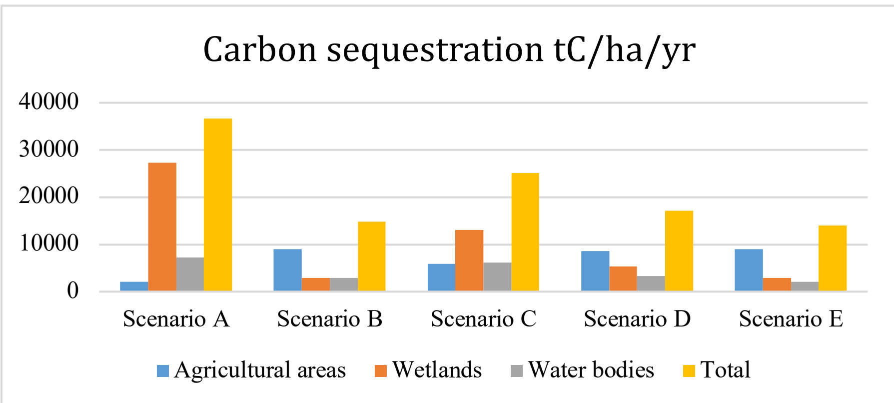


Figure 20 Carbon sequestration under the different reconstruction scenarios using the data for the temperate climate wetlands

Table 17 Net Primary Production (gC/m2/yr)

Ecosystem	Amthor et al. 1998	Racoviceanu et al. 2021, in press*
Forest, temperate and plantation	670	621
Grassland, temperate	350	188
Lake and stream	200	395
Wetlands	1180	700
Peatland, northern	-	-
Cultivated and permanent crop	425	457
Urban areas	100	429
*** data used in NPP estimations under reconstruction scenarios**		

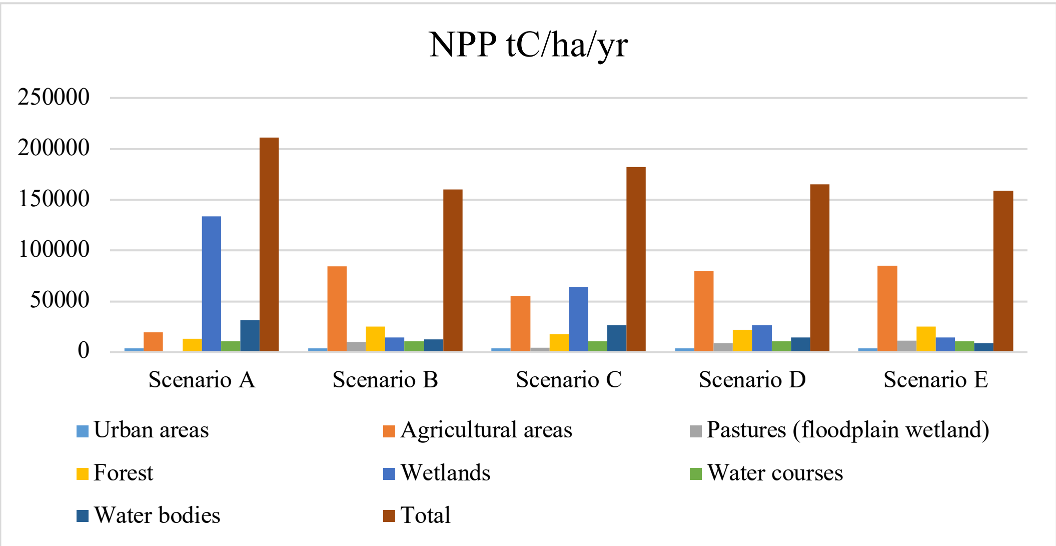


Figure 21 Biomass carbon content under the different reconstruction scenarios based on net primary production data presented in the table 17

Table 18 Soil carbon content

Ecosystem	Amthor et al. 1998 (gC/m2)	Nikolaidis and Adamescu unpublished data (tC/ha)*
Forest, temperate and plantation	12000	
Grassland, temperate	23600	
Lake and stream	-	
Wetlands	72000	481(+-36)
Peatland, northern	133800	
Cultivated and permanent crop	7900	224.16+-120
Urban areas	5000	
*** data used in Soil estimations under reconstruction scenarios**		

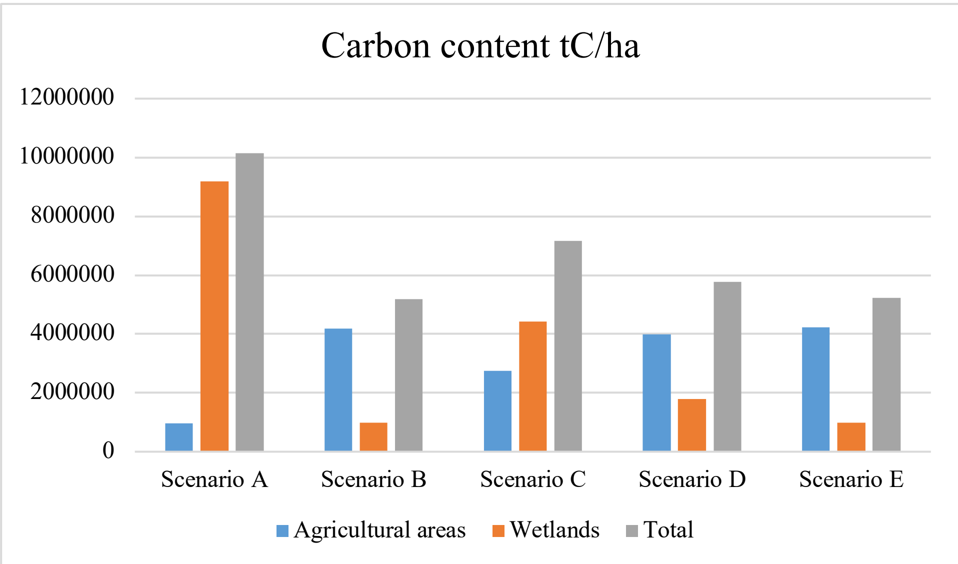


Figure 22 Soil carbon content under the different reconstruction scenarios based on relevant data presented in table 18

Estimating the storage capacity for the Bistret case study area shows that the full restoration of the former wetland area (Scenario A) has the highest impact in terms of carbon sequestration and primary productivity. Long-term investigation of carbon dynamics and cycling in restored and created wetlands is need in order to further advocate for wetland conservation and restoration.

The Carbon stock (tC ha-1) is highly variable depending on multiple factors (location, wetland type, flooding frequency, vegetation type etc). The carbon stocks are very high in the normal functioning wetlands with values reaching up to 481±36 $tCha^{-1}$ as compared with areas that have been transformed to agriculture (224.16±120.48 36 $tCha^{-1}$) and suffered C loss due to intensive exploitation. Even so the values for these areas are 10 times higher than the typical values found in agricultural soils. The values obtained by us are comparable with the results obtained by others (Nahlik & Fennessy, 2016). Nevertheless others have obtained even higher carbon densities up to 723 $tCha^{-1}$ (Post et al., (1982) .We are stressing that, in fact, this is a very conservative estimate given the fact that we have the Carbon stored in the first 30 cm and that the organic layer is over 2 m depth (at least in some areas).

4 CONCLUSIONS

This report included the key elements underlying the assessment of the benefits and ecosystem services provided by the natural capital components, considered for the analysis of the Bistreț area.

The present study addresses the issue of benefits and services provided by different categories of ecosystems, including wetlands, which are part of the Bistreț landscape structural configuration both in the reference situation before the hydrotechnical works and in the current configuration. The analysis is based on the elaboration of hypothetical scenarios in which the structural configuration and implicitly the functional one changes. The evaluation of the ecosystem services and benefits provided is done from this perspective, using different categories and sources of data and information.

Based on the methodology proposed by Burkhard et al. 2009 identified the main categories of ecosystem services, namely production, regulation and cultural services and the level at which they are provided based on the expert's opinion, taking into account the ecological integrity of the Bistreț ecosystem complexes for the reference ecosystem state, the year 1990, and current ecosystem configuration.

Five scenarios were elaborated in which different structural configurations of the Bistret area were proposed, respectively scenario A "restoration of the former Bistret wetland area to the landscape configuration prior wetland conversion"; scenario B " Bistret lake area will be increased "; scenario C "total restoration for water storage at high flows of the Danube"; scenario D " half of wetland area will be restored ", Scenario E "preserving the area with exclusively agricultural destination, as it is now".

The proposed ecological restoration scenarios were discussed and evaluated by local communities from the perspective of the ecosystem services provided. Local communities have shown openness in discussions, diversity of opinion and a desire to get involved in decision-making that concerns both the communities to which they belong.

The options of the local communities and stakeholders were different, but all of them opted for the ecological restoration of some types of ecosystems that existed before the damming of the Bistret area. No detailed elements related to the feasibility, technical or financial aspects of possible ecological reconstruction projects were addressed in the study or in the discussions with the local communities.

The local communities expressed their hope to reorganize the local economic system towards increasing social welfare by making more efficient use of the existing potential in the area. The results of this study could be used in discussions and debates on the development of investment projects or ecological restoration, for a sustainable development of the Danube floodplain.

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DANUBE FOODPLAIN PROJECT, WP 4.3:

HUNGARY: TISZA PILOT CBA

REKK

April 2020

DANUBE FOODPLAIN PROJECT, WP 4.3: HUNGARY: TISZA PILOT CBA

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Table of Contents

1 INTRODUCTION

This document is part of Interreg DTP project, "Reducing the flood risk by examining the restoration of flood plains in the Danube river basin". It belongs to Work package 4.3 (Cost Benefit Analysis of Pilot areas integrating ESS). It contains the extended Cost-Benefit Analysis of the Hungarian partner, the Middle Tisza pilot case study, focusing on the dyke relocation project at Fokorú puszta on the river Tisza floodplain (KÖTIVIZIG, Middle-Tisza Case).

The document describes the main features of the dyke relocation project in chapter 2, necessary to acquire a good background to understand the analysis. The area's ecosystem services were collected and structured during the Work Package 4.2 phase of the project (The 23rd January 2019 stakeholder workshop in Szolnok, organized by KÖTIVIZIG, Szeged University and WWF Hungary, and further elaborated by CUEI). The summary of the findings that served as a starting point of the ESS-CBA analysis is in chapter 3. The subsequent chapters show the results of the ESS-CBA analysis integrated into the decision support structure and the use of the ESS-CBA Module.

This document applies the methodology to the extent made possible by data availability - ESS-CBA DECISION SUPPORT MODEL AND METHODOLOGY (2020) that was developed under the same work package. The CBA calculations of the Middle Tisza case are supported by an MS Excel based tool, The Danube Floodplain ESS extended Cost Benefit calculation and impact structure Module. Two version of the Module are supplied: 1) a blank file without case specific data and 2) a file with the Middle Tisza pilot case study data.

In our judgment the pilot site calculations proved the usefulness and the practical applicability of the methodology that follows a decision flow approach the extended CBA analysis is a part of. The sustainability analysis phase was conducted on a simpler dataset than what the methodology deemed suitable in order to grasp the most important dynamics of ecosystem service asset change. We are convinced that the right way ahead in this aspect is the improvement of the information supply, not the change of the methodology. The post CBA element of the decision flow, the structuring of the stakeholder group impact also proved a useful method to make the results understandable.

2 DESCRIPTION OF THE DYKE RELOCATION PROJECT

In the middle of Hungary, north of the city of Szolnok, a section of the current dyke will be relocated in order to give more space to the river and achieve multiple benefits as described in this document. Figure 1 below illustrates the project. The location is about 10 km upstream of the city of Szolnok, the biggest settlement in the area, which has the highest flood risk exposure along the Middle Tisza.

Figure 1 The modelling area including the dyke relocation project

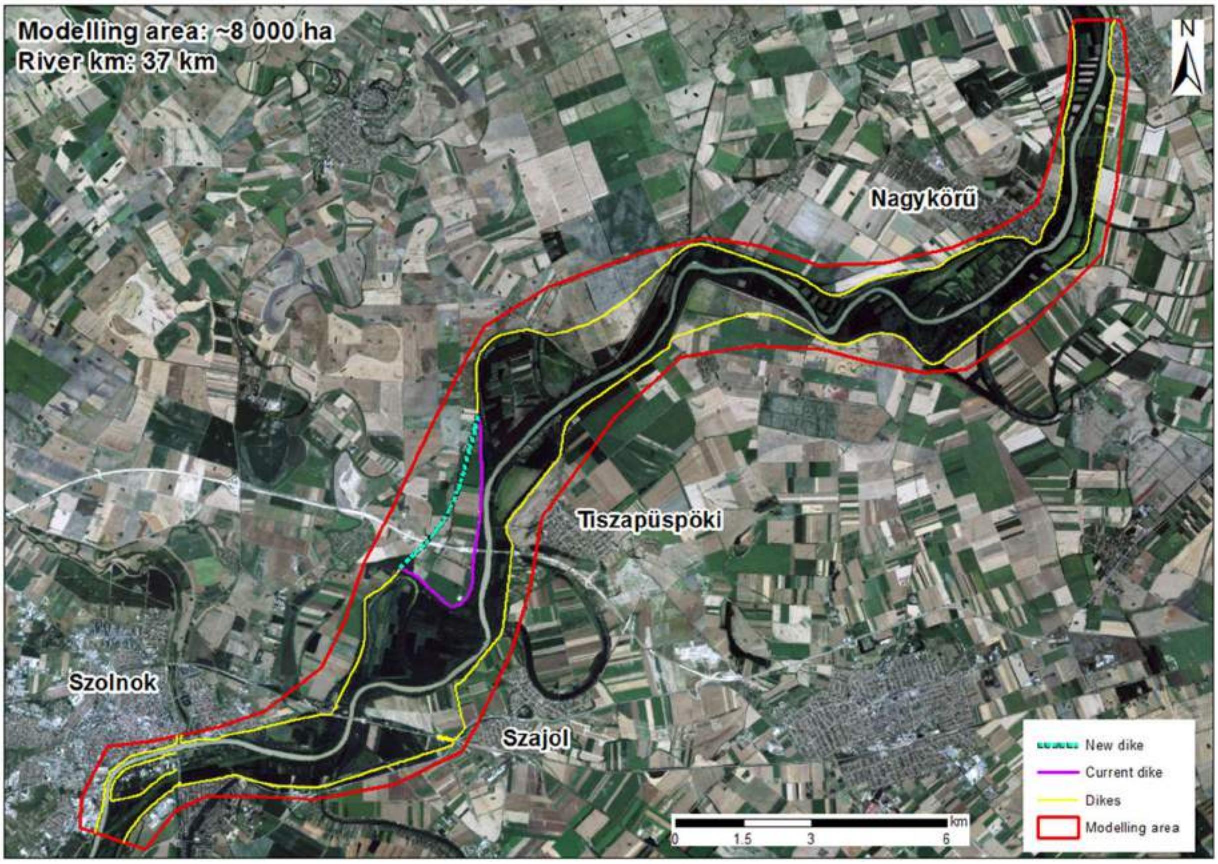
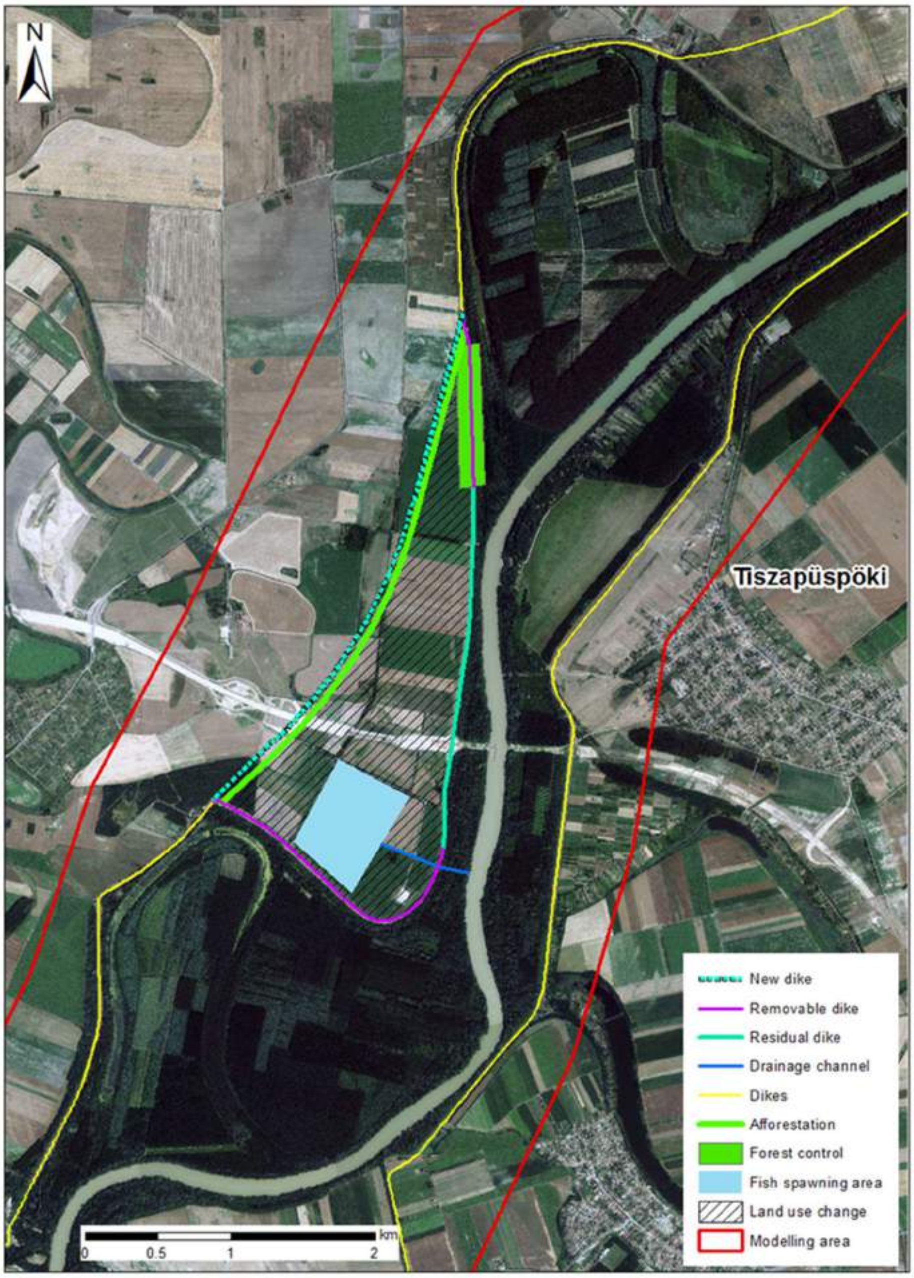


Figure 2 below provides more detail on the project. The shaded area is mainly cropland today. It is being purchased from its private owners and most of it will be turned into meadows, with a strip protective forest and a fish spawning area making up the rest of the purchased land. The fish spawning area will be connected to the river bed through a drainage channel. Part of the original dyke is removed, but the northern section is left in place, while a new dyke is erected west of the river, on its right bank. The total area that is added to the floodplain measures 325 hectares.

Figure 2 Key features of the dyke relocation project



The newly added floodplain is expected to be flooded about 10 percent of the time, although, as Figure 3 shows, there is a substantial interannual variability. We can also observe in Figure 4 that most of the flooding affecting the area takes place during the spring while the area essentially stays dry during the autumn.

Figure 3 Number of days when the newly annexed floodplain would have been flooded in given years

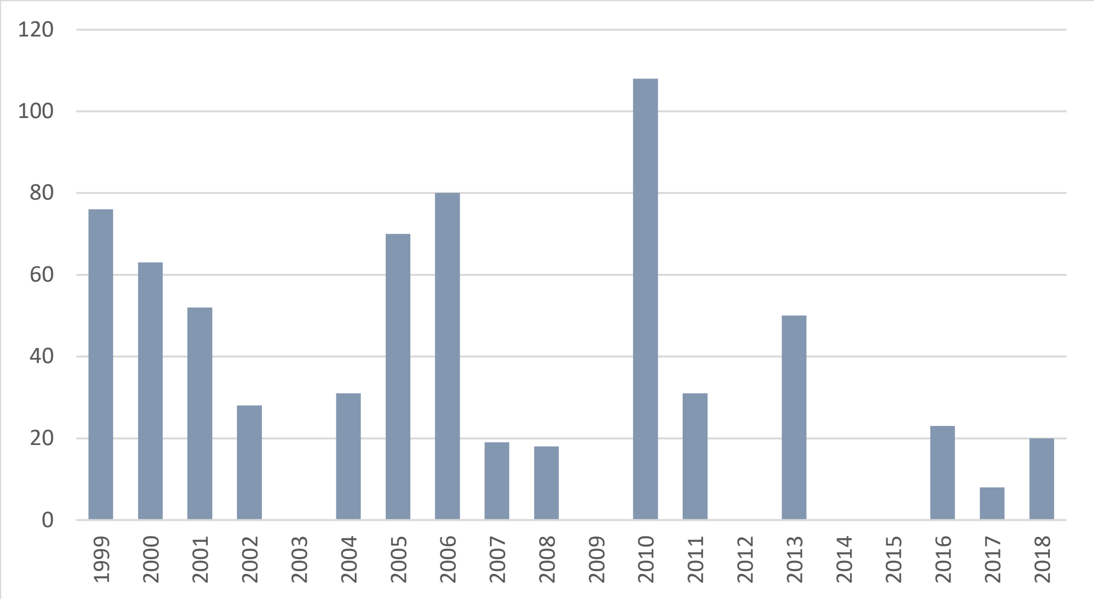
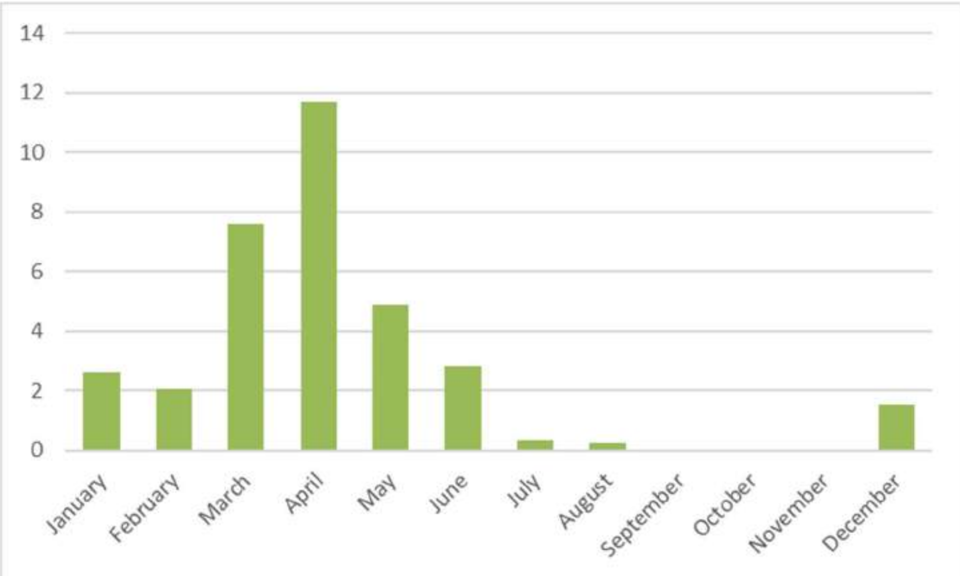


Figure 4 Average number of days in each month when the newly annexed floodplain would have been flooded between 1999 and 2018



3 RESULTS OF THE STAKEHOLDER WORKSHOP ON ECOSYSTEM SERVICES

On 23 January 2019 a stakeholder workshop took place in Szolnok, organised by KÖTIVIZIG, Szeged University and WWF Hungary, to assess the perceived changes resulting from the dyke relocation project. In this chapter we go through the main findings of this meeting and discuss how we handle specific ecosystem services and other land use related consequences within the study (Table 1). We supplemented the stakeholder consultations with a number of expert and stakeholder interviews to fine-tune our understanding of specific aspects of the dyke relocation: Lipták (2019), Katona (2019), Ficzere (2019), Právetz (2019), Horváth (2019), Lovas (2019), Vizi (2019), Járvás (2019), Tarkó (2019).

At the stakeholder workshop the assessment of ecosystem services took place in three groups, identified by colours: blue, green and red. The groups assessed the level of the ecosystem service in the pilot area before and after dyke relocation. A scale of 0 to 5 was applied, 5 indicating a high level of service. If a team could not agree on an actual score, they could still signal the direction of change, indicating it with an arrow. Additional comments are also included in Table 1, and we also indicated how / if we evaluate the given ecosystem service within the analysis.

Mainly based on Table 1, Figure 5 below reviews those ecosystem services that resulted in significant changes caused by the analyzed interventions the impact of which is compared between the scenarios (The significance of the changes were judged by REKK). Ecosystem services the value of which can be monetised, are described and evaluated in subsequent chapters. Ecosystem services that cannot be monetised within the current research due to lack of data, uncertainties or the feature of the service, are inspected in Chapter 11.

Figure 5 Ecosystem services significantly affected by the dyke relocation

Ecosystem service change that is monetised	**Ecosystem service change that is not monetised**
• Flood risk reduction (Chapter 7) • Greenhouse gas sequestration (Chapter 8) • Agricultural crop production (Chapter 9.1) • Fish spawning (Chapter 9.2) • Grass production on meadows (Chapter 9.3)	• Biodiversity • Habitat for various species, more robust fauna and flora • Lower pollution • Timber production • More hunting and more game meet • Increased water infiltration into the soil, ground water recharge • Micro-climate regulation • Increasing recreational, sport, hobby and educational activities • Beekeeping

Table 1 Assessment of ecosystem services at the stakeholder workshop and additional observations

		Blue Team		Green Team		Red Team		Comments from the workshop / **Handling of the service within the CBA**
		Before	After	Before	After	Before	After	
Provisioning Services	Agriculture			2	0	2-3	↑	crops not known, cover 80% of the area of the floodway channel on the protected side / **Cropland is turned into meadows and forest, agricultural production will decline. On the other hand, farmers receive a decent price for their land, enabling them to pursue other farming activities. This item is not assessed separately**
	Cereals					5	0	
	meat production			2	↑	?	2-3	Pastures (with livestock) / **There is a possibility for increasing meat production through grazing, but as we learned from KÖTIVIZIG, there is not much demand for the rental of grassland for grazing purposes**
	meadows (greenland)			2	↑	2-3	↑	**/ about 270 hectares of cropland replaced by meadows**
	gardens of weekendhouses, fruit orchards	2	-	2	-	2	↓	
	Vegetables	2	-	2	?	2	↓	
	timber/fire wood production			4	-	2	-	managed by NEFAG?, also for paper mill (wrapping paper), fire wood **/ Timber production from new afforestation has a life cycle of about 60 years, revenues from timber are not relevant in the near future**
	fish production (aquaculture + fishery)			5	↑	4	↑	commercial fishing forbidden, just selective fishing for ecological purposes, aquaculture, fishery **/ No change due to the project, no need to assess it. For angling and sport fishing see further below.**
	hunting			?	↑	3	↑	Game meat, dear meat, roe deer meat. Rabbit meat, pheasant meat **/ As the size of natural area increases, more wild animals are likely to be present. Due to lack of data, the value of this change is not estimated**
	hay, straw			2	?	4-5	0	grazing/pasturing increasing, hay harvesting consistent **/ More hay can be harvested but it is difficult to sell it at a cost-covering price. A rough estimate of costs and benefits is provided**
	Oil well			0	0			unused/not cultivated

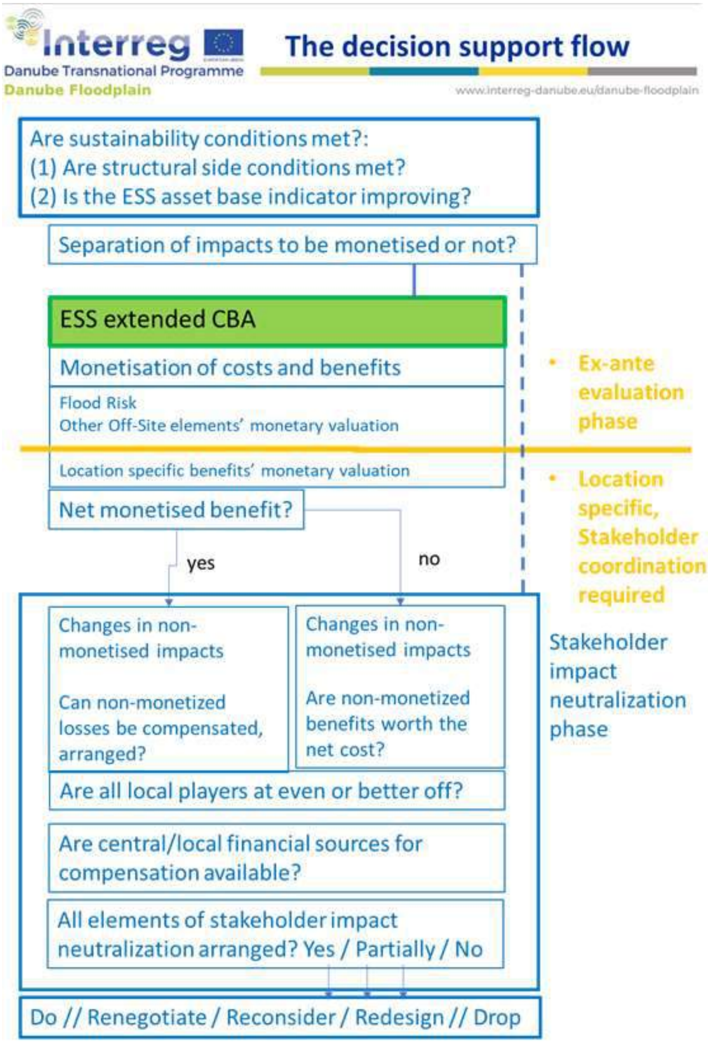
	Drinking water supply			5	-			supply for Szolnok **/ The project will not impact the drinking water supply, therefore this service is not assessed**
	water supply for industry			4	-	4	-	corn processing factory in Tiszapüspöki / **The project will not impact the industrial water supply, therefore this service is not assessed**
Regulating Services	(primal) forest and its regulating functions			3	↑	?	↑?	sinking CO_2, evaporation, regulating microclimate, cleaning the air **/ The shift in carbon balance and its value is estimated. Microclimate regulation is not, due to lack of data.**
	retention volumes			5	↑			draining floods **/ Flood risk change due to altered river morphology is estimated**
	Soil production					1-2	3	**/ Under meadow and forest management there should be an improvement or at least no deterioration**
	Sediment regulation in floodplains					4	-	
	waste water/nutrient retention: Tiszapüspöki	4	-	5	-	2	↑	all washed into the groundwater, biochemical detoxification/decomposition/mineralisation of pollutants in soil/water, biological filtration/sequestration/storage/accumulation of pollutants in soil **/ Due to land use change, less fertilisers will be applied which reduces nutrient transport volumes. The value of this change is not assessed as we do not have adequate information.**
	waste water/nutrient retention: Dobapuszta			5	-			
	waste water/nutrient retention: weekendhouses			2	-			
	waste water/nutrient retention: M4 motorway construction			0	0			
	waste water/nutrient retention: Fertilizers			2	0			
	provisioning of habitats for juvenile fish / spawning area			4	↑			in the Kovácsi Oxbow, increasing the fish stocks (carp, pike, perch, bream), better conditions on the right side than on the left **/ Due to the to be created fish spawning area, related costs of fish stock replenishment can be saved**
	Provisioning of habitats			4	↑	3	↑	especially fish, birds (nesting and migration), beaver **/ As over 300 hectares of cropland is converted into more natural land use, habitat will sustain an increased fauna and flora. The corresponding value is not analysed due to lack of data and methodological difficulties**
Cultural Services	recreational/sport fishing			5	-	4	↑	angling in oxbow **/ Not only can fish stock replenishment costs be saved, but an increased diversity of fish species will be available for sport fishers. This additional feature is not evaluated within the project.**
	aquatic sports	5	-	4	-	4-5	-	Beach at Tiszapüspöki **/ Unlikely to change due to the dyke relocation**

	recreation					3	↑	**/ More natural areas may entice more people to spend increasing recreational time in nature. However, due to lack of data this feature is not analysed**
	boats			3	-			**/ Unlikely to change due to the dyke relocation**
	cycling			2	↑	2-3	↑	no pavement on the dyke, in case in future -> tourism may grow, big potential **/ This is a future possibility which may or may not be fulfilled, therefore it is not assessed within the current study**
	hiking/jogging			2	↑	2-3	↑	**/ Unlikely to be affected, as the location is too far from the settlements**
	hunting			3	-	3?	↑	**/ As a result of an increasing number of wild animals due to more natural territory, the value associated with hunting may increase. Because of lack of data, we do not assess this service.**
	educational function			3	↑	3	↑	awareness-raising = IS **/ The project offers the option of educational activities. We do not evaluate this service**
	Excursion Ship Victor Hugo			2	-			periodically **/ Not related**
	cultural events			0	0			maybe PET Cup Waste Collection Action **/ Minimal relevance**
	weekendhouses	5	-	2	-	3-4	-	**/ Not allowed in the floodplain and the settlements are further away**
	bird watching			3	?			**/ More natural areas with more birds may entice more people to spend increasing time bird watching here. However, due to lack of data this feature is not analysed, and bird watching is not too widespread in rural Hungary**
	photographing	3	-	3	?	de?	3-4	**/ More natural area lends itself to more people taking photos, however, this feature will have minimal relevance here due to distance from settlements**
	mushrooms					1-2	↑	for private use **/ Possibly more mushroom picking than previously. Not evaluated due to lack of data.**

4 THE DECISION FLOW

The methodology document that was prepared parallel with this case elaboration developed the below the decision flow protocol. It is intended to support the realization of comprehensive, ecosystem service approach extended flood risk mitigation investments. In the subsequent chapters of this document the elements of this decision support analysis are elaborated for the Fokorú puszta dyke relocation case study. Chapter 5 examine the sustainability conditions, the extended CBA analysis cover the chapters from chapter 6 to chapter 9. Chapter 9.4 discuss the status of the non-monetized benefits. Chapter 11 summarizes the findings and calculations in a format that structures for the main stakeholder groups the financial and non-monetized impact of the intervention to prepare the scene for the necessary arrangements and highlight the potential conflicting points with the broad financial terms for reaching resolution. This last two chapters belongs to the phase, what the decision flow name as "Stakeholder impact neutralization". This process can set the scene for the development to step ahead.

Figure 6 The decision flow



5 ARE SUSTAINABILITY CONDITIONS MET?

Sustainability conditions are analyzed from two aspects: "Are structural site conditions met?" and "Is the ESS asset indicator improving?"

5.1 STRUCTURAL SITE CONDITIONS

In case of the structural site conditions the following four aspects are investigated:

- The continuity or connection of natural areas that make animal and plant species migration possible are not destroyed. Or, even better, new connections are developed.

The wider floodplain, the partial removal of the former, existing dyke, and the new spawning area (potential wetland) with no disturbance along the riparian lines are the elements that ensure that the condition is met.

- The size of open water surface area and the length of the shoreline doesn't decrease.

There will be newly created water surface, the river shoreline doesn't decrease. Besides the new spawning area, the relief of the meadow (the new area in the active floodplain) will maintain temporary water covers if the area is inundated during the floods.

- Heterogenity of the area's land use pattern is increased or stays constant.

Crop lands are transformed to meadows, forests and the spawning water body; moreover the use of the former dyke as savior hill for wild animals during flood. This pattern condition is also satisfied.

- The size of non-cultivated (natural) areas doesn't decrease and the area doesn't fragment

The size of the non-cultivated area increases, contiguous grassland area will be created with forest patches.

The changes meet all the requirements of the structural site condition.

5.2 IS THE ECOSYSTEM SERVICE ASSET BASE IMPROVING?

This sustainability condition consists of two aspects. The concept of the indicator is developed and described in the connecting methodology paper. This chapter shows the results and in the annex of the case study the application of the methodology is detailed, the available data sets are described reflecting to the possibilities and limits they provided.

- Compared to the water resource allocation efficiency of the baseline situation, REF(t0) to the change in allocation efficiency, REF(t1) what the floodplain intervention caused will describe the direction of change in the ecosystem service asset base. If the REF(t1) / REF(t0) ratio is higher than 1, there is a positive change in the Ecosystem Service Asset Base, the condition is met. If the ratio is below 1, there would be a decrease in the Ecosystem Service Asset Base, that requires the redesign of the details of the intervention.

The water resource allocation efficiency is the part of the indicator set that describes the cumulative functional ecosystem performance of the investigated area. The indicator reflects on how successfully the vegetation can transform the available water resources (on an annual basis) to transpiration beyond the readily available precipitation volumes.

The two figures below show the changes in the hydrological water balances of the case study area due to the dyke relocation and land use change.

Figure 7 Hydrological water balance of the initial status in the case study area

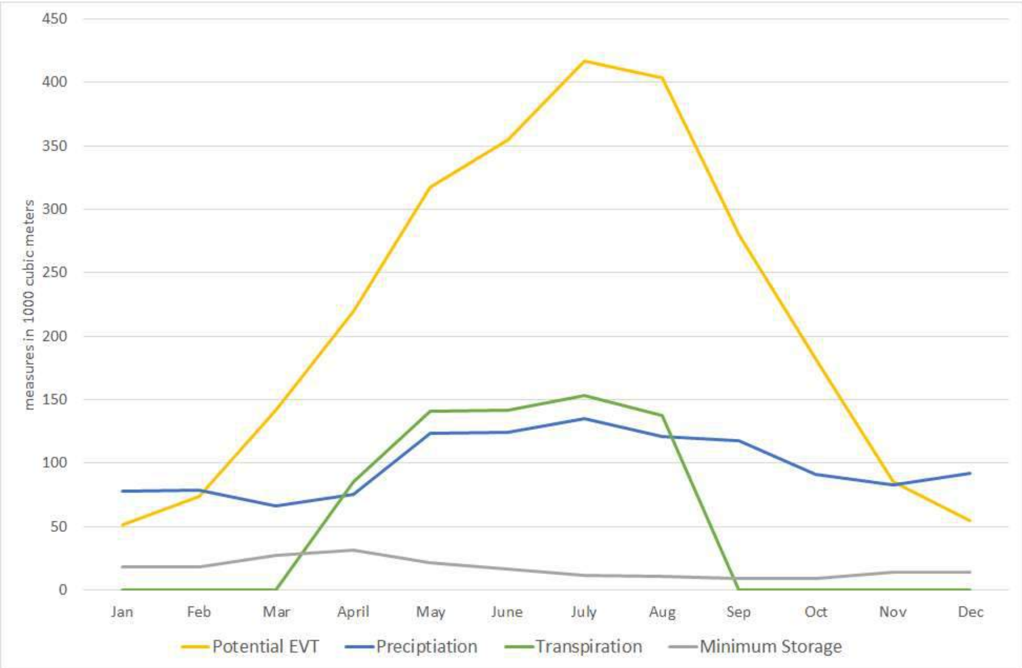
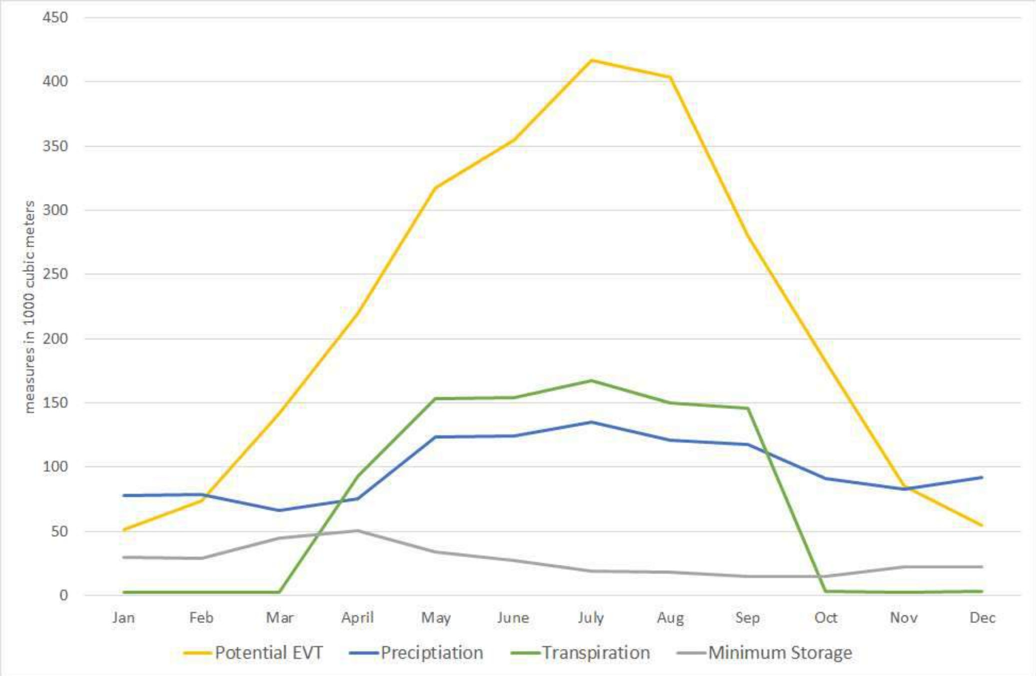


Figure 8 Hydrological water balance after the intervention in the case study area



Each figure represents the allocation efficiency status. The area between transpiration and the precipitation curves when the transpiration value is higher means the successfulness of water storage from the annually available quantity. In these two figures the available quantity is substituted for technical reasons (described in annex 14.1) with a storage quantity that shows a minimum estimation for the infiltration volumes. The difference in the two figures show that due to the interventions the infiltrated quantity and the transpired quantity also increased. In Figure 7 the vegetation period transpiration is 80 thousand m^3, while the minimum estimation for infiltration is 205 thousand m^3, thus the allocation ratio is 39%. In Figure 8 based on 166 thousand m^3 of vegetation period transpiration and a minimum of 329 thousand m^3 infiltration, a 50% ratio is calculated that shows a better status in itself, but for an equal basis comparison the rate of increase in excess transpiration is higher than the rate of increase in infiltration (2.08/1.61=1.28). This reveals a water allocation efficiency increase. The natural foundations of the ecosystem service asset base is considered as improving.

- Is soil loss prevented on the area? In case of natural, constant cover vegetation it obviously is. In case some kind of cultivated area covers (partly) the site, then it depends on the cultivation method, whether that disturbs the soil or not.

The crop land to grassland and forest transformations result in constant soil cover that feature in a flat terrain provide protection against soil loss. The long term land management practices will determine whether soil accumulation can take place. But with the land use transformation at a minimum the soil loss is prevented.

Sustainability from an ecosystem service asset base perspective is met.

6 MONETISED UP-FRONT COSTS

The dyke relocation project requires substantial up-front investments, as detailed by Table 2. Most of the costs are associated with construction activities, especially the demolition and reconstruction of dyke segments, the development of the fish spawning ditch in place of the mine used for the extraction of construction materials, and the reconstruction of a high voltage electricity transmission line. Purchase of land from private owners is also a sizeable expenditure, although not nearly as high as the construction related expenses.

Table 2 Upfront costs related to the dyke relocation

Measure	Upfront costs (million HUF)	Upfront costs EUR* (million)
Dyke construction	2,200	6.76
Demolition of the old dyke	400	1.23
Afforestation of protective forest	70	0.22
Recultivation of mine for construction materials, development of fish spawning ditch	750	2.31
Reconstruction of the high voltage line crossing the river	600	1.84
All other non-itemised initial cost	700	2.20
Acquisition of land from private owners, price paid for 325 hectares of land	540	1.66
Transaction costs related to the acquisition of land (Surveying, legal expertise, appraiser, dedicated manpower within KÖTIVIZIG)	21	0.06
Total	5,281	16.23

Source of information: Kötivizig (2019); * Using the 2019 average HUF/EUR rate (1€=325.30 HUF).

There is an additional cost item that is excluded from the above calculations. In case agricultural land is withdrawn from cultivation, a fee needs to be paid to the government. Part of this fee is returned when, after the investments are concluded, the land is classified as meadow or forest. Still, altogether, about HUF 100 million (=307.000 EUR) of net payment is expected. Since the project owner, KÖTIVIZIG, is a government authority, this transfer takes place within the government, and as such, we do not consider it to be a valid cost item.

7 MONETISED FLOOD RISK REDUCTION

The areas along the Hungarian section of the river Tisza (that belong to the river's morphological floodplain) are protected by dykes. Dykes alone, however, are not always sufficient to ensure protection for these areas. Large floods require additional (just in time, top of the dyke) defense operations, and a catastrophe may also occur in case a dyke fails or its height is not sufficient to hold the water, and the protected areas are flooded. These are the two main types of costs associated with large flood events from a flood defense perspective: the costs of defense operations and catastrophe damage in case a catastrophe takes place.

In order to reduce the risk of a flood catastrophe, flood defense development projects are regularly implemented by governments. These projects may consist, for example, of strengthening or raising the dykes, investing into peak flood polders, ensuring smoother water flow in the river bed or giving more room to the river via the relocation of dykes, or reconnecting swathes of land of the morphological floodplain to the active floodplain for flow mitigation.

To judge the cost effectiveness of investing into and operating peak flood polders, a hydrologic simulation based economic decision support model was developed within the "Coordinated peak-flood polder management on the river Tisza" project (Tisza Üzemirányítási projekt, 2017-19). While the original model was designed to assess the economic viability of peak flood polders, it was now amended to be able to inspect the economic benefits of the Fokorúpuszta dyke relocation project.

The core idea behind our analysis is that the changed river morphology will alter the behaviour of flood waves, thereby requiring a different level of defense operation and altering the risk of a catastrophe. The economic model is based on the relationship between water levels, defense costs and the probability of dyke failure. For any given flood wave we are comparing two scenarios: how the flood would move along the river under the original and the new, altered river morphology, when more space is available for the water. These scenarios are hydrologically simulated in HECRAS and the hydrological results are converted to become an input for the economic model. From this perspective any, above mentioned intervention that modifies the features of the flood-wave can be measured (or compared to each other) that how beneficial their impacts are on flood defense from an economic perspective.

Even relatively benign floods (with return periods of 2-5 years) require some flood defense preparations, such as the daily inspection of the condition of the dykes, while higher floods tend to demand growing efforts, such as reinforcing the side of the dykes or piling sand bags on top of the embankment. Within the economic model the relationship between flood characteristics and defense operation costs along the dykes was derived from a regression analysis of historic flood defense data from the river Tisza and its tributaries between the 2000-2013 period. The input data of the cost estimation comprised the physical characteristics of the flood waves (peak water level of the flood, the number of days under stage three defense alert, the length of the defended dike section) and the flood defense activities taking place during the analyzed period officially characterized as "extreme level" defense. The resulting statistical relationship was reliable, with a relatively large standard deviation.

The economic model also depicts the connection between flood events and catastrophe damages. This relationship was to a large extent formulated based on the ÁKK (Árvíz Kockázat Kezelési projekt – Flood Risk Management project) database, created by the flood risk mapping project triggered by the EU Flood Directive[1]. The ÁKK project surveyed all dykes to identify the most vulnerable dyke sections, which were called „rupture sections". For all these sections the water level was determined at which static problems may start occurring. Within the economic model – based on consultations with the engineers of the ÁKK project – a water level based dyke failure probability function was generated for all rupture sections. Higher water levels thus translate into a higher probability of catastrophe. If high water levels stay for an extended period, then the value of this probability further increases. The ÁKK project also assessed the areas that would be flooded if the dyke at a given rupture section fails, and how much damage would register in this case. All of this information is incorporated into the economic model.

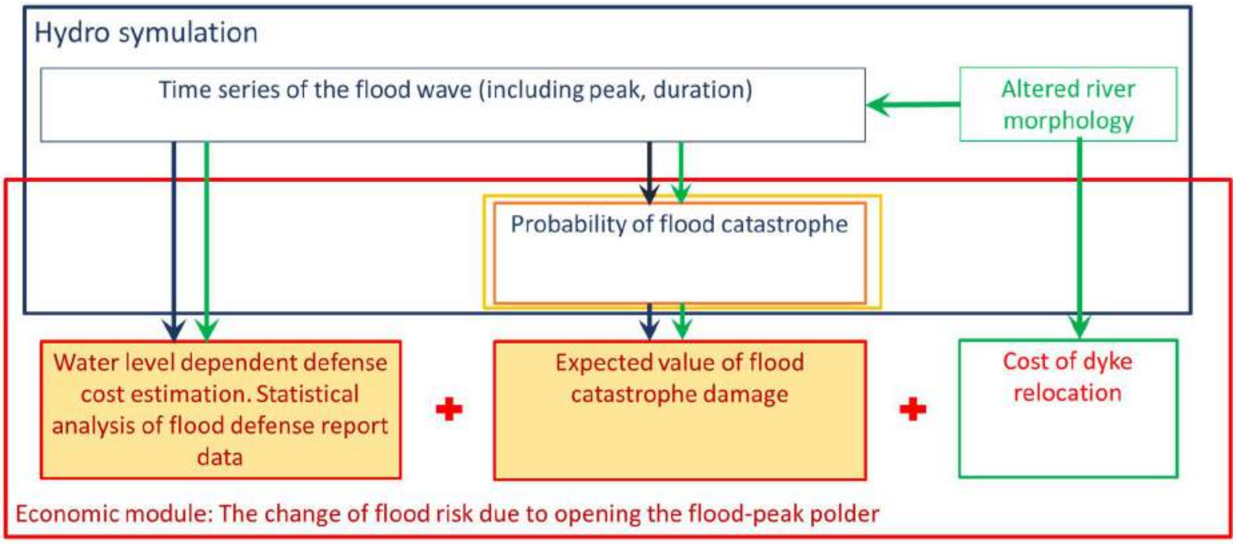
The economic model is a Monte Carlo simulation based probabilistic model. The main reason for applying the Monte Carlo approach in this case is that the dyke rupture and the resulting flood catastrophe is a small probability event, but one that comes with a huge economic loss. Simply looking at the average case – in which no catastrophe takes place – is misleading. A flood wave is better depicted by the expected value of the full event horizon, which also includes the probability of a catastrophe. The full event horizon can be rather complex. Even a short river stretch may contain multiple rupture sections, and once a section breaks the water level within the river bed drops, thus a second dyke rupture cannot happen. Moreover, a dyke breach may happen at different water levels (with increasing probability at higher levels), implying that the flooded area is also different, and so is the corresponding damage. To be sure that the majority of the event horizon is captured, each model scenario needs to be run at least 10,000 times.

The connection between the hydrologic simulation and the economic model is depicted by Figure 9 below. The hydrologic simulation (blue rectangle) generates flood time series data for each river section. Using this data the economic model (red rectangle) determines if a dyke failure (=catastrophe) has taken place or not. In case of a catastrophe, the corresponding damage is calculated based on the flooded area and the land use / damage profile of that area. At the same time, the defense costs are also estimated using the flood data and the built-in statistical relationships. This model is run a large number of times, and the results will differ based on the risk of flood catastrophe.

The models need to be run for both the baseline scenario and the altered river morphology reflecting the relocation of the dyke. By comparing the expected total cost of the two scenarios it becomes possible to conclude if the dyke relocation has generated net benefits in terms of lower overall flood related costs.

[1] There are some disagreements between the case study project partners retroactively about the suitability of the risk assessment results of the ÁKK project to serve as a common ground of understanding of further strategy development, because they differently evaluate the appropriateness of the ÁKK project's public participation process and the spatial coverage of the risk maps. Maintaining their disagreement, they acknowledge that the data, the project acquired from the ÁKK database is the best available information and suitable for the purpose of the CBA analysis.

Figure 9 Illustration of the connection between the hydrologic simulation and the economic model



Note: in our analysis we refer to the damages from flooding as a type of cost, and defense operations and dyke relocations are also costs. Thus the expected value of damages are a part of the total costs.

The above process is applicable to a specific flood, and the results will show the flood related benefits of dyke relocation for that one specific flood event. However, the dyke relocation is supposed to generate benefits not only for a single flood event, but for an extended time horizon. Therefore, it makes sense to look at a long time horizon (e.g. 100 years) and consider all the possible floods that can take place during the period. Alternatively, we can look at the annual probability that specific floods will occur. Floods are defined by their "return period", which is the estimated average time between events. A 10 year flood, for example, is a flood with a peak water level that has a 1/10=10% chance of being exceeded in any given year. In a similar vein, a 50 year flood has a 1/50=2% chance of being exceeded in any given year.

We can compute the annual expected cost of floods if we simulate floods with different return periods, compute the cost associated with each flood, calculate the annual expected value of each flood by multiplying its cost (including damage and defense) and the probability that the flood would occur in any given year, and finally sum all of the annual expected values to arrive at the cost of the full event horizon (all possible floods). If we wish to see the impact of the dyke relocation, then we have to repeat this exercise with the flood wave modified due to the new river morphology. This is exactly what we did to see the impact of the Fokorúpuszta dyke relocation on flood related costs. Our results are summarised in Table 3.

Table 3 The impact of the Fokorúpuszta dyke relocation on the annual expected cost of floods

		Cost of flood event, based on the economic model (million HUF)		Annual expected cost of flood event (million HUF)		
Range of return period (year to year)	Probability of flood	Current river regime	After dyke relocation	Current river regime	After dyke relocation	Difference
0-10	0.9000	0	0	0	0	0
10-30	0.0667	2,437	2,442	162	163	0
30-50	0.0133	25,749	23,461	343	313	-31
50-100	0.0100	69,710	62,917	697	629	-68
100 and more	0.0100	91,704	82,707	917	827	-90
All floods together	1.0000			2,120	1,932	-188

Note: Flood risk is frequently interpreted as the annual expected damage. In this analysis costs include more than just the damage, they also include the cost of defense operations, which are executed with the intention of avoidance (expected reduction) of the damage. The annual expected cost (2120 and 1932 million HUF) is therefore the flood risk adjusted with the expected flood defense cost.

For the return period a range has been provided. For example, in case of the 10-30 year return period both a 10-year and a 30-year flood has been simulated, and the average cost of the two floods were used for the analysis.

As the table shows, small floods, with return period of less than 10 years, do not generate costs. In case of floods with a return period between 10 and 30 years, the relocation of the dyke does not meaningfully alter the level of flood related costs. For all larger floods the dyke relocation reduces the cost of the flood. In terms of annual expected costs, the total benefit of dyke relocation is 188 million HUF. Most of this gain originates from the rare, but extreme flood events that happen less frequently than once in 50 years.

8 MONETISED GREENHOUSE GAS EMISSIONS AND REMOVALS

In this chapter we look at changes in greenhouse gas emissions (GHG) and carbon sequestration, as an ecosystem service generated by the project. We assess the GHG impacts of land use change, but disregard the emissions arising from construction activities during the dyke relocation due to the lack of available data on related resource use, such as fuel consumption.

8.1 CASE STUDY LAND USE CHANGE AND ITS ANNUAL GHG BALANCE

Due to the relocation of the dyke, 325 hectares of land is affected. The overwhelming majority of this land was cropland originally, with small fragments of forest, pasture, artificial land cover, or reeds (less than 1% in each category). For the purpose of our analysis we assume that all of the affected land was used for crop production. The new land use will consist of 270 hectares of grass land (meadow), 35 hectares of fish spawning area and 20 hectares of forest.

For the purpose of Danube Floodplain climate analysis the TESSA toolkit has been recommended. The TESSA toolkit makes further reference to the Tier 1 methods of the Intergovernmental Panel on Climate Change (IPCC). However, even those methods require data that is not readily available, therefore we relied on other, even further simplified calculations, which, on the other hand, are also based on the IPCC methods.

We made use of the National Inventory Report for 1985-2016 (NIR, 2018) and its Annexes submitted by Hungary to the UNFCCC. We divided the total sector and land use specific GHG figures by the corresponding land area published by the Central Statistical Office of Hungary. We received average GHG figures per hectare. These results are Hungary specific, though there is some variation of the carbon balance of different land use locations even within the same land use category, which makes our results less precise compared to strictly following the IPCC Tier 1 methods.

According to NIR (2018) croplands sequestered 379 kt of CO_2 in 2016. This figure, however, is misleading since activities on cropland (e.g. cultivation with machines, application of fertilisers, pesticides, manure) represent an important source of emissions. Total agricultural emissions, in 2016 reached 6878 kt of CO2e (CO_2 equivalent), the most important components of which include enteric fermentation, manure management and agricultural soils, the latter is related to the use of fertilisers. If we add emissions from agricultural soils (3472 CO_2e in 2016) to the sequestered CO_2 then we receive 3093 kt CO_2e of net emissions. Dividing this figure with the 2016 croplands of 4,332,400 hectares, a unit emission figure of 0.714 ton/hectare/year appears. This is the figure that we will continue to use.

In 2016 there was 783,200 hectares of grassland in Hungary, while the corresponding net emission figure from NIR (2018) is 14 kt of CO_2e. Therefore there is a unit emission of 0.018 ton/hectare/year. The fish spawning area is essentially a low lying and wet meadow with seasonal water coverage. Therefore we also employ the unit emission figure of the grassland in this case.

Concerning forests, 3141 kt of carbon-dioxide was sequestered in 2016 on 1,940,700 hectares, resulting in a unit figure of 1.618 ton of CO_2 removal per year per hectare. However, this is an average figure, which corresponds to mature forests. For new afforestation reaching this level of sequestration takes 10-15 years, after that it will surpass this benchmark. For the sake of simplicity, we assume constant CO_2 sequestration.

As summarised by Table 4, land use change will altogether improve the carbon balance of the pilot area substantially, as net emitting land use (cropland) is terminated, while the land use types that replace it have either a lower emission factor (grassland and fish spawning area) or they remove CO_2 from the air (forest).

Table 4 Net balance of CO_2e emission / removal due to land use change

Land use	Land use change (hectare)	CO_2e emisson / removal (ton/hectare/year)	Total CO_2e emission / removal (ton/year)
Cropland	-325	0.714	-232.1
Grassland	270	0.018	4.9
Forest	20	-1.618	-32.4
Fish spawning area	35	0.018	0.6
Net balance			-258.9

8.2 THE ECONOMIC VALUE OF CO2 EMISSIONS AND REMOVALS

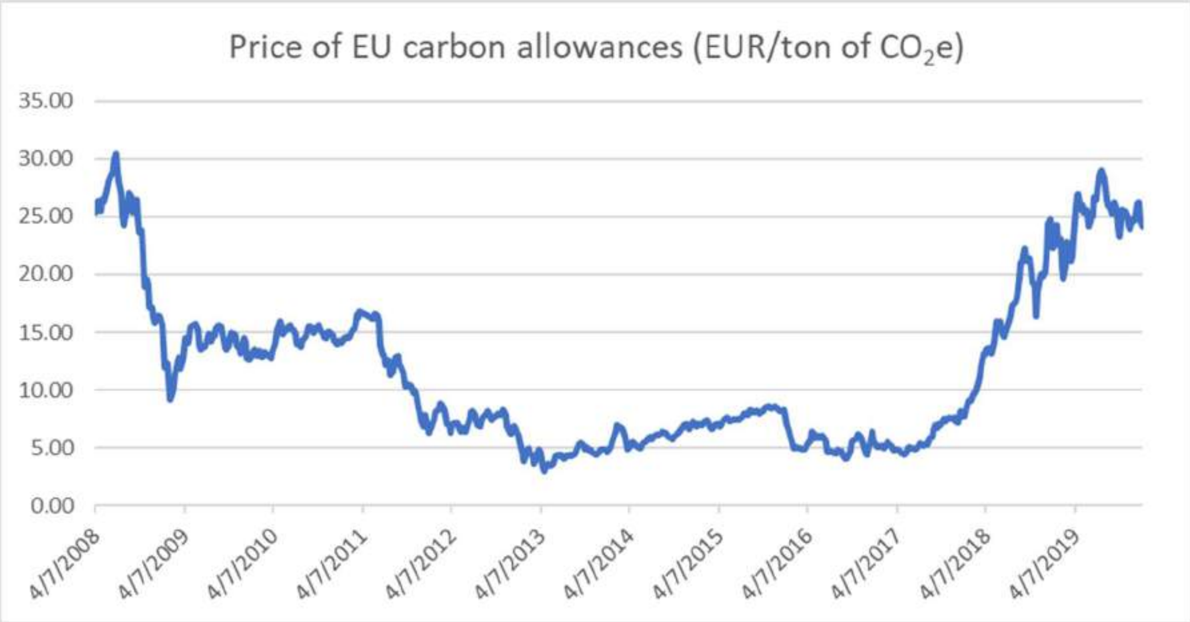
In calculating the economic value of CO2 emissions and removals, we follow the approach developed and applied by the EBRD, as we believe that this is a methodologically sound approach that well approximates the true cost of carbon emissions (and vice versa, the actual benefit of carbon sequestration).

The EBRD (2019) has adopted a carbon pricing approach under which the carbon impact of all projects is assessed using a "shadow price". The shadow price considers all socials costs as opposed to market based CO_2 emission allowance prices which reflect the operation of a carbon market that is to a large extent driven by the number of carbon allowances made available to market participants by regulation. The latter price fluctuates, it's movement driven by supply and demand, independently of the true cost that the release of CO_2 into the atmosphere generates. The shadow carbon price is incorporated into decision making, when the costs and benefits of a new investment are assessed, it puts a value on greenhouse gas emissions, thus correcting for the market failure of not fully considering the externalities caused by the emission.

Regarding the actual cost level, the EBRD follows the recommendations of the High-Level Commission on Carbon Prices (https://www.carbonpricingleadership.org/). This commission was created in 2016 with the explicit purpose of benchmarking the cost of pollution. The recommended carbon price range is 40-80 USD/ton of CO_2 for the year 2020, rising to 50-100 USD/ton of CO_2 by 2030. Beyond 2030 carbon prices are increased by 2.25% per year. All of these values are in real terms, in 2017 prices. Thus any inflation of the US dollar would result in further increase of the nominal value of the shadow price. The EBRD carries out a sensitivity analysis by applying both the lower and the upper edge of the price range during its CBA calculations.

To be able to compare the shadow price and the actual market price of CO2, we should look at the EU ETS market, which is the the most relevant such market in European economies. Figure 10 unambiguously shows that the EU carbon allowance price is below the cost-reflecting shadow price of 40-80 USD/ton (36-72 EUR/ton at the current EUR/USD exchange rate). In addition, there is a large price variation and for years the price stayed below 10 EUR/ton due to overallocation of rights to emitters.

Figure 10 EU carbon allowance price in the EU ETS market



8.3 MONETISED IMPACT OF CHANGES IN LAND USE RELATED GHG EMISSIONS AND SEQUESTRATION

By multiplying the amount of CO_2 removed from the atmosphere and the year specific shadow price of CO_2, we arrive at the annual carbon related benefit of land use change, as depicted in Table 5.

Table 5 Monetised benefit of carbon removal due to land use change

Year	Net CO_2 removal	Minimum carbon shadow price (EUR/ton)	Maximum carbon shadow price (EUR/ton)	Minimum CO_2 benefit of land use change (million HUF)	Maximum CO_2 benefit of land use change (million HUF)
2020	258.9	36.0	72.0	3.1	6.2
2021	258.9	36.9	73.8	3.2	6.3
2022	258.9	37.8	75.6	3.2	6.5
2023	258.9	38.7	77.4	3.3	6.6
2024	258.9	39.6	79.2	3.4	6.8
2025	258.9	40.5	81.0	3.5	6.9
2026	258.9	41.4	82.8	3.5	7.1
2027	258.9	42.3	84.6	3.6	7.2

2028	258.9	43.2	86.4	3.7	7.4
2029	258.9	44.1	88.2	3.8	7.5
2030	258.9	45.0	90.0	3.8	7.7
2031	258.9	46.1	92.3	3.9	7.9
2032	258.9	47.3	94.6	4.0	8.1
2033	258.9	48.5	96.9	4.1	8.3
2034	258.9	49.7	99.3	4.2	8.5
2035	258.9	50.9	101.8	4.4	8.7
2036	258.9	52.2	104.4	4.5	8.9
2037	258.9	53.5	107.0	4.6	9.1
2038	258.9	54.8	109.7	4.7	9.4
2039	258.9	56.2	112.4	4.8	9.6
2040	258.9	57.6	115.2	4.9	9.8
2041	258.9	59.0	118.1	5.0	10.1
2042	258.9	60.5	121.0	5.2	10.3
2043	258.9	62.0	124.1	5.3	10.6
2044	258.9	63.6	127.2	5.4	10.9
2045	258.9	65.2	130.3	5.6	11.1
2046	258.9	66.8	133.6	5.7	11.4
2047	258.9	68.5	136.9	5.9	11.7
2048	258.9	70.2	140.4	6.0	12.0
2049	258.9	71.9	143.9	6.1	12.3
2050	258.9	73.7	147.5	6.3	12.6

9 OTHER MONETISED BENEFITS AND COSTS

9.1 AGRICULTURAL CROP PRODUCTION

The approximately 325 hectares that becomes part of the active floodplain is mostly crop land. It is not a high quality crop production area, it was transformed from pasture to arable plot during the 1980's. The land quality is under the average of 18-20 AK (="aranykorona", or golden crown, the traditional indicator of land quality in Hungary). The average wheat yield here is 3.5-4 tons/hectare which is 60-70% of the national average of the years 2014-2016, FADN, 2018. Without the CAP subsidies the area is barely worth to cultivate. The profitability of the wheat is around break even without the subsidies, while the years when sunflower is cultivated (recently every fifth year, following four years of wheat production), generates extra revenue, but the five year longevity of the cycle is prone to weather and market turmoil that easily consumes this surplus. Due to the land property law most of the production takes place on rented land, that means that the impacts on the owners' position and the cultivators' position are different. The corresponding elements will be represented in the calculation module, here the main aspects of the approach are discussed. Calculations are based on interviews (Járvás, 2019, Tarkó, 2019, Katona, 2019) and the information derived from the Farm Accountancy Data Network.

The retransformation of the cropland to floodplain meadows and the expropriation/purchase of the land area has the following economic impacts:

1) Loss of income / livelihood production for the agricultural users that is compensated in the expropriation price.

> The value of land as a production input reflects the present value of future incomes the property could provide. Based on the 2014-16 years of the FADN (2018) report the post tax result of wheat/sunflower rotation is about 330 €/year (approximately 70% of that annual income is generated by the agricultural subsidy). The expropriation land price includes a 20% premium to enhance cooperation between the farmers and the state, also contributing to lower administration costs and presumably compensating for the inconvenience caused to farmers. The land price (not including the price premium) covers about 35 years of such net revenue, using a 4% discount rate. Concerning the lifespan of the revenue equivalent, one can argue that it covers all connected cost that can emerge from the crop production side.
>
> In Hungary agricultural production is heavily based on rented land. The expropriation or land purchase included an element that targeted the tenants for compensating the burden of adaptation in the business procedures that the termination of the rental agreement brings forth.

2) Decreasing demand for agricultural services of crop production due to the cease of operation on the plots. While from a plot based financial perspective the lack of agricultural production activities is a loss, it should not be categorized as such. The production needs financial resources (in our estimate it is a 50-60 million HUF annual financial requirement) and these resources are not destroyed by the transformation of the plots. Farmers - their firms or their families – will utilise the resources probably in a way to generate further income. Theoretically some temporary decrease of economic activity level can happen because decisions on new activities and transformation needs time, but it is beyond the scope of the analysis to track this phenomenon.

> The cost distribution of wheat production costs (FADN, 2018) shows that 30% of the costs are spent on fertilizers (19%) and pesticides (11%). The discontinuation of using these agro-chemicals is an environmental gain, pollution of ground water as well as surface water is reduced. As a result, notable external costs are avoided, the value of which, however, is methodologically complicated to estimate. The overall effect depends on exactly which activities the freed-up resources will finance.

3) Some overall productivity loss for the farmers will emerge from the shrinking farm size (ceteris paribus). Plots the productivity of which is close to the break even point (no financial gains on it) still have a useful contribution to the overall profitability of the farm as the operation and maintenance of expensive machinery needs scale to spread the costs. By shrinking the overall size of farms, this type of scale economy will be reduced. Moreover, farm level regulation requires set-aside areas to maintain. These are usually the lowest productivity plots within a farm. If such plots are purchased by the state due to the dyke relocation project, the farmers will need to sacrifice other, more productive areas to satisfy the set-aside requirement. These are negative impacts that farmers – as owners and/or renters of cropland - must absorb. At least there is one sizable farm enterprise that has a 1.5%, 6 hectare-cultivation-share in the area, the other plots are much smaller, the described

effect is not traceable. Nevertheless, in the case study this is a non-monetised burden for farmers.

4) The area according to the water directorate staff's experience is prone to waterlogging. However, there is no specific data on how frequently the excess water cover decreased or damaged the agricultural production. This suggests that the estimated value of non-realized agricultural production due to waterlogging events is relatively small, but there is no adequate information to specify its extent. Moreover, there are drainage channels across the area (4 km length). The land use change that the project initiates makes the maintenance of these infrastructure elements unnecessary. The annual maintenance cost (cc 450 thousand HUF) can be saved. However, there is no information whether the farmer community in whose interest the maintenance of the channels was, actually had spent resource for that goal.

Within the new floodplain there is a small track of land (5 hectares) currently registered as pasture, the animal husbandry here is not in contrast with the new land use requirements, mutually suitable arrangements can probably be formed.

9.2 FISH SPAWNING AREA

When the fish spawning area within the enlarged floodplain is flooded, which happens for at least a few days in about 80% of all years, then the fish that gets stranded there lays her eggs and fish reproduces. Later on when the water is released from the pond through a lock and a canal, the fish will migrate to the river and be available for angling. This is process resembles the traditional method of fish spawning, while in modern times the more widespread method is that juvenile fish is purchased from fish pond operators, transported to and released in the river („fish stock replenishment")

Compared to artificial replenishment, spawning-grounds offer some advantages:

- They can preserve and develop the biodiversity of the fish population (and therefore also of the related ecosystem) more effectively
- The cost of this type of reproduction method is notably lower (Bíró et al., 2006)

Newly built and managed spawning-grounds can substitute and/or supplement the yearly replenishment, which is the responsibility of the owner/maintainer of the territory. In the river Tisza, the control of fish-population (including its replenishment) generates significant costs to these organisations, usually angler associations, which could be reduced effectively by the proposed spawning-ground. Next we detail how we monetised the benefits that accrue due to avoided cost of fish stock replenishment.

The success and the productivity rate of a spawning-ground always depends on the characteristics of the territory, but Bíró et al. (2006) estimated that one hectare of spawning-ground ensures the natural population reproduction of ten hectares of river area. This rate is one of the cornerstones of our estimation method. With the use of the mentioned rate we estimate that the proposed spawning-ground with its 35 hectare size can substitute fish replenishment on 350 hectares of river area.

Unfortunately, data about the cost of fish replenishment/hectare/year is not available from the inspected region, however there is such data from one of the tributary rivers of the Tisza, the Körös. "Körösvidéki Horgász Egyesületek Szövetsége" (Association of Körös Region Angler Clubs, the maintainer of the mentioned territory) published its fish replenishment data. In 2019, the association populated 45.4 kg/hectare of carp in its river territories. (Körös Hírcentrum, 2019). A different source provides the net price of carp purchased from fish ponds with the goal of riverine replenishment, HUF 790 +VAT per kg of carp in 2018 (kozep-tisza.hu, 2018). In our calculations we applied the gross price of 1003.3 HUF/kg.

From the collected information and the estimation method, we predict that the proposed spawning-ground can reduce the maintenance cost by 16.0 million HUF/year. Besides this reduction, the organisation also needs to maintainer the constructed spawning-ground. Bíró et al (2006) estimated that the maintenance cost is about 60 thousand HUF/hectare for spawning-grounds. Inflating this figure to current prices using the consumer price index data published by the Central Statistical Office results in 88.4 thousand HUF/hectare, or 3.1 million HUF for all 35 hectares. Thus, the net annual saving ensured by the fish spawning area has been estimated at 12.9 million HUF.

We need to emphasize that the estimated value of cost savings is only applicable in those years, when the water level in the river is high enough to flood the spawn-ground for several days. This was true in the 80 percent of the last 20 years. Thus, in essence, the expected value of annual savings is lower: 16 mFt * 0.8 – 3.1 mFt = 9.7 million HUF/year. We assumed that the maintenance costs take place in all years.

In our estimation due to lack of data we did not calculate the replaced replenishment cost of other fish species besides carp. However we must underline that in spawning-grounds, many other species will also reproduce, generating additional, but non-monetised benefits for anglers as well as for the ecosystem. Thus our estimation on cost savings is rather a conservative valuation.

9.3 GRASS PRODUCTION ON MEADOWS

Once land use change has been completed, 270 hectares of grassland (meadow) will be under the management of KÖTIVIZIG. The meadows need to be maintained in order to ensure low surface roughness for the smooth flow of water in case of flooding. From the perspective of KÖTIVIZIG the easiest solution is rental of the area to agricultural enterprises that would use it for grazing and/or hay production. However, there is limited demand for such areas (Katona, 2019) and often only a symbolic rental fee, such as 1000 HUF/year/hectare can be collected. A specific rental agreement with the Hortobágy National Park has been under discussion, according to which the national park would be able to use the area to graze gray cattle on it, without a rental fee payment. Even despite the lack of revenue this could be an attractive arrangement for KÖTIVIZIG, as the obligation to take care of the meadow and cut the grass would be handed over to the national park. In addition, if shrubs appear in the floodplain, the cost of clearing the area could escalate compared to the cost of cutting grass. A rental agreement with clear clauses for responsibility could help to preclude such costs.

The other alternative is own management of the land and selling any harvested hay in the market. The hay market is not very liquid and the corresponding revenue is modest and not well predictable. The cost of meadow management, on the other hand, can be substantial.

External enterprises are hired at a cost of about 40 – 70 thousand HUF/hectare to harvest the grass, and ideally the grass should be cut twice a year, doubling the cost (Lipták, 2019). If the grass is cut with KÖTIVIZIG's own machine, the direct cost is only about 10 thousand HUF/hectare, but some of the corresponding costs of labour and depreciation is not included. In case KÖTIVIZIG takes care of the meadow, it is eligible to receive EU CAP subsidies, which – together with revenue from hay – substantially improves the economic position of meadow management. Since the dyke relocation project is supported from EU sources, for the first five years after the project has been implemented, KÖTIVIZIG is not allowed to generate revenue on it, also including the receipt of CAP subsidies.

Since there is very limited demand for land rented out to graze or mow because livestock management is hardly profitable, a market-based outsourcing of land management can't be calculated. We assume that KÖTIVIZIG hires an external enterprise or use their own equipment to take care of the meadow and the net annual cost of this task including two harvests and some revenue from selling the grass, is 80 thousand HUF/hectare/year. At the same time, 70 thousand HUF/hectare/year of EU subsidies are collected from year 6. These are the figures that we use within the CBA. In case of changing demand KÖTIVIZIG is able to conclude a rental agreement under which the area is grazed or taken care of in a different way, the annual net cost could drop to zero (and the EU CAP subsidy would be the revenue of the renter, not KÖTIVIZIG)

9.4 FOREST MANAGEMENT

The cost of afforestation - already accounted for under up-front-costs – is estimated at HUF 70 million. Regular maintenance costs of the forest will take place, in the beginning to ensure that weeds and shrubs do not restrict the growth of trees, later on thinning to help the most attractive trees to succeed. At the same time revenues will also be generated, minor revenues from thinning and increasing revenues later on from selective cutting. State support for forest maintenance will also be available. Experience shows that after initial afforestation maintenance costs and revenues from thinning can more or less balance each other if a long enough period is examined.

Concerning timber harvest two options are available: 1) Clear cutting at the end of the forest cycle, which would be 60 years here (Ficzere, 2019) and 2) Continuous selective cutting. Since this is a protective forest the main goal of which the protection of the dyke from the force of flooding, only selective cutting is feasible. This type of forest management, however, will require some timber harvest before the conventional cutting age. In our analysis we assumed an oak forest to grow and the selective cutting starts 30 years from now and will take place every 10 years from there on. As the forest grows, the amount of harvested timber will also increase with each 10 year period, but we assume that the process leaves 10 percent of the area intact with a final stabilized cut of a 90 year old segment every 10 years. Selective cutting ensures that the forest naturally regenerates, therefore no reforestation costs were assumed. The results of our analysis are summed in Table 6 below. During the first 50 years HUF 10.4 million worth of timber is harvested.

Table 6 The volume of timber stock, harvested timber and the value of the timber for all 20 hectares together

Year	Timber stock before harvest (m^3)	Timber harvest (m^3)	Timber stock after harvest (m^3)	Value of timber harvest (HUF)
10	0	0	0	0
20	1,040	0	1,040	0
30	1,540	154	1,386	2,464,000
40	1,944	216	1,728	3,456,000
50	2,344	280	2,064	4,480,000
60	2,666	344	2,322	5,504,000
70	2,886	402	2,484	6,432,000
80	3,034	456	2,578	7,296,000
90	3,114	504	2,610	8,064,000
100	3,144	548	2,596	8,768,000
110	3,128	586	2,542	9,376,000
120	3,080	504	2,576	8,064,000
130	3,108	504	2,604	8,064,000

Notes: The timber stock values are based on timber growth data for oak. 16,000 HUF/m^3 of timber revenue has been used for the calculations.

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10 NON-MONETISED BENEFITS AND COSTS

10.1 BEEKEEPING

More bee families can be released to the additional natural area. From the beekeepers' point of view it is an additional opportunity to let their bees collect pollen.. According to Ficzere (2019) the floodplain extension would make it possible for 2-3 small holder beekeepers to use the place. Monetizing the value of the additional potential however is problematic as beekeepers usually use the dikes as a launch base to let the bees reach specific agricultural fields like rapeseed and less frequently the forests and meadow in the floodplain. Meanwhile there are several licenses issued for beekeepers to place hives along the dike, at the moment it is not a constrained opportunity to ask for an additional permit (issued by the directorate with no fee attached). Therefore beekeeping, from the perspective of the available area, has been an underutilised opportunity recently, therefore the value that can be assigned to this activity as an option value for potential future use is rather uncertain. We do not make attempts to monetise it.

This approach doesn't mean that the area has no value from beekeeping point of view or improving the utilization of this ecosystem service potential of the area wouldn't be advisable. The analysis is focusing on the additional impacts. Based on the findings, the recent economic constraints of beekeeping in the area would be interesting to study.

10.2 HUNTING

As the size of natural area increases, more wild animals will be present. According to Ficzere (2019) water fowl is more likely to thrive than wild mammals. Altogether, the value of hunting may increase, but the extent if this change is difficult to predict.

Due to the land use change the area won't be prone to agricultural damages by wild animals. Based on the data of the National Game Management Database in Jász-Nagykun-Szolnok County the annual compensation payment for the reported damage of wild animals paid by the local game management organisations was 6.2 million HUF (for the entire county; the NUTS 3 level unit), equivalent to 19,000 EUR (5 year average 2014-2018). The proportional value for the case study area cc. 300 hectar is too small to include in the calculation.

10.3 RECREATIONAL, SPORT, HOBBY AND EDUCATIONAL ACTIVITIES

More natural areas may entice more people to spend increasing time in nature pursuing different activities. For jogging and leisure walking the location is too far from the settlements, we do not expect significant change, however, for biking and longer distance hiking it is more accessible. Participants of canoe and kayak tours on the river Tisza may wander into the area to enjoy the natural environment. The new floodplain can become an attractive spot for bird watching, but we do not have a basis to estimate the actual number of such visitors. The natural area provides educational potential, such as nature trails and on-site biology and ecology classes, school trips and camps.

10.4 ECOSYSTEM IMPROVEMENT

As approximately 300 hectares of cropland is converted into more natural land use, the habitat will sustain an increased fauna and flora, it is supposed to exhibit increased biodiversity and more resilience to external disturbances.

The new water surface of the fish spawning area will increase the diversity of the habitat types. It will inadvertently serve as a feeding ground for different bird and mammal species. The multiple connected positive impacts of such additional water habitats are proven at other sites along the same river section. A balance in habitat resource management must be set between the bird habitat maintenance interests (maximizing the feedstock for valuable species) and the fish stock management interest (maximizing the volume and selection of the new breed that can be discharged into the river.)

10.5 INCREASING GROUNDWATER RECHARGE

Due to a larger surface area of the floodplain more groundwater recharge is expected, contributing to the healthy water balance of the region. Higher groundwater levels are beneficiary both for nearby farmers and the ecology.

Even though there were no waterlogging channels on the incorporated area due to the arable type of cultivation, the area theoretically discharged to the otherwise disconnected regional drainage system, but its share by cover is miniscule and doesn't add to the regional waterlogging prevention costs.

11 SUM OF COSTS AND BENEFITS AND THEIR EVALUATION

11.1 NET BENEFITS

We created a spreadsheet tool to assist in the calculation of the balance of all costs and benefits (CBA Tisza pilot.xlsm). All the benefit and cost items described in the previous chapters are entered into this spreadsheet, indicating also the year in which given items occur. Non-monetised benefits are also entered in order to have everything in one structure, and stakeholders who bear the cost or enjoy the benefit also need to be supplied to help the structured discussion of distribution impacts and compensation mechanisms.

Within the tool the present value is calculated for all monetised costs and benefits through the application of a real discount rate (discount rate in excess of the rate of inflation) supplied by the user. For this exercise we used a 2% discount rate, and made sensitivity analysis with 1% and 3% values as well. Additional sensitivity analysis is in Chapter 11.2.

The detailed results of the analysis using 2% real discount rate and a 50 year time horizon (discounting all costs and benefits that register during the next 50 years) are in Table 7. There is a net monetised overall benefit of about HUF 1.16 billion. In case of a 1% real discount rate net benefits would increase to HUF 2.71 billion, while a 3% discount rate would reduce them to HUF 0.02 billion, still a positive result. Obviously, results are highly sensitive to the level of the real discount rate. A low interest rate will result in a higher present value for costs and benefits farther in the future, and since most of the costs are up-front investment type costs while most benefits take place in the future, lower interest rates will improve the cost benefit balance substantially.

A number of non-monetised items could further modify these results, but it is unlikely that they would represent such a high level of cost that would turn the current positive expectations around, especially since non-monetised benefits substantially outnumber non-monetised costs.

The main cost type is the up-front investment cost (altogether HUF 5.3 billion) paid by the state[2], while the main benefit is reduced flood risk (HUF 6 billion) enjoyed by and spread through society. From a different perspective this is also a state benefit, since it reduces other types of flood defense costs of the state. From the perspective of the state, the relocation of the dyke is a good investment, already justified by flood risk reduction alone.

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[2] By state cost we mean the central budget and KÖTIVIZIG together

Looking at other stakeholders, society (in its numerous manifestations) will reap a wide variety of benefits, only part of which was possible to monetise, to some extent balanced by one type of cost, due to ending crop production. We can safely assume that for society as a whole, the project is advantageous.

Part of the local population can benefit from enhanced opportunities for hunting, beekeeping, fishing and other activities, all in all, the changes are positive for them.

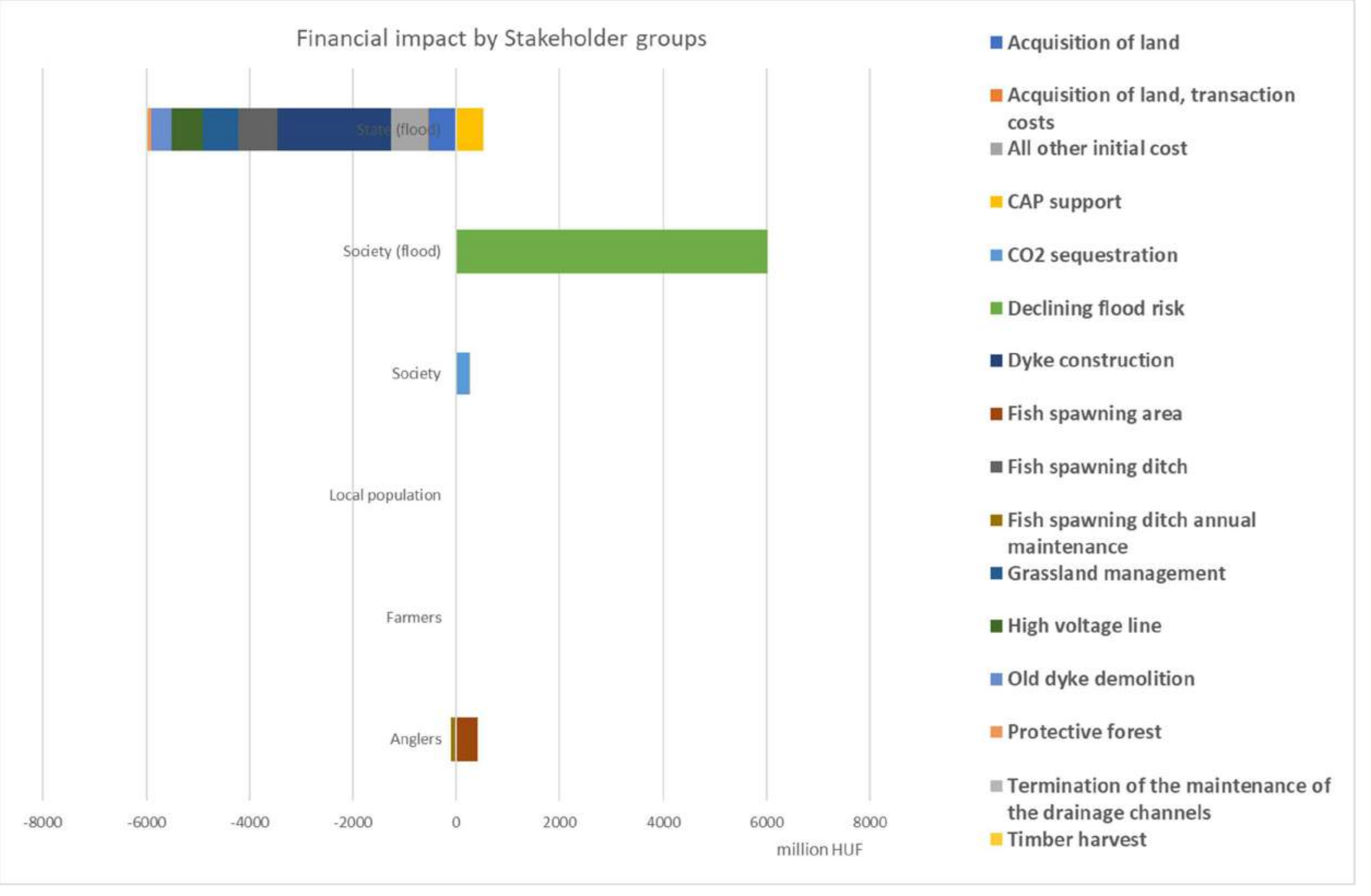
Anglers, through their associations, – if in charge of taking care of the spawning grounds – will face a new annual expenditure, but in exchange they can substantially reduce their fish stock replenishment expenditures, overall enjoying a sizeable financial benefit.

Table 7 Costs and benefits of dyke relocation, 2% real discount rate

Stakeholder	Costs / Benefits	Name	Description	Present value (million HUF)
State (flood)	Costs	Dyke construction	All the design, construction etc.	-2,200
State (flood)	Costs	Old dyke demolition		-400
State (flood)	Costs	Protective forest	Cost of afforestation.	-70
State (flood)	Costs	Fish spawning ditch	Recultivation of mine for construction materials, development of fish spawning ditch	-750
State (flood)	Costs	High voltage line	Reconstruction of high voltage line	-600
State (flood)	Costs	All other initial cost		-700
State (flood)	Costs	Acquisition of land	Price paid for acquired land	-540
State (flood)	Costs	Acquisition of land, transaction costs	Surveying, legal expertise, appraiser, dedicated manpower within KÖTIVIZIG	-21
State (flood)	Costs	Grassland management	Maintaining, cutting the grass	-692
State (flood)	Benefits	CAP support	CAP support to manage the meadow	515
State (flood)	Benefits	Timber harvest	Selective cutting from the protective forest	5
State (flood)	**Net monetised benefit (+) or cost (-)**			**-5,453**
Society (flood)	Benefits	Declining flood risk	Due to change in river morphology, there is a lower flood risk	6,026
Society (flood)	**Net monetised benefit (+) or cost (-)**			**6,026**
Society	Benefits	CO2 sequestration	Average value of captured CO2 for the first 10 years	47
Society	Benefits	CO2 sequestration	Average value of captured CO2 for years 11-30	101
Society	Benefits	CO2 sequestration	Average value of captured CO2 for years 31-50	111
Society	Benefits	Recreational, sport, hobby and educational activities	Hiking, running, photography, bird watching, education	Non-monetised
Society	Benefits	Ecosystem improvement	Enlarged habitats, enhanced biodiversity, more resilient ecosystem	Non-monetised

Society	Benefits	Lower use of agrochemicals	Reduced pollution of water bodies	Non-monetised
Society	Benefits	Increased ground water recharge	Due to a larger surface area of the floodplain	Non-monetised
Society	Benefits	Termination of the maintenance of the drainage channels	The area will not have to be drained due to the land use change	15
Society	**Net monetised benefit (+) or cost (-)**			**274**
Local population	Benefits	Bee keepers	Potential for more bee families	Non-monetised
Local population	Benefits	Hunters	More water fowl and potentially more game animals	Non-monetised
Local population	**Net monetised benefit (+) or cost (-)**			**0**
Farmers	Costs	Productivity loss	Productivity loss due to lower economies of scale and less opportunity for vertical integration	Non-monetised
Farmers	**Net monetised benefit (+) or cost (-)**			**0**
Anglers	Costs	Fish spawning ditch annual maintenance	Maintenance	-99
Anglers	Benefits	Fish spawning area	Reduced cost of fish stock replenishment in the river	410
Anglers	**Net monetised benefit (+) or cost (-)**			**311**
All stakeholders together	***Net monetised benefit (+) or cost (-)***			***1,157***

Figure 11 Financial impact by stakeholder groups



11.2 SENSITIVITY ANALYSIS OF NET BENEFITS

Our standard cost benefit analysis that Chapter 11.1 presented used a 50 year time horizon and a 2% real discount rate. With these parameters the net result of the calculation is 1,157 million HUF. We applied this combination because in case of public investments on long life-cycle infrastructure the 1%-3% interval of discount values could be considered as an acceptable range (Drupp et. al. 2015). In this range of discount rates the time horizon becomes crucial, if it is too long, it implies an unjustified bet on unchanging circumstances, while setting it too short keeps important segments of the impacts out of the analysis. Dyke developments are a long term public investment, it is safe to assume that at least a 50 year period of operation should be expected. As the results of the below table show, this timescale is sufficient to generate enough benefits that the project is worth executing.

To better understand the sensitivity of net benefits to both the time horizon and the discount rate, we inspected different combinations of time horizon (30 to 100 years, with 10 year intervals) and discount rate (0% to 10% with 1% intervals). The results are summarised in Table 8.

Table 8 Net benefits of dyke relocation under various combinations of real discount rate and time horizon (million HUF)

	Length of analysis (years)							
Discount rate	30	40	50	60	70	80	90	100
0%	699	2,774	4,849	6,926	9,003	11,082	13,161	15,241
1%	-100	1,373	2,706	3,914	5,008	5,998	6,895	7,708
2%	-753	296	1,157	1,864	2,444	2,920	3,311	3,631
3%	-1,291	-540	19	435	745	975	1,147	1,275
4%	-1,737	-1,197	-833	-586	-420	-307	-231	-180
5%	-2,109	-1,720	-1,481	-1,334	-1,244	-1,189	-1,155	-1,134
6%	-2,422	-2,140	-1,983	-1,895	-1,846	-1,818	-1,803	-1,794
7%	-2,686	-2,482	-2,378	-2,325	-2,298	-2,284	-2,277	-2,273
8%	-2,912	-2,762	-2,693	-2,661	-2,646	-2,639	-2,636	-2,635
9%	-3,105	-2,995	-2,949	-2,930	-2,921	-2,918	-2,916	-2,916
10%	-3,271	-3,191	-3,160	-3,148	-3,143	-3,141	-3,141	-3,141

As shown, in the 1%-3% discount rate range the project turns to net financial positive result if at least 40-50 years of operation was assumed. A real discount rate of 4% or higher would make the project a loss making one on any of the inspected time horizons, but these discount rate – time horizon combinations shouldn't be considered relevant for the evaluation of this project. The consideration of shorter than 40-50 years as a time horizon in case of flood risk mitigation investment doesn't comply with the public expectation of how long time the impacts pf such an investment should last. The utilization of 4% or higher discount rate in case of a long time horizon public investment project, doesn't comply with the public considerations regarding the weight with which the impacts on stakeholders in the future must be taken into account. The higher the interest rate the less importance is given to impacts in the future. Above the 3% discount rate there is a significant decrease in the weight of future impacts. For an illustration of how the time horizon and the discount rate together impact the present value of a given sum, please visit Annex 14.2.

12 CONCLUSIONS

The results of the complex, extended CBA based analysis of the Fokorú puszta dyke relocation project show that implementing the intervention would be a beneficial public investment both from financial and natural point of view. Based on the analysis one can assume that no stakeholder group would be left behind in terms of bearing the cost of others' benefit without having compensation.

While the biggest share from the benefits is associated with flood risk reduction, the calculations show that the proper, ecosystem service benefit oriented management of the transformed territory also has a key role to ensure the positive balance of the investment. From this point of view the proper management agreements with the angler associations about the operation of fish spawning area for rejuvenating and supplementing the native fish population has high importance.

Although CO2 sequestration represent a smaller benefit element it is worth noting that this benefit comes from a relatively small area (20 hectares), that is only 6% of the transformed territory. Because it is a forest patch with defense function that protect the dyke, our calculation expected a constant forest cover management approach. Our results also illustrate that constant cover forests can be considered as a viable land use alternative for publicly acquired land for flood protection.

It is also worth acknowledging that these "fringe" benefits are responsible for 50% of the positive balance of the investment. Especially the creation of forests with carbon storage purpose in mind is a financial surplus generating efficient additional service implementation, if land is already available for public reconsideration of use optimalization.

Like in the case of the above mentioned additional ecosystem service provisions, it can be decisive to reach agreement on the terms of a development, but it requires site specific information and stakeholder bargains to reach in order to include them in a real ex-ante decision support calculation in a credible way, otherwise it represents only a theoretical potential and not a realised benefit.

The applied methodology helped to structure the intervention as a bundle of development elements whose economic and natural benefits exceeded costs. Importantly, the analysis also shows that evaluating the cost and benefit components separately will highlight items where additional considerations, issues can be raised for further improving the balance. The excel based support tool had a good helping hand in that element.

Economic analysis with a positive balance is only a part of the necessary approval of a flood risk mitigation intervention. That is the reason why the methodology we tried to follow and test at the same time, introduced a decision flow approach with a (1) sustainability check, (2) extended CBA and (3) stakeholder negative-impact neutralization. So far aspect (2) and (3) were assessed. The sustainability check of the intervention takes two steps, from one part showed that the decisive conditions of the environmental quality that dispatch through the land use patterns of the area don't deteriorate due to the intervention (actually improves).

The criteria/condition list itself were judged appropriate and practically useable for the purpose by both partners who collaborated with Rekk in the case study elaboration (Kötivizig, WWF). The second step monitors the change of the functional capacity of the area, how it provides ecosystem services. Did the asset (on which the actual bundle of ecosystem services are based on) change? In the methodology we laid down a theoretical framework that connected this measurement of ecosystem service asset base to the inter-seasonal water budget allocation efficiency of the analyzed territory. Based on the available data we can state that the intervention improved this capacity of the area. Meanwhile we couldn’t prepare the dataset what we consider the suitable one for such a judgement. This element needs further development in simulation capacity to improve the integrated use of discharge, infiltration and transpiration models whose resolution can cope with the land use changes considered along the analyzed intervention.

By our opinion the case study demonstrated the applicability of the methodology. The ecosystem asset base change indicator for the decision flow as a whole needs further elaboration in the future in order to be able to handle the full spectrum of the risks an intervention poses on the aspects of sustainability of the impacted territory, but even without it the methodology provides a sufficiently high level of certainty on evaluating complex, nature related flood risk mitigation interventions.

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14 ANNEXES

14.1 SUSTAINABILITY CALCULATIONS

The sustainability calculation focuses on an area close to Szolnok city that surrounds the river Tisza. This studied area spreads over 4100 hectares and divided into 52 separate regions based on their CORINE coverage characteristics. Information about the area in focus has been stored in vector spatial data provided by KÖTIVIZIG (2019).

Furthermore, spatial information about those area affected by the dyke relocation and by changing land use has been provided, KÖTIVIZIG (2019). Based on these data we could found – as it has been discussed earlier – that two regions were added to the analyzed floodplain that have been used as cropland before the relocation. These regions, with an area of 125,9 and 133,6 hectares each, are then divided into further sub-regions due to changing land-use type. As a result, 32,6 hectares of cropland are to be transferred to woodlands area and an additional 10,6 hectares fish spawning area is to be developed.

The two analyzed scenarios are based on these changes: the baseline and the alternative scenario with changes both from dyke relocation and changing land use are analyzed.

The process of the sustainability calculations is introduced in the following sub-chapters.

14.1.1 CALCULATING THE MONTHLY AVERAGE POTENTIAL EVAPOTRANSPIRATION

The regional potential evapotranspiration calculations are based on national monthly data by Vitkuki (2008). The monthly data – provided in millimeters measure – is applied for each analyzed region. Furthermore, the size of each studied region is calculated by using the area measure tool in QGIS software. Therefore, the total monthly average potential evapotranspiration (TMAPE) for the entire studied area is provided as the sum of the monthly average potential evapotranspiration of each region ($MAPE_r$), that is the product of the unit national monthly average potential evapotranspiration (NMAPE) and the size of the region ($AREA_r$). The monthly average potential evapotranspiration is measured cubic meters and can be formulated as:

$$TMAPE = \sum_{r=1}^{R} (MAPE_r) = \sum_{r=1}^{R} (NMAPE)\,(AREA_r)$$

where r denotes each specific region and R is the number of regions within the studied area.

14.1.2 CALCULATING THE MONTHLY AVERAGE PRECIPITATION

The monthly average precipitation is calculated based on monthly average precipitation spatial data by KÖTIVIZIG (2019). The monthly average spatial data are provided in raster layer format.

Using QGIS software, the monthly average precipitation is calculated for each studied region by the following steps:

1) The raster layers are converted into vector layers using the „polygonize (raster to vector)" tool.
2) The vector layer containing information about the studied regions is then intersected by the previously converted monthly average precipitation vector layers in order to calculate the size of the sub-regions with a given precipitation value for each region.
3) Finally, the area-size weighted average precipitation for each region is estimated.

The total monthly average precipitation (TMAP) for the entire studied area is given as the sum of the monthly average precipitation of all regions (MAP_r).

$$TMAP = \sum_{r=1}^{R} (MAP_r)$$

where r denotes each specific region and R is the number of regions within the studied area. The monthly average precipitation is measured in cubic meters.

The same method is applied in the case of the alternative scenario as the monthly average precipitation is recalculated for those affected areas by changing land use.

14.1.3 CALCULATING THE MONTHLY AVERAGE TRANSPIRATION

The monthly average transpiration is calculated as the product of the monthly average precipitation and the land-use based transpiration value. The former data is calculated as described in the previous sub-chapter, using the monthly average spatial data. The transpiration values for cropland, woodland and grassland are provided by Móricz, 2011. These measures have been distinguished between periods of high and low evapotranspiration seasons for each land use. The transpiration value indicates the transpiration from both precipitation and infiltration and measured as a percentage of precipitation.

The transpiration values can be assigned for each studies region based on their CORINE characteristics. Thus, the monthly average transpiration (MAT_r) for a region is calculated as the product of its transpiration value (TV_r) and the monthly average precipitation (MAP_r), while the total monthly average transpiration (TMAT) is the sum of the monthly average transpiration of all regions.

$$TMAT = \sum_{r=1}^{R} (MAT_r) = \sum_{r=1}^{R} (TV_r)\,(MAP_r)$$

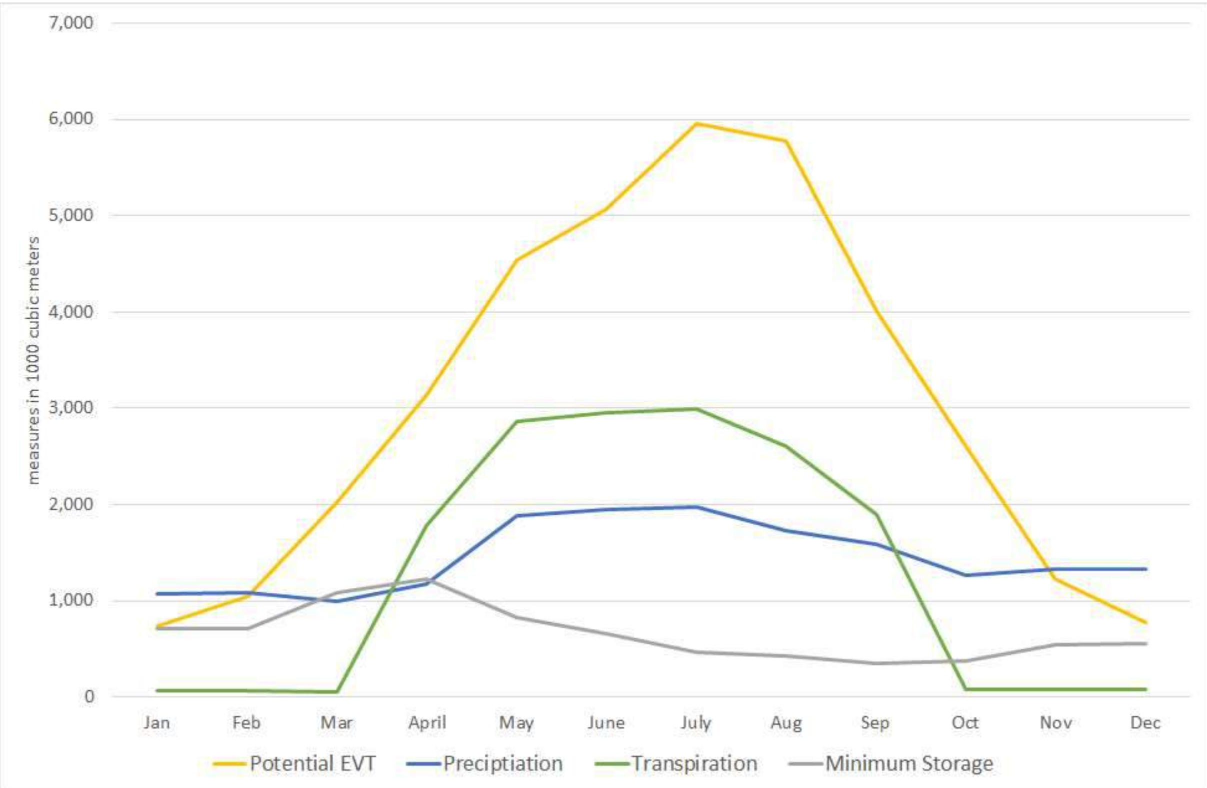
where r denotes each specific region and R is the number of regions within the studied area.

14.1.4 DEVELOPING INFORMATION FOR CALCULATING THE WATER RESOURCE ALLOCATING EFFICIENCY

The available data extorted some compromise on how the water resource allocation efficiency can be calculated that need further considerations to develop. One of the more important issues is the definition of the initial resource of water that originates from the surface flows and will add to the water supply of transformed floodplain. It is important to obtain to have an equal basis of water use comparison across scenarios. The current calculation this supply side information was replaced with the infiltration quantity as additional source of water with precipitation. The other issue was that calculating the indicator along the lines the methodology laid down a vegetation and water supply sensible data set would have been needed for calculating infiltration. Our effort with the available data sources didn't provide consistent results therefore coefficients based on Móricz, 2011 very detailed measurements on riparian forest and fallow were used. To solve this problem, for the calculations, a minimum estimation was created for the temporarily stored water quantity based on the Móricz (2011) site measurements that provided the share of transpiration from the groundwater budget and the overall change of the groundwater budget itself driven by the flow regime of the river. , .

The below figure shows the elements that were formulated for the calculation that reflects the hydrologic water balance of the extended case study territory from which the Fokorú puszta focus area was cut.

Figure 12 Hydrologic water balance of the simulation area



14.2 THE ROLE OF TIME HORIZON AND DISCOUNT RATE IN DISCOUNTING

To illustrate this issue of time preferences and choosing the discount rate, in **Hiba! A hivatkozási forrás nem található.** the power of discounting is represented. The table shows how much an original 100% value is considered in the net present value of a future cost or benefit using various discount rates on given time frames. The higher the interest rate and the longer the period, the less the discounted value. For example a cost or benefit value that will be expected to happen after 40 years will be considered only as 67%, 45%, 31% of the nominal value in the present value. It shows its declining weight in the calculation (and the decision support) with the increase of the discount rate. A discount rate in excess of 4% and a time horizon in excess of 50 years will reduce at least 95% of the future value. We think that these values are therefore not really appropriate for decision supporting analysis in a case where public investments are considered.

Table 9 Illustration: the results of discounting under various time frames and discount rates

	Length of analysis (years)							
Discount rate	30	40	50	60	70	80	90	100
0%	100%	100%	100%	100%	100%	100%	100%	100%
1%	74%	67%	61%	55%	50%	45%	41%	37%
2%	55%	45%	37%	30%	25%	21%	17%	14%
3%	41%	31%	23%	17%	13%	9%	7%	5%
4%	31%	21%	14%	10%	6%	4%	3%	2%
5%	23%	14%	9%	5%	3%	2%	1%	1%
6%	17%	10%	5%	3%	2%	1%	1%	0%
7%	13%	7%	3%	2%	1%	0%	0%	0%
8%	10%	5%	2%	1%	0%	0%	0%	0%
9%	8%	3%	1%	1%	0%	0%	0%	0%
10%	6%	2%	1%	0%	0%	0%	0%	0%