Act. 4.3

Extended Cost-Benefit Analysis Methods

Deliverable D 4.3.2

Deliverable 4.3.2. Method documentation describing the implementation of ESS and biodiversity to traditional CBA as input for D 4.3.4 and therefore of output 5.1.

WP	**WP4: Flood prevention pilots**
Activity	Activity 4.3
Deliverable	D 4.3.2 Deliverable 4.3.2. Method documentation describing the implementatio of ESS and biodiversity to traditional CBA as input for D 4.3.4 and therefore of output 5.1.
Activity-leader	TUM and CUEI
Deliverable prepared by	Francesca Perosa (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 4.3.1, D 4.3.4, and output 5.1

Responsible project partners

PPs Role	Responsible person	E-mail address
TUM – WP4 leader	Francesca Perosa	francesca.perosa@tum.de
	Johanna Springer	johanna.springer@tum.de
	Veronika Zwirglmaier	veronika.zwirglmaier@tum.de
	Markus Disse	markus.disse@tum.de
CUEI – Activity co-leader	Marion Gelhaus	Marion.Gelhaus@ku.de
	Florian Betz	florian.betz@ku.de
	Bernd Cyffka	Bernd.Cyffka@ku.de
JCI –Begecka Jama pilot area	Dragana Ninković	dragana.ninkovic@jcerni.rs
	Marko Marjanović	marko.marjanovic@jcerni.rs
	Zoran Knezevic	zoran.knezevic@jcerni.rs
	Ljiljana Marjanović	ljiljana.marjanovic@jcerni.rs
	Laszlo Galambos	laslo.galambos@gmail.com
	Tanja Bosnjak	tanja.bosnjak2@gmail.com
NARW – Bistret pilot area	Petrisor Mazilu	petrisor.mazilu@rowater.ro
	Andreea Galie	andreea.galie@hidro.ro
	Sorin Randasu	sorin.randasu@rowater.ro
	Cristian Rusu	cristian.rusu@rowater.ro
DRSV – Krka pilot area	Marjan Jarnjak	Marjan.Jarnjak@gov.si
	Leon Gosar	leon.gosar@gov.si
	Jurij Krajcic	Jurij.Krajcic@gov.si
KOTIVIZIG – Middle Tisza pilot area	David Vizi	vizi.david.bela@kotivizig.hu
	Tamas Pravetz	Pravetz.Tamas@kotivizig.hu
	REKK	Andras Kis (andras.kis@rekk.hu) and Ungvári Gábor (gabor.ungvari@rekk.hu)
VUVH – Morava pilot area	Marek Comaj	comaj@vuvh.sk
	Katarina Mravcova	katarina.mravcova@vuvh.sk
	Martin Studeny	studeny@vuvh.sk
MRBA – Morava pilot area	David Vesely	vesely@pmo.cz

Content

Figures

Tables

1. Summary

Deliverable D 4.3.2 presents the methodologies followed to include ecosystem services in a standard cost-benefit analysis (CBA), resulting in an "extended cost-benefit analysis". Herein, we show the methodology followed to estimate six ecosystem services (ESS) types by applying the Toolkit for Ecosystem Service Site-based Assessment (TESSA) and complementary methodologies (e.g., stakeholder engagement). The flood mitigation ESS was assessed by estimating the avoided flood risk. The water depth maps for each pilot area resulted from the application of damage functions to two-dimensional hydrodynamic models' results of three hydrological scenarios (three return period groups of the flood hazard), produced and analyzed under Activity 4.1 (for current state and restoration scenarios). For the global climate regulation ESS, the carbon storage ESS estimation was done following the Tier 1 methodology of the IPPC reports from 2006 and complemented with carbon storage information from other literature sources. The greenhouse gases fluxes ESS were also estimated with the Tier 1 methods from the 2006 IPCC reports and complemented with emission factors and forests' growing rates from other literature sources. The estimation of cultivated goods ESS was based on the market prices of agricultural, livestock, and aquaculture goods, using input data provided by project partners and publicly available data, such as the Food and Agriculture Organization (FAO). For the estimation of the nutrients retention ESS, we analyzed the data from the DanubeGIS database of total nitrogen (TN) measurements at the Danube and its tributaries. Then, we applied a benefit transfer value of this ESS, based on a database of floodplains' ESS values for the Danube catchment. Following TESSA's guidelines, the individual travel cost method (ITCM) was applied to assess the nature-based recreation ESS provided by the floodplain areas and their restoration, based on interviews, conducted online and advertised on social media. Finally, we show how the co-benefits of floodplain restoration measures can be estimated in monetary values and discounted, to obtain commonly used parameters in CBA analyses. Deliverable D 4.3.1 presents the outcomes of applying the methodology to four pilot areas of the Danube Floodplain Project (Begecka Jama, Bistret, Krka, and Morava) and discusses its implications for the results. Finally, Annex A4 to this deliverable shows the methodology followed for the extended cost-benefit analysis in the Middle Tisza pilot area in a document was prepared by the Regional Centre for Energy Policy Research (REKK).

2. Introduction

Adapted from Perosa et al. (2021b)

Floodplain restoration projects are sometimes difficult to finance. Therefore, the Danube Floodplain Project aims to show the profitability of these measures, since floodplain restoration can help for flood risk reduction, but can also bring other ecosystem services (ESS) (Guida et al., 2015). Moreover, the huge economic losses due to floods at the Danube River Basin level, e.g. 2 billion Euros in 2010 and 2.3 billion Euros in 2013, (ICPDR, 2015) lead to considering the inclusion of ESS in monetized form. Therefore, an extended cost-benefit analysis is used to estimate ecosystem services of floodplains and show their additional value, leading to integrated planning and improved regional policymaking, which was called for by scientists (Petz et al., 2012). This deliverable presents the methodologies followed to include ecosystem services to a more traditional cost-benefit analysis, resulting in an extended cost-benefit analysis and in deliverable D 4.3.1 (Danube Floodplain, 2021), which presents the outcomes of applying the methodology.

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 assessment. 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 in the pre-selected pilot areas and were partly involved in the development of the measures. This process, which included stakeholder workshops in the pilot areas, is described in deliverable D 4.2.1 (Danube Floodplain, 2019), where the fundamental knowledge of the stakeholders is recorded and was later used to evaluate the ecological, economic, and cultural values of the pilot areas with the aid of the ecosystem services approach. The ecosystem services were mapped for deliverable D 4.2.2 (Danube Floodplain, 2020b), which provided information about nature's regulatory services like nutrient retention, the supply of natural products like water, and 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 Floodplain, 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.

To support decision-making processes, we developed a method to assess the potential ESS availability of planned but not yet implemented restoration projects. We used version 2 of TESSA (Peh et al., 2017) as theoretical background for ESS estimation and in some cases for ESS valuation.

All steps were implemented in a Python code that can be run from QGIS3 (QGIS.org, 2020). For the ESS assessment, a consistent quantity of input data was necessary, such as agricultural yields, population density, or emission factors of greenhouse gases. When lack of data characterized the study areas, we used publicly available data from different institutions and databases (e.g. the Intergovernmental Panel on Climate Change (IPCC) reports (IPCC, 2006; IPCC, 2014), FAOSTAT (FAO, 2019), EUROSTAT (Eurostat, 2020a; Eurostat, 2020b), and EarthStat (Monfreda et al., 2008)). Moreover, the maps resulting from stakeholder workshops were used as input data for the estimation of global climate regulation and cultivated goods ESS. To show potential changes, we applied the methods for both prior restoration states, namely the current scenario (CS) and two restoration scenarios: a so-called "realistic" restoration scenario (RS1) and an "optimistic" one (RS2).

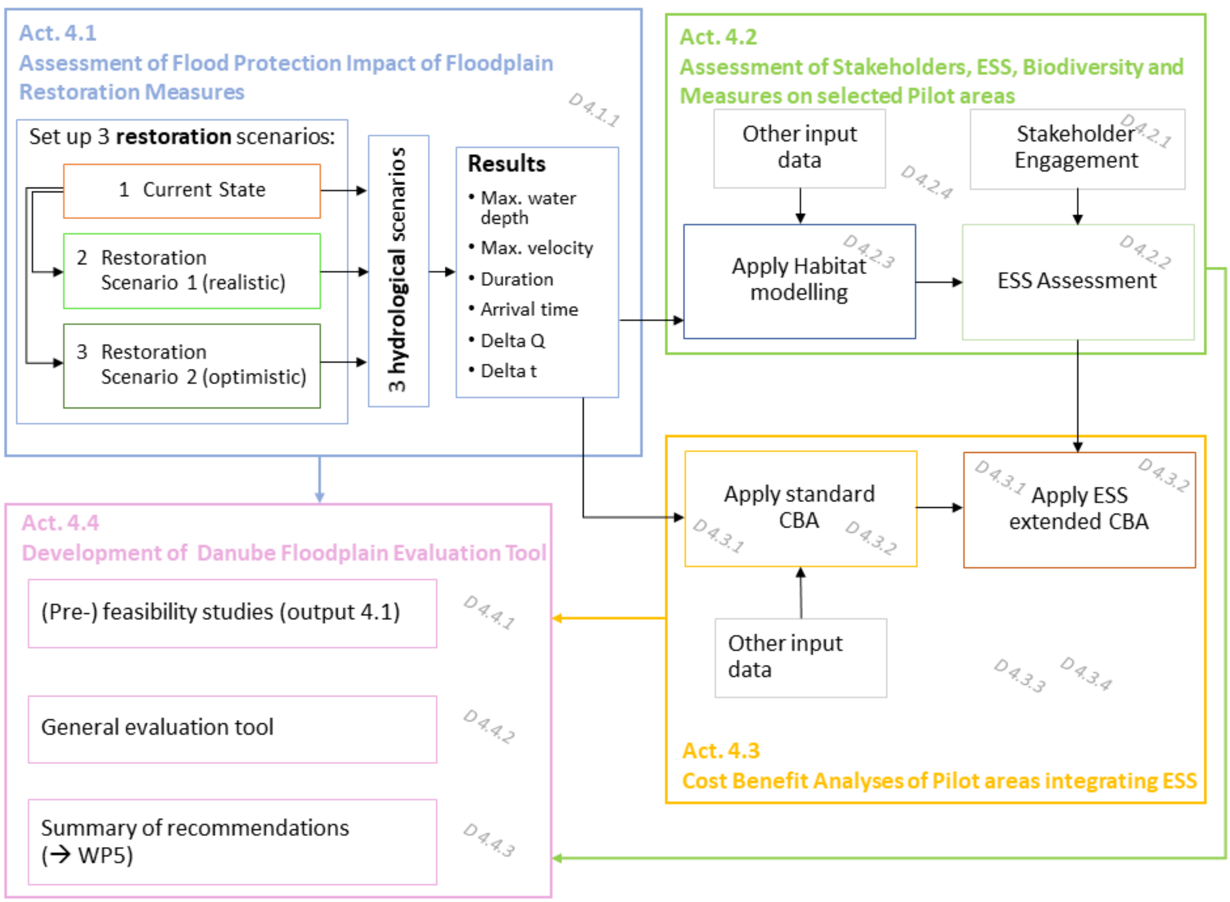


Figure 1. Flow chart of the tasks in WP4 in the pilot areas including activities and deliverables

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. The methodological approach described in this deliverable was designed to fit the local scale of these pilot areas and has been applied to four study sites within the DRB. The results are published in Deliverable 4.3.1 (Danube Floodplain, 2021).

The floodplain restoration measures considered in the restoration scenarios consist of modifying the water regime to affect the flow conditions and the water supply in the floodplain areas throughout the year. In all pilot areas, these modifications had the goals of improving flood risk management, protecting the ecosystems, increasing biodiversity, improving habitat quality (terrestrial and aquatic, e.g. spawning areas or better conditions for fish migration), and increasing the diversity and quality of ecosystem services.

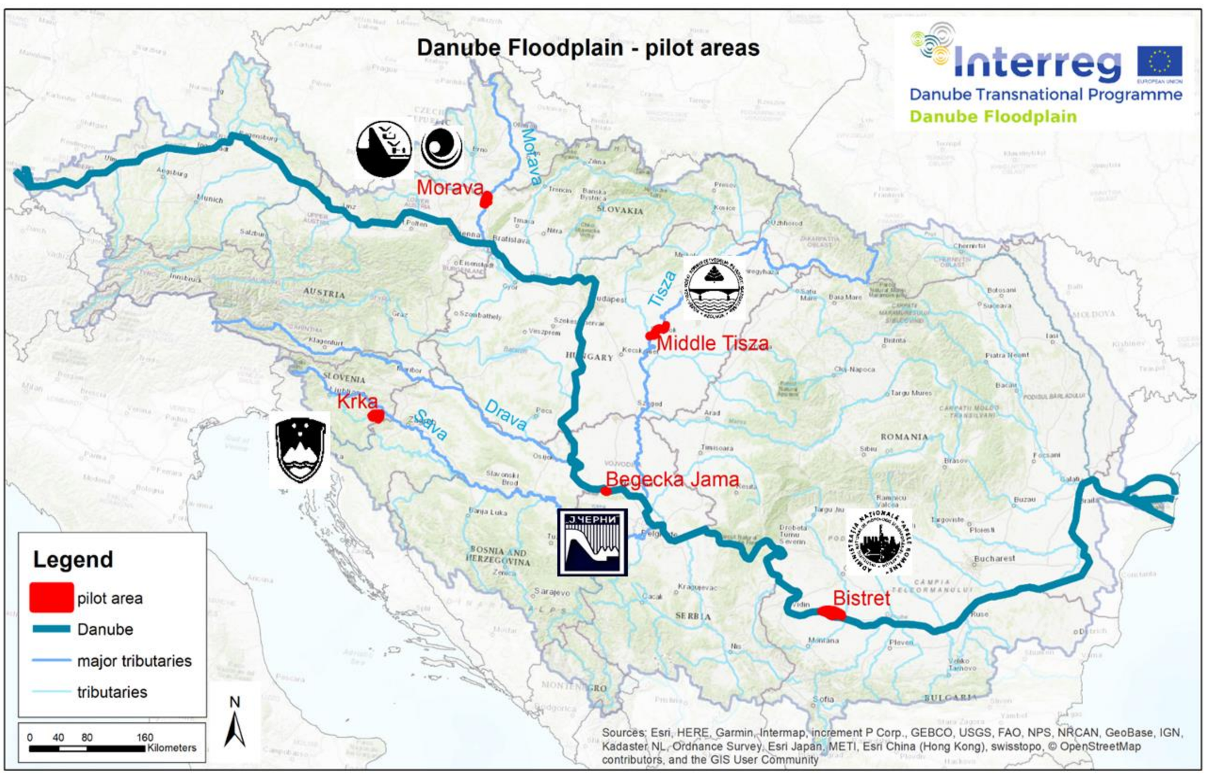


Figure 2. Location of the five pilot areas in the Danube Basin with the responsible partners (Danube Floodplain, 2020a)

3.2 Restoration Scenarios in the Pilot Areas

The responsible project partners developed two restoration scenarios (RS1 and RS2) individually in cooperation with national authorities as well as the identified. The planned restoration measures were 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).

Deliverables D 4.1.1 (Danube Floodplain, 2020a), D 4.2.2 (Danube Floodplain, 2020b), and D 4.3.1 (Danube Floodplain, 2021) present a summary of all restoration measures in the pilot areas for both scenarios. 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.

4. Methodology

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

4.1 Stakeholders' Consultation in the Pilot Areas

The stakeholder workshops took place in the study areas between January and February 2019. During the meetings, between 17 (Krka) and 71 (Middle Tisza) stakeholders from various interest groups attended first a presentation regarding the state of the floodplains and the potential restoration measures. The stakeholders belonged to different interest groups and went from local to international level. Therefore, it was not possible to differentiate them into groups belonging to the floodplain's upstream and downstream areas. In a second step, the participants were divided into multiple mixed groups and discussed, identified, and marked the locations and intensity of use (on a scale from 1 to 5, where one stands for "Missing to very low" intensity and five stands for "Very high" intensity) of different ecosystems in the current state scenario of the pilot areas. In a third step, the stakeholder groups were asked to repeat the second step, but for a potential floodplain restoration scenario; in this case, the intensity of ecosystem services had to be only recognized as increasing, decreasing, or stable. As a result of the meetings, Table 1 reports the ESS that were recognized by the stakeholders in the study areas (Danube Floodplain, 2019). A summary of the corresponding potential TESSA methods used for each ESS sub-group in this paper can be seen in the last column of Table 1.

Table 1. Summary of the ecosystem services (ESS) identified by stakeholders and the corresponding potential methodology to estimate ESS within the TESSA framework (Danube Floodplain, 2020b).

ES group	ES sub-group	Begecka Jama	Bistret	Krka	Middle Tisza	Morava	ES estimate method
	Greenhouse gases sequestration	✓		✓	✓	✓	Tier 1 of IPCC[1]
	Flood retention	✓		✓		✓	Not available in TESSA
	Flood mitigation	✓	✓	✓	✓	✓	Hydrodynamic modeling and damage functions (Huizinga et al., 2017)
	Water quality: Nutrients retention	✓		✓			Statistical analysis of nutrients in DRB
	Local climate regulation	✓	✓	✓	✓	✓	Not available in TESSA
	Noise regulation					✓	Not available in TESSA
	Crops		✓	✓	✓	✓	

ES group	ES sub-group	Begecka Jama	Bistret	Krka	Middle Tisza	Morava	ES estimate method
Provisioning of cultivated goods	Livestock and bees	✓	✓	✓	✓	✓	Mixture of TESSA and publicly available information
	Aquaculture		✓	✓		✓	
Provisioning of harvested wild goods	Wood	✓	✓	✓	✓	✓	Available in TESSA, neglected due to high data requirement
	Fish	✓	✓	✓			
	Game meat		✓	✓	✓		
Nature-based recreation and tourism	Recreational ES	✓		✓	✓	✓	Online questionnaires and individual travel cost method (adapted from TESSA)
	Tourism	✓	✓	✓	✓	✓	
	Education	✓		✓	✓	✓	
Habitat provisioning	Terrestrial habitats	✓	✓	✓	✓	✓	Not available in TESSA
	Spawning areas	✓	✓	✓	✓	✓	

4.2 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, 2015). According to Feuillette et al. (2016), the lack of information in CBA on interactions in the ecological system leads to limited and biased results, due to the high complexity of ecosystems; CBA requires therefore specific methods to express environmental services in monetized benefits. As a consequence, according to ICPDR (2015), the economic/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, which have an impact on society as a whole. In the case of environmental policy measures, an extended CBA will often be called for, but the external environmental effects often do not correspond to any market prices.

In flood risk management, the standard CBA considers as benefits the avoided flood risk. These benefits can be extended to integrate the results of the ecosystem services assessment of alternative strategies of potential restoration areas. The costs and benefits addressed in an economic CBA may include indirect and non-priced external effects (ICPDR, 2015), such as environmental effects. If such externalities are included in the analysis in monetary terms, we refer, according to Brouwer and Sheremet (2017), to a "social CBA”. One of the main challenges of the proposed work is to translate the ESS into quantitative values so that they can be compared with standard costs and benefits of the floodplain restoration measure, and therefore considered in the decisional process.

CBAs of river restoration projects are rare and a reason for this is the relative scarcity and difficulty of data acquisition related to the costs of restoration activities (Logar et al., 2019). 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. Some authors, such as Baveye et al. (2013), criticize the use of monetary valuation of ESS. Nevertheless, ESS monetization is a way to include the benefits that nature brings to humans that would otherwise be neglected in decision-making (Schägner et al., 2013). Also, economics and ecology are very influential aspects when dealing with ESS (Chaudhary et al., 2015).

The extended CBA process is graphically conceptualized in Figure 3. The description of the methodology to assess the ecosystem services of Chapters 0 to 0 partially corresponds to the Methods section in Perosa et al. (2021b).

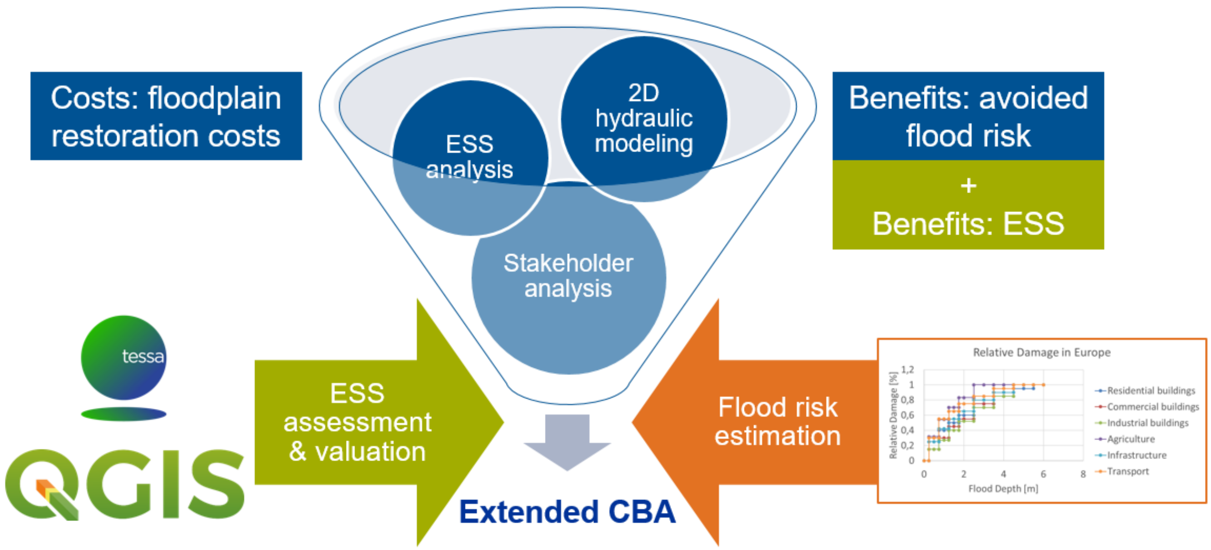


Figure 3. Workflow of the extended cost-benefit analysis for floodplain restoration measures in the Danube Floodplain project.

Before analyzing the benefits and costs of the restoration measures, these have to be discounted, to be made comparable with each other, assuming the discounting parameters presented in Table 2. The discount rate was chosen based on the literature: Monge et al. (2018) used various discount rates ranging from 1 to 5% for estimating payments for forest ecosystem services; Dittrich et al. (2019) applied a rate of 3.5% up to year 30 (Dittrich et al., 2019) for a cost-benefit analysis of afforestation related to flood-risk nature-based solutions; Jeuland and Pattanayak (2012) took an average of 4.5% discount rate (social) for assessing the implications of cookstoves in health, forest and climate impacts (Jeuland and Pattanayak, 2012). The European Commission recommends that for the social discount rate 5% is used for major projects in Cohesion countries and 3% for the other Member States (Sartori, 2015). However, Terrado et al. (2016) used also lower discount rates (2% and 3%) to assess the sensitivity of the results to this parameter. In general, there is a lack of consensus on the discount rate to use in ecosystem services valuation studies (Hein et al., 2016).

Table 2. Parameters used for the cost-benefit analysis

Parameters for discounting
r = 0.04
N = 50

These parameters are used in the following equation (1), to derive the multiplication factor used to estimate the present value (PV) of the costs and benefits, based on annual values, for a discount rate r and a project life of N years.

$$Annuity\ to\ present\ = \frac{((1+r)^N)-1}{r*((1+r)^N)} \quad (1)$$

The discounted values were then used in this project to estimate the benefits-costs difference and the benefits-costs-ratio. The benefits-costs difference (BC-difference) is the simple subtraction of the costs PV from the benefits PV of the restoration measures. A positive BC-difference represents a profitable project for the selected timeframe. The benefits-costs-ratio (BCR) is a common parameter used in CBA analysis to evaluate its results. It consists of the following equation (2). A BCR higher than one corresponds to a profitable project.

$$BCR\ = \frac{PV\ of\ Benefit\ Expected\ from\ the\ Project}{PV\ of\ the\ Cost\ of\ the\ Project} \quad (2)$$

4.3 Ecosystem Services Assessment with TESSA

The TESSA Toolkit (Peh et al., 2013) was used as theoretical background for the ESS estimation and evaluation. To make the estimation faster, the assessment steps were reproduced in a python code for QGIS3. The workflow followed can be seen in Figure 4.

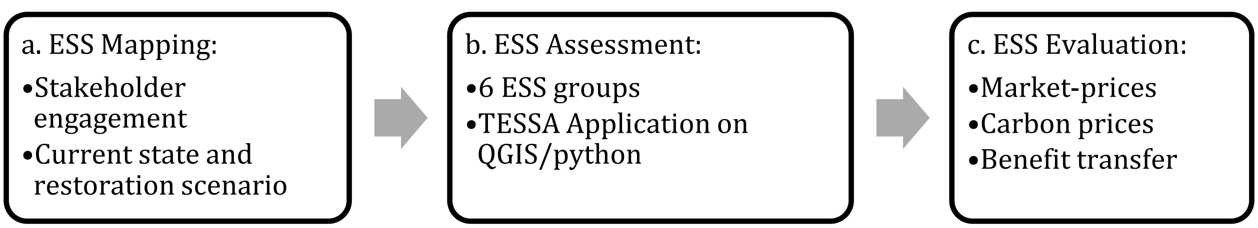


Figure 4. Workflow of the ecosystem services assessment with TESSA (Peh et al., 2013)

In general, to estimate the value of ESS, four categories of approaches exist (Grizzetti et al., 2016):

- cost-based: e.g. replacement costs;
- revealed preferences: e.g. travel costs;
- stated preferences: e.g. willingness to pay;
- benefit-transfer, e.g. meta-analytic value transfer functions.

A detailed description of the methods can be seen in Table 3.

Table 3. Summary of the most common ESS valuation methods, adapted from Grizzetti et al. (2016)

Approach	Valuation method	Description of the method	Examples of ecosystem service value assessment
Cost-based	Damage cost avoided	Method that values an ecosystem service estimating the **damage** that might be incurred if this service disappears	Assess the value of the storm protection service provided by wetlands through estimation of avoided damage in case of a storm
	Replacement cost	Method that uses the **cost of a substitute** for an ecosystem as a proxy for the value of services	Assess the value of the water purification service through an estimation of the construction cost of artificial wetlands
Revealed preferences	Travel cost	**Survey-based** technique that uses the cost incurred by individuals taking a trip to a recreation site as a proxy for the recreational value of this site	Assess the value of the recreational service of a lake based on the number of visitors and the money they spend to visit the lake
	Hedonic price	Method that estimates the value an environmental characteristic of an ecosystem by looking at differences in **property prices**	Assess the value of lake amenities by comparing real-estate prices located at different distances of this lake
Stated preferences	Contingent valuation	**Survey-based** technique in which respondents answer questions regarding their **willingness to pay** for an environmental service or a change in this environmental service	Assess the value of an aquatic species by asking individuals how much they are ready to contribute for preserving it
	Choice experiment	**Survey-style** technique in which respondents are asked to state their choice over different **hypothetical alternatives** (alternatives consist in a combination of attributes of an ecosystem and a price associated with this combination)	Assess the value of services provided by a river by the choice respondents make between different options (combinations of water quality, number of species, and vegetation) combined with different prices to be paid for each combination.
Benefit transfer	Unit value transfer	Method that values an ecosystem service by transferring a monetary value derived from a different, but with common characteristics, study from a different, but not too far, location	Assess the value of the recreational service of a lake applying a constant value per unit of ecosystem (e.g. the surface area) taken from another study
	Adjusted unit value transfer	Method that values an ecosystem service by transferring a monetary	Assess the value of the recreational service of a lake applying a value

Approach	Valuation method	Description of the method	Examples of ecosystem service value assessment
		value derived from another study, this value being adjusted using an ad-hoc factor to account for differences between the two sites	per unit of ecosystem (e.g. the surface area) that depends on the income level of the local population
	Value transfer functions	Method that values an ecosystem service using a value function estimated from another site	Assess the value of the recreational service of a lake by plugging site-specific parameters into a value function estimated from another study
	Meta-analytic value transfer functions	Method that values an ecosystem service from a function estimated through statistical regression analysis of many primary valuation studies	Assess the value of the recreational service of a lake by plugging site-specific parameters into a value function estimated from a meta-analysis

The practical tool used to implement TESSA is written in python and can be run from QGIS3. It consists of three packages (up to now), divided according to the division of the methodologies implemented in the TESSA Toolkit and to ESS types. .The code can be run from QGIS3 (QGIS.org, 2020) and, together with illustrative input data, is available on GitHub (GitHub, 2020). Each section is described in the next chapters. The sections can be run independently and each of them corresponds to different files of functions (included in the library of the code).

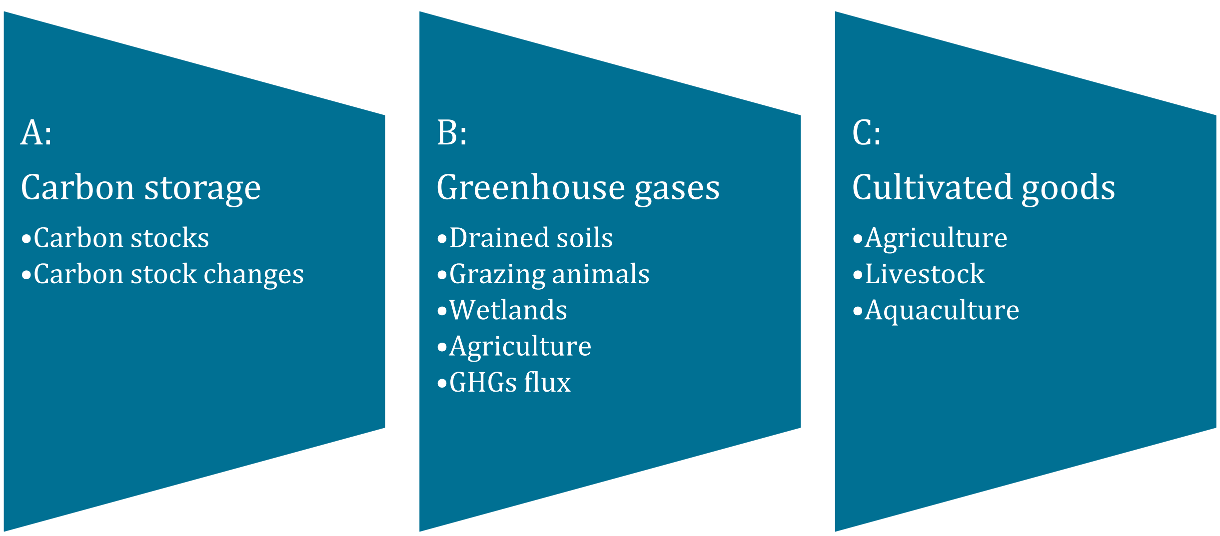


Figure 5. Sections of the python code available in GitHub (GitHub, 2020), written to estimate ecosystem services according to TESSA (Peh et al., 2013).

4.4 Input Data and Expected Outcome

A set of important input data is given by the shapefiles of ESS maps, a result of the stakeholder meetings and ecosystem services analysis described in Deliverable 4.2.2 (Danube Floodplain, 2020b). For more information on the meetings, the methods of stakeholder engagement, and the resulting maps, please refer to the Deliverable D4.2.1 (Danube Floodplain, 2019) and Deliverable D4.2.2 (Danube Floodplain, 2020b) of the Danube Floodplain Project.

For the ESS assessment, a consistent quantity of input data was necessary. The statistics deal with the parameters that affect ESS, such as agricultural production, population density, or emission factors of different greenhouse gases. We also divided the study areas into the following habitat types:

- Grass-dominated
- Tree-dominated
- Crop-dominated (no rice)
- Crop-dominated (rice)
- Wetland-dominated

When lack of data characterized the area of study, publicly available data were used for each country or the corresponding NUTS2 areas from different institutions and databases: such as IPCC reports (IPCC, 2006; IPCC, 2014), FAOSTAT (FAO, 2019), Eurostat (European Commission, 2020), EarthStat (Monfreda et al., 2008), etc.

The expected output of ESS evaluation with TESSA consists of singular ESS monetary values and ESS maps for each scenario (CS, RS1, RS2) and each ESS group (flood mitigation, global climate regulation, cultivated goods, nutrients retention, nature-based recreation). Then, the total sum of the ESS values was calculated by summing the singular ESS groups for each scenario. This was used for the subsequent inclusion of the additional benefits of the restoration measures in the extended cost-benefit analysis.

4.5 Flood Mitigation

The flood mitigation ESS was estimated through flood risk estimation. The water depth maps for each pilot area resulted from the 2D hydrodynamic modeling of the three return period groups of high probability (2 to 5 years), medium probability (10 to 20 years), and low probability (100 years), produced and analyzed under Activity 4.1 (Danube Floodplain, 2020a) for both current state and restoration scenarios. For the estimation of the flood-caused damages, we applied to all scenarios the Joint Research Centre (JRC) damage functions (Huizinga et al., 2017) shown in Figure 6 to estimate the flood-caused damage in the pilot areas. As Table 4 shows, the flood damage functions are applied to six land use types, which were derived for the pilot areas from the CORINE land use land cover dataset (EEA, 2019) as shown in Table 6. Finally, we applied the trapezoidal method for flood risk (expected annual damage) estimation (Olsen et al., 2015).

Table 4. Land use types included in the JRC damage functions (Huizinga et al., 2017)

JRC land use types
Residential buildings
Industrial or commercial buildings
Agriculture
Infrastructure
Transport
Other

Finally, we applied the trapezoidal method for flood risk (expected annual damage, EAD) estimation (Olsen et al., 2015), as shown in the following function:

$$EAD = \frac{1}{2}\sum_{i=1}^{n}\left[\left(\frac{1}{T_i} - \frac{1}{T_{i+1}}\right)(D_i + D_{i+1})\right] + \frac{D_n}{T_n}, \quad (3)$$

where $n = 3$ is the number of return periods, T is the return period in years (shown in detail for each study area in Table 5, together with their corresponding lower and upper uncertainty boundaries), and D is the corresponding damage.

Table 5. Return periods T used for the flood risk estimation with corresponding lower and upper uncertainty boundaries, with a number of return periods of $n = 3$.

	Begecka Jama	**Bistret**	**Krka**	**Morava**
T_1 - High probability	3.5 yr ± 1.5 yr	2 yr ± 1 yr	3.5 yr ± 1.5 yr	5 yr ± 1.5 yr
T_2 - Medium probability	15 yr ± 5 yr	10 yr ± 2 yr	10 yr ± 2 yr	30 yr ± 5 yr
T_3 - Low probability	100 yr ± 5 yr	100 yr ± 5 yr	100 yr ± 5 yr	100 yr ± 5 yr

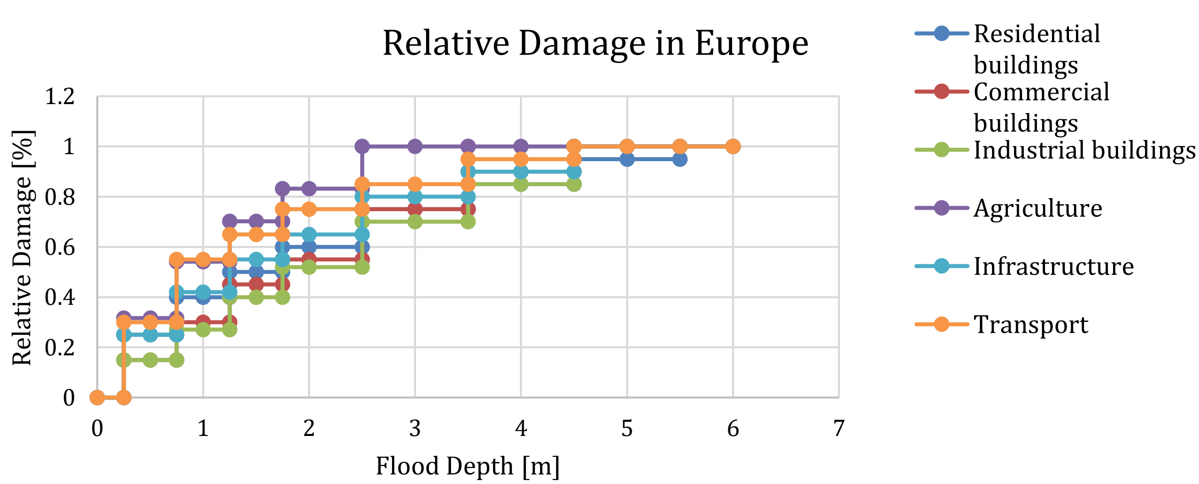


Figure 6. Damage curves, used to estimate flood risk in the pilot areas (Huizinga et al., 2017). The singular functions for each country are presented in Annex A1.

Table 6. Land use translation from CORINE to JRC

CLC18 code	CLC18 description	JRC code	JRC description
111	Continuous urban fabric	110	Residential buildings
112	Discontinuous urban fabric	110	Residential buildings
121	Industrial or commercial units	121	Industrial or commercial buildings
122	Road and rail networks and associated land	122	Transport
123	Port areas	120	Infrastructure
124	Airports	120	Infrastructure
131	Mineral extraction sites	130	Infrastructure
132	Dump sites	130	Infrastructure
133	Construction sites	133	Industrial or commercial buildings
141	Green urban areas	140	Infrastructure
142	Sport and leisure facilities	140	Infrastructure
211	Non-irrigated arable land	200	Agriculture
212	Permanently irrigated land	200	Agriculture
213	Rice fields	200	Agriculture
221	Vineyards	200	Agriculture
222	Fruit trees and berry plantations	200	Agriculture
223	Olive groves	200	Agriculture
231	Pastures	200	Agriculture
241	Annual crops associated with permanent crops	200	Agriculture
242	Complex cultivation patterns	200	Agriculture
243	Land principally occupied by agriculture with significant areas of natural vegetation	200	Agriculture
244	Agro-forestry areas	200	Agriculture
311	Broad-leaved forest	0	Other
312	Coniferous forest	0	Other
313	Mixed forest	0	Other
321	Natural grasslands	0	Other
322	Moors and heathland	0	Other
323	Sclerophyllous vegetation	0	Other
324	Transitional woodland-shrub	0	Other
331	Beaches dunes sands	0	Other
332	Bare rocks	0	Other
333	Sparsely vegetated areas	0	Other
334	Burnt areas	0	Other
335	Glaciers and perpetual snow	0	Other
411	Inland marshes	0	Other
412	Peat bogs	0	Other
421	Salt marshes	0	Other
422	Salines	0	Other
423	Intertidal flats	0	Other
511	Water courses	0	Other
512	Water bodies	0	Other
521	Coastal lagoons	0	Other
522	Estuaries	0	Other
523	Sea and ocean	0	Other
999	NODATA	0	Other

4.6 Global climate regulation: Carbon storage

In the context of the TESSA toolkit, the ecosystem service of "global climate regulation" refers to the exchange of carbon dioxide and other greenhouse gases between the atmosphere and the plants, the animals, and soil within ecosystems. In the Danube Floodplain Project, the tasks of the global climate regulation ESS were divided into two blocks: the "Carbon storage" package and the "Greenhouse gases" package.

The carbon stocks estimation is done following the Tier 1 methodology of the IPPC reports (IPCC, 2006) by separating the biomass stocking into four parts: the above-ground biomass (AGB), the below-ground biomass (BGB), the litter biomass (LB), and the dead wood biomass (DWB). For each part, the carbon stock estimates are read from the IPPC tables (IPCC, 2006). For some land uses and habitats, the IPCC reports did not provide the default factors for biomass calculation; therefore, the estimates of carbon dioxide flux (CO_2), methane flux (CH_4), and nitrous oxide flux (N_2O) of various habitat types were found in the estimates done by ANDERSON-TEIXEIRA and DeLUCIA (2011). The tables used for the specific cases are described in Table 7. Additionally, spatial data provided by the FAO and ITPS (2018) was used to estimate the organic carbon stored in soils.

Table 7. Tables used to extract the carbon stocks estimates according to the different biomass types and the habitat types

Biomass source	Habitat/Land use	Data sources
AGB	Tree-dominated	IPCC 2006 Guidelines - table 4.7 (IPCC, 2006)
AGB	Grass-dominated, Wetland-dominated	Values of GHGs flux for various habitats (ANDERSON-TEIXEIRA and DeLUCIA, 2011)
BGB	Tree-dominated	IPCC 2006 Guidelines - table 4.4 (IPCC, 2006)
BGB	Grass-dominated	IPCC 2006 Guidelines - table 6.1 (IPCC, 2006)
BGB	Wetland-dominated	Values of GHGs flux for various habitats (ANDERSON-TEIXEIRA and DeLUCIA, 2011)
LB	Tree-dominated	IPCC 2006 Guidelines - table 2.2 (IPCC, 2006)
LB	Grass-dominated, Wetland-dominated	Values of GHGs flux for various habitats (ANDERSON-TEIXEIRA and DeLUCIA, 2011)
DWB	Tree-dominated, Grass-dominated, Wetland-dominated	Values of GHGs flux for various habitats (ANDERSON-TEIXEIRA and DeLUCIA, 2011)

After extracting all carbon stocks estimates, the above-ground and below-ground carbon stocks were calculated in tons by multiplying them times the corresponding habitat area and by applying the following conversion factors:

- 0.5 for tree-dominated, forest plantations, woody savannas, perennial crop-dominated habitats, and urban parks;
- 0.47 for grass-dominated habitats, inland wetlands, and urban lawn.

Similarly, the litter and dead wood carbon stocks were calculated by multiplying the carbon stocks estimates by the areas of the shapefile of habitats types and by using a conversion factor of 0.5 for litter and a conversion factor of 0.4 for dead wood. For the soil organic carbon, due to the lack of data availability, the estimate was extracted from the GLOSIS - GSOCmap (v1.5.0), a global soil organic carbon map (GSOCmap) created by FAO and ITPS (2018).

By summing up the carbon stocks and the soil carbon stocks, the total carbon stocks of the status quo are calculated in tons. Note that the carbon stocks are a static calculation of the status quo of the carbon stored in the pilot area. Per se, they do not have a role in the extended CBA, unless a change in the habitat types would take place in the planned restoration scenarios.

4.7 Global climate regulation: Greenhouse Gases Flux

4.7.1. Carbon stock increment (in tree-dominated areas)

In this estimation, it was assumed that the change of carbon stocks takes place in the tree-dominated area only. To calculate the growth of carbon stocks, the growing rates of planted trees (Mean Annual Increment, MAI, expressed in m^3/ha/yr) were taken from the Planted Forests Database (PFDB) (FAO, 2003). After obtaining the MAI, the Carbon Fraction (CF) to dry matter of wood was read (in tons carbon/tons dry matter) from table 4.3 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2014). Required are also the biomass conversion and expansion factors (BCEF_R), expressed in tons of biomass removal (m^3 of biomass removals)-1 [tons/m^3] and extracted from table 4.5 of the IPCC report (IPCC, 2014). They are default values for conversion of wood and fuelwood removals in merchantable volume to total above-ground biomass removals. The BCEF_R is chosen based on the forests' growing stock level in m^3/ha/year, estimated by the Global Forest Resources Assessment (FRA) (FAO, 2016). Finally, the increment of the carbon stock in tree-dominated areas was calculated in tons C/year by following the formula (4).

Annual growing stock [m^3 dry matter/ha/year]	X	BCEF_R [ton dry matter / m^3 dry matter]	X	CF [ton C/ton dry matter]	X	Area [ha]	(4)

4.7.2. Carbon stock losses (in tree-dominated areas)

The carbon losses due to disturbances in the pilot area according to the suggestions of the TESSA Toolkit (Peh et al., 2013) was based on IPCC's default Tier 1 methods (IPCC, 2014). The procedure assumes that the change of carbon stock takes place in the tree-dominated area only. Disturbances can come from wood removals, fuelwood collection, and charcoal removals, or other disturbances (e.g. illnesses, fires, etc.).

The procedure follows the same concept of the carbon stock increment, but in this case, instead of considering the growth rate, we consider the removals. These were derived in the estimation from different sources. The "Forestry Production and Trade" section of the FAOSTAT database (FAO, 2019) provides data on the national level on annual roundwood removals, annual fuelwood removals, and annual charcoal removals [m^3/year]. The data are then scaled from the country values to the pilot area. The reference year was 2017.

Other disturbances (such as illnesses and fires) can only be estimated; this requires that the user provides the entries on the size of the area affected by disturbances, the biomass in tons dry mass/hectare that is removed by the disturbance in the above-ground biomass area, which is affected by the disturbance, and the fraction of hectares in respect to the hectares of the area of disturbance in the pilot area that is affected by the disturbance itself.

The total carbon stock losses were then calculated as the sum of the carbon losses due to the three disturbances types wood removal, fuelwood and charcoal removal, and losses due to other disturbances.

4.7.3. Net carbon sequestration

Based on the previous sections, the net carbon sequestration is calculated for the existing scenario (whether it is the current state scenario or any other restoration scenario), as shown in equation (5).

Annual Net Carbon Sequestration of Pilot Area [ton C/yr]	=	Annual Gross Carbon Sequestration of Pilot Area [ton C/yr]	-	Annual Carbon Loss (Total) [ton C/yr]	(5)

4.7.4. Greenhouse Gases Emission and Sequestration

The procedure for estimating the quantity of greenhouse gases (GHGs) sequestered from the atmosphere in the floodplain areas follows the steps suggested by the second part of the section on "global climate regulation" ESS in the TESSA Toolkit (Peh et al., 2013).

The following IPCC tables were used to extract coefficients for the GHGs flux estimation:

- Tier 1 CO_2 emission/removal factors for drained organic soils in all land-use categories (IPCC, 2014)
- Tier 1 CH_4 emission/removal factors for drained organic soils (EFCH4_land) in all land-use categories (IPCC, 2014)
- Default CH_4 emission factors for drainage ditches (IPCC, 2014)
- Default emission factors for CH_4 from rewetted organic soils (all values in kg CH_4-C ha-1 yr-1) (IPCC, 2014)
- Enteric fermentation emission factors for Tier 1 method (IPCC, 2006)
- Tier 1 enteric fermentation emission factors for Cattle (IPCC, 2006)
- CH_4 measured emissions for flooded land (IPCC, 2006)

Moreover, look-up tables from other sources were used:

- Table from Eurostat with the heads of domestic animals in the NUTS 2 regions (Eurostat, 2020a)
- Table from FAOSTAT with the emissions of different GHGs from agricultural practices (FAO, 2019)
- CH_4 emission factors of wild grazers following the methodology suggested in the TESSA Toolkit (M11, Table B) (Peh et al., 2013)
- CH_4 emission factors of natural wetlands following the methodology suggested in the TESSA Toolkit (M11, Table A) (Peh et al., 2013)

Additionally, spatial information about wetlands categories was used, as suggested in TESSA (Peh et al., 2013)

4.7.4.1. CO_2 emissions from drained soils

In the case of drained soils, input data used for CO_2 emissions are those found in Table 2.1 of Chapter 2 of IPCC (2014), which gives the appropriate default emissions factors as the annual flux of carbon as CO_2 from on-site oxidation or sequestration (expressed in tons CO_2 ha-1 y-1). Fundamental for this section is also the information on the percentage of habitat land that was drained in the past and has not been rewetted, for the following tree-dominated, grass-dominated, and crops-dominated habitats. According to the different types of land use, the emission factors are extracted from Table 2.1 and the emissions of CO_2 are calculated by multiplying the emission factor times the area of the land use, with a result expressed in tons CO_2/yr.

4.7.4.2. CH_4 Emissions from grazing animals

To estimate the emissions of CH_4 due to the presence of grazing animals in the pilot area, the procedure is divided into two sections: one for the domestic animals, and one for the wild grazers. In this case, also a reliable estimate of the number of domestic animals present and/or a population estimate for wild grazers is necessary. Therefore, the Eurostat database on was used to extract the information on the heads of domestic animals counted per hectare (Eurostat, 2020a) in the NUTS2 regions (Eurostat, 2019). Otherwise, the information was provided by the pilot area owners. Besides that, the estimation of emitted CH_4 from domestic grazers requires Tables 10.10 and 10.11 of Chapter 10 of the IPCC reports (FAO, 2006), which present the information on the emission factors in [kgCH_4/head/yr]. By knowing the number of grazers' heads, it is possible to calculate the emissions of CH_4 in one hectare per year [tons CH_4/ha/yr] due to domestic grazers, by multiplying that value times the emission factor corresponding to the grazer type and adjusting the units of measure.

The same procedure used for the domestic grazers was used for the wild grazers. The emission factors for this section are not provided by the IPCC reports but are found in the TESSA Toolkit (Peh et al., 2013). To provide a reliable value of wild grazers heads present in the pilot area each year, the estimates were provided by local partners and were not extracted from publicly available statistics.

Finally, the emissions from both kinds of grazers were summed up into one value to express the total emissions of CH_4 per year caused by the presence of grazers in the pilot area. The estimate of CH_4

emissions from grazers was then assumed to be present only on the grass-dominated sections of the pilot areas.

4.7.4.3. CH_4 emissions from wetlands

Important to estimate the CH_4 emissions from wetlands is to know the type of wetland that characterizes the pilot area. For this, the optimal way to import this information into the tool is by creating a shapefile of the wetlands divided according to their different categories. The shapefile should include:

- Habitat Class: in this case, it will always be a wetland dominated habitat or a rice field;
- The wetland category:
    - Natural inland;
    - Managed drained;
    - Managed not drained;
- Specified characteristics of the category:
    - Position of the water table for the natural inland wetlands:
        - Distance to water table more than 20 cm;
        - Distance to water table less than 20 cm;
    - For the managed drained wetlands, whether they have been:
        - Rewetted;
        - Not rewetted;
    - For the managed not drained wetlands, whether the wetland is:
        - Flooded;
        - Used for wastewater treatment;
- The presence of shunts in the wetland (only where the water table > 20 cm).

The estimation of emitted CH_4 from natural wetlands requires the table of the emission factors taken from the TESSA Toolkit (Peh et al., 2013), which presents the information on the emission factors in [kgCH_4/head/yr]. For the other wetland types, Tables 2.3 and 3.3 from the IPCC reports (IPCC, 2014) are used to get the emission factors of "Drained not rewetted" and "Drained and rewetted" wetlands respectively. For "Managed not drained wetlands", only the case of flooded wetlands was used so far. This requires the IPCC table 3.A.2 from the IPCC Report's Volume 4's "Appendix 3: CH_4 Emissions from Flooded Land: Basis for Future Methodological Development" (IPCC, 2006).

4.7.4.4. N_2O emissions from agriculture

An excursion from the TESSA's methodology was done for the estimation of the N_2O, due to the complexity of the tasks and to the high requirements of data. The alternative to the TESSA-suggested methods was the use of FAO estimated data that were found on the FAOSTAT data portal (FAO, 2019). The FAO dataset requires the following information to extract the emissions information:

- Desired year for the statistics, now set at "2017" by default;
- Source of the N_2O emissions, here set as "Agriculture total";
- The country in which the pilot area is located.

This requires the information on the agricultural land area which was extracted from the CORINE 2018 (EEA, 2019) with code 2 of the first detail level. The raster was then used to extract the area size of croplands in the corresponding country of the pilot area. The emissions for the whole country per year [tons N_2O/yr] were then scaled to the pilot area assuming that the crop-dominated and the grass-dominated areas are emitting N_2O (the total agriculture emissions come from the use of fertilizers and from the grazing animals that are located in the grass-dominated areas).

For all other habitat types, it was assumed that no N_2O emissions are produced.

4.7.4.5. CO_2 equivalent and overall GHG flux

For each separate habitat at the site, we put together all annual greenhouse gas fluxes and express them in a single figure. This required the following steps.

First, the carbon sequestration from trees was considered. Since each atom of carbon sequestered represents one molecule of CO_2 removed from the atmosphere, we expressed the net carbon sequestration (tons C y-1) and in terms of CO_2 (tons CO_2y-1) by multiplying the values by $\frac{44}{12}$. This is because the molecular weights of C and O are 12 and 16 respectively.

In a second step, the estimations of emissions and sequestrations were converted to carbon dioxide equivalents, so that they could be added together to calculate the overall greenhouse gas flux. In the case of the Danube Floodplain Project, no climate-carbon feedbacks were considered, being the GWP_{100} for methane 28, for nitrous oxide 265, and for carbon dioxide 1.

Third, all values were summed over the area from which the emissions are estimated, to get a singular value that can be used for the extended CBA.

4.8 Monetary value of Carbon storage and GHGs flux

We calculated the corresponding monetary value of the stored carbon and the GHGs flux by multiplying the estimated CO_2 equivalents times the values of the CO_2 emissions taxation systems documented in the report of the World Bank (World Bank, 2020b). The Slovenian Carbon tax rounded up to the nearest integer is 19 USD^{2020} per metric tons of carbon dioxide equivalent (tCO2e) (World Bank, 2020b) as well as the European Union (EU) Emissions Trading System (ETS) for the year 2020 (World Bank, 2020a). In the previous years, the EU ETS values were 16 USD^{2020} per tCO2e in 2018 and 25 USD^{2020} per tCO2e in 2019 (World Bank, 2020a). Since the overarching framework of the international carbon market remains unclear and decisions for future prices in the EU are postponed to 2021 (World Bank, 2020b), we used the values from 2018 (16 USD^{2020}/tCO2e) and 2019 (25 USD^{2020}/tCO2e) to estimate error calculations of the values of stored carbon and GHGs flux services.

4.9 Cultivated goods

The estimation of cultivated goods ESS was divided into three parts, based on the most important (and possible to estimate) provided goods: agricultural, livestock, and aquaculture goods. In the analysis, we tried to follow the TESSA guidelines (Peh et al., 2013) as much as possible, according to the data availability.

4.9.1. Input data

The necessary input data for agriculture and livestock ESS provisioning come from FAOSTAT tables:

- for agriculture: national market prices of primary crop products;
- for livestock: number of livestock heads at the national level, the quantity of livestock primary products at the national level, national market prices of primary livestock products.

The necessary input data for aquaculture ESS provisioning come from Eurostat tables:

- quantity of aquaculture primary products at the NUTS2 level;
- market prices of primary aquaculture products at the NUTS2 level.

Fundamental for the estimations was also the use of spatial data from EarthStat (Monfreda et al., 2008) raster files of the harvested areas, one file for each indicated most important crops, and of the yield, one file for each indicated most important crops.

4.9.2. Agricultural products

The basic knowledge of the crop types present in the pilot area was provided by the local authorities. The spatial extension of the agricultural production areas was given instead by the stakeholder ESS maps on cultivated goods. From the list of crop types, we used two maps per crop type published by EarthStat (Monfreda et al., 2008):

1. A raster map of the harvested hectares [ha/pixel];
2. A raster map of the yield [tons/ha].

The EarthStat maps were created by combining national, state, and county-level census statistics with a global data set of croplands on a 5 by 5 minutes (~10 km by 10 km) latitude/longitude grid. The resulting datasets depict circa the year 2000 of 175 distinct crops of the world (Monfreda et al., 2008). The two maps were then used to extract the average value of harvested hectares and of yielded crop per each entry of the stakeholders' ESS shapefile with a recognized ESS = "agricultural product" for all crop types. With this information, it was then possible to calculate the total yield of each listed crop type for the selected areas in tons per year.

The ESS value of crop production was then estimated with the market-based valuation methodology of market prices. The necessary data are found in the "Trade - Crops and livestock products" section of the FAOSTAT database (FAO, 2019), which provides the producer prices per unit [USD/ton]. We extracted the data from the uploaded FAOSTAT table and calculated the total earnings of crop cultivation in the pilot area by multiplying the market prices times the production for each crop type.

In case the product did not show a price in the FAOSTAT tables for the specific country, we took an average of the prices of the other Danube countries for the years 2016 to 2018.

4.9.3. Livestock products

The basic knowledge of the livestock species present in the pilot area should be provided by the user. The spatial extension of the "animal" production areas is given instead by the stakeholder ESS map on cultivated goods. Due to the missing data from the local stakeholders, this section uses as input data the national data from the FAOSTAT database (FAO, 2019) that are then scaled according to the size of the area recognized by the stakeholders (in the stakeholder ESS map).

The tables used from FAOSTAT provide:

- livestock quantity [Number of stock's heads];
- primary production according to livestock type and product [ton];
- market prices of primary livestock products [USD/ton] (example in Annex A2)

The ESS value of livestock products is estimated with the market-based valuation methodology of market prices. The necessary data are found in the "Trade - Crops and livestock products" section of the FAOSTAT database (FAO, 2019), which provides the producer prices per unit [USD/ton]. In case, the product does not show a price in the FAOSTAT tables for the specific country, the code makes an average of the prices of the other Danube countries for all provided years (2016 to 2018).

4.9.4. Aquaculture

The basic knowledge on the fish species cultivated in aquaculture in the pilot area was provided by the pilot area owners. The spatial extension of the fish production areas was given by the stakeholder ESS map on cultivated goods. Due to the missing data from the local stakeholders, this estimation used as input data, the national data from the Eurostat database (Eurostat, 2020b) that were then scaled according to the size of the area recognized by the ESS map. The Eurostat tables provide information on the fish production in tons liveweight produced per year and on the revenue of the fish production in each European country in Euros (from the first transaction) per year.

4.9.5. Uncertainty estimation of cultivated goods

To estimate the results' uncertainty boundaries, we used the minimum and maximum national statistics values of primary production (for livestock goods), producer prices (for agricultural goods), or both (for aquaculture goods) in the periods 2014 to 2018 (for agricultural and livestock goods) or 2008 to 2017 (for aquaculture goods).

4.10 Nutrients retention

Although some steps overlap with the guidelines, the estimation of the nutrients retention by the floodplains did not follow TESSA because we did not have access to measured data of water quality upstream and downstream of the studied floodplain areas. Instead, we analyzed the data from the DanubeGIS (ICPDR, 2020) of total nitrogen (TN) measurements at the Danube and its tributaries and combined them with our knowledge on the presence of active floodplains in the DRB (Danube Transnational Programme, 2020). We analyzed comparable measurements (5 days of buffer) between upstream and downstream of the floodplains and obtained an average value of TN retention of floodplains as 1.51 mg N/l and of $1.69 \cdot 10^{-4}$ mg N/l/ha (Figure 7).

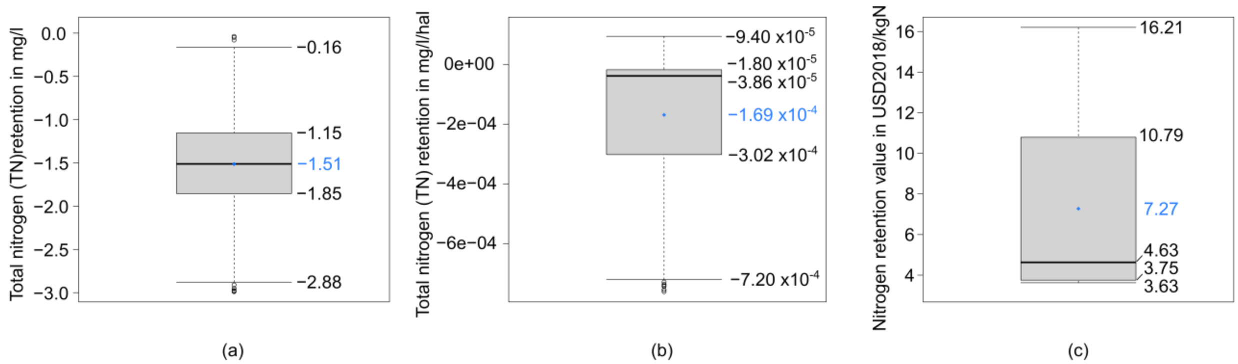


Figure 7. Boxplots of the variables used to estimate the retention of nutrients from the floodplains (blue points and values indicate the average value): (a)-(b) total nitrogen (TN) retention in the Danube (representation without outliers) in terms of measured retained concentrations (in mg/l) downstream from upstream of Danube active floodplains (a) and in terms of measured retained concentrations per unit area of the active floodplains (in mg/l/ha) (b); (c) value of the nutrients retention ecosystem service according to the database set up by Perosa et al. (2021a) on the values of Danube floodplains' ecosystem services (in USD^{2018}/kg N). Adapted from Perosa et al. (2021b).

To understand the TN retention of the whole floodplain, i.e. to scale the value in mg N/l/ha to a total value of retained kg TN, we needed the volume of water filtered by the floodplain per year. Therefore, we took the floodplains' activated volume that we simulated for extreme flood events (HQ2 to HQ5, HQ10 to HQ20, and HQ100) and calculated the expected annual retention volume (EARV) with the trapezoid method, as shown in the following function:

$$EARV = \frac{1}{2}\sum_{i=1}^{n}\left[\left(\frac{1}{T_i} - \frac{1}{T_{i+1}}\right)(RV_i + RV_{i+1})\right] + \frac{RV_n}{RV_n}, \qquad (6)$$

where $n = 3$ is the number of return periods, T is the return period in years, and RV is the corresponding retention volume. The specific values of T (together with their corresponding lower and upper uncertainty boundaries) and RV for each pilot area can be found in Table 5 and Table 8 respectively. The estimation is valid under the assumption that the volume that is additionally retained by the restored floodplain in comparison to the CS scenario is also the volume that is additionally filtered by the floodplain.

To attribute a monetary value to the TN retention of the floodplain, we applied the benefit transfer (BT) method by using the database of floodplains' ESS values in the DRB and its intersecting countries (Perosa et al., 2021a). We used only the values expressed in USD^{2018}/kg N and applied their average of 7.27 USD^{2018}/kg N (Figure 7) to the estimated annual quantity of retained TN for each pilot area. To estimate the corresponding errors, we applied the values 3.75 USD^{2018}/kg N and 10.79 USD^{2018}/kg N, being these the first and third quartiles of the benefit transfer values respectively.

Table 8. Retention volumes RV associated to a number of return periods (T) of $n = 3$. The RV values were used for the retention volume estimation of the current state (CS) and restoration scenario (RS) of all four study areas, according to formula (6).

	Begecka Jama			Bistret			Krka			Morava		
	RV_1	RV_2	RV_3	RV_1	RV_2	RV_3	RV_1	RV_2	RV_3	RV_1	RV_2	RV_3
CS [m³]	4.19×10^7	5.54×10^7	6.07×10^7	3.02×10^8	3.53×10^8	3.96×10^8	1.43×10^7	1.87×10^7	2.67×10^7	7.40×10^7	7.87×10^7	8.61×10^7
RS1 [m³]	4.21×10^7	5.55×10^7	6.08×10^7	3.02×10^8	3.71×10^8	5.21×10^8	1.44×10^7	1.88×10^7	2.66×10^7	5.86×10^7	6.50×10^7	7.40×10^7
RS2 [m³]	4.50×10^7	5.82×10^7	6.36×10^7	5.87×10^8	8.06×10^8	9.88×10^8	1.42×10^7	1.88×10^7	2.65×10^7	7.26×10^7	8.04×10^7	9.13×10^7

4.11 Nature-based recreation

Following TESSA's guidelines, the individual travel cost method (ITCM) was applied to assess the nature-based recreation (e.g. exercising, experiencing nature, etc.) provided by the floodplain areas and their restoration. As a response to the COVID-19 pandemic and its consequent travel restrictions (Süddeutsche Zeitung, 2020), this method was based on interviews that were conducted online through LimeSurvey (LimeSurvey GmbH) from 7th August 2020 to 1st September 2020 for the pilot areas Begecka Jama, Krka, and Morava, and from 5th November 2020 to 31st December 2020 for the Bistret pilot area. We used Facebook events (Facebook Inc., 2020a) and Instagram (Facebook Inc., 2020b) posts (with hashtags related to the pilot areas) to advertise the survey (in locations with a radius of 20 km around Begecka Jama, 20 km around Kostanjevica na Krki, 40 km around Lanzhot for Morava, and 40 km around Bistret). To retrieve data on the restoration scenarios, the interviews included a section in which the respondents described their potential reaction to the hypothetical floodplain restorations. A template of the interviews can be found in Annex A3. The ITCM requires as input data the count of the visits of an individual to a site in a year, the corresponding travel cost (TC) to the site (sum of the cost to get to the site with fuel prices for each country from the European Commission (IEA, 2020) and additional expenses), and can include other characteristics (e.g. age, education level, etc.). As described for example in Hanauer and Reid (2017) or Borzykowski et al. (2017), each respondent was represented by applying the function of equation (7):

$$number\ of\ visits\ per\ year = \alpha + \beta \times TC + \gamma \times age \qquad (7)$$

where α is the intercept, and β and γ are the coefficients estimates. Based on the fitted Poisson model, the consumer surplus per visit was calculated as the negative inverse of the constant (-1/β) of the TC variable. Multiplying the consumer surplus by the total number of visits gave a total consumer surplus for the site. To estimate the results' uncertainty boundaries, we propagated the lower and upper boundaries derived from the standard error of the β coefficients. The total number of visits was retrieved from additional e-mail conducted interviews (Nisavic, 08/18/2020; Krhin, 08/17/2020; Bártek, 08/19/2020; Motyčková, 08/17/2020) and personal communication with local authorities (Čechová, 08/25/2020).

5. Conclusions

This deliverable presents the methodologies followed to include ecosystem services in a standard cost-benefit analysis (CBA), resulting in the extended cost-benefit analysis. The deliverable shows the methodology followed to estimate six ecosystem services types: flood mitigation, carbon storage, greenhouse gases sequestration, cultivated goods provisioning, and nature-based recreation. Moreover, we show how the co-benefits of floodplain restoration measures can be estimated in monetary values and discounted, to obtain commonly used parameters in CBA analyses.

Deliverable D 4.3.1 (Danube Floodplain, 2021) presents the outcomes of applying the methodology to four pilot areas of the Danube Floodplain Project (Begecka Jama, Bistret, Krka, and Morava) and discusses its implications for the results.

References

ANDERSON-TEIXEIRA KJ, DeLUCIA EH. The greenhouse gas value of ecosystems. Global Change Biology 2011;17(1):425–38.

Bártek V. Questions on the Nature-Based Recreation around the Morava River. E-mail, 08/19/2020.

Baveye PC, Baveye J, Gowdy J. Monetary valuation of ecosystem services: It matters to get the timeline right. Ecological Economics 2013;95:231–5.

Borzykowski N, Baranzini A, Maradan D. A travel cost assessment of the demand for recreation in Swiss forests. Rev Agric Food Environ Stud 2017;98(3):149–71.

Brouwer R, Sheremet O. The economic value of river restoration. Water Resources and Economics 2017;17:1–8.

Čechová A. Characteristics of the Morava pilot area. E-mail, 08/25/2020.

Chaudhary S, McGregor A, Houston D, Chettri N. The evolution of ecosystem services: A time series and discourse-centered analysis. Environmental Science & Policy 2015;54:25–34.

Danube Floodplain. D 4.2.1. Report about the stakeholder analysis, their interests and their benefits from the floodplains in the pilot areas resulting from the workshops; 2019.

Danube Floodplain. D 4.1.1. Report on the technical realization scenarios taken into consideration for modelling, the implementation in a 2D model and assessment of the impact; 2020a.

Danube Floodplain. D 4.2.2. Report, database and maps of ESS analysis of the pilot areas including a list, description, assessment, and ranking concerning the demands and supplies; 2020b.

Danube Floodplain. 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; 2021.

Danube Transnational Programme. Interreg Danube Floodplain: Reducing the flood risk through floodplain restoration along the Danube River and tributaries, 2020. http://www.interreg-danube.eu/approved-projects/danube-floodplain/outputs?page=1 (accessed 2020).

Dittrich R, Ball T, Wreford A, Moran D, Spray CJ. A cost-benefit analysis of afforestation as a climate change adaptation measure to reduce flood risk. J Flood Risk Management 2019;12(4).

EEA. Corine Land Cover (CLC) 2018, 2019. https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=metadata.

European Commission. Eurostat, 2020. https://ec.europa.eu/eurostat/home? (accessed 2020).

Eurostat. NUTS 2016: European Union; 2019.

Eurostat. Main livestock indicators by NUTS 2 regions: Eurostat Statistical Database; 2020a ef_lsk_main.

Eurostat. Production from aquaculture excluding hatcheries and nurseries (from 2008 onwards): Eurostat Statistical Database; 2020b fish_aq2a.

Facebook Inc. Facebook, 2020a. https://www.facebook.com (accessed 2020).

Facebook Inc. Instagram, 2020b. https://www.instagram.com/ (accessed 2020).

FAO. Planted forests database (PFDB): Structure and Contents. Rome: Forest Resources Development Service, Forest Resources Division, FAO; 2003. Planted Forests and Trees Working Papers 25.

FAO. Global Forest Resources Assessment 2005: Progress towards sustainable forest management. Rome: Food and Agriculture Organization of the United Nations; 2006.
FAO. Global Forest Resources Assessment 2015: How are the world's forests changing?; 2016.
FAO. FAOSTAT: Statistical Database. Rome: FAO; 2019.
FAO and ITPS. Global Soil Organic Carbon Map (GSOCmap): Technical Report. Rome: FAO and ITPS; 2018.
Feuillette S, Levrel H, Boeuf B, Blanquart S, Gorin O, Monaco G et al. The use of cost–benefit analysis in environmental policies: Some issues raised by the Water Framework Directive implementation in France. Environmental Science & Policy 2016;57:79–85.
GitHub. TESSA4QGIS, 2020. https://github.com/FPerosa/TESSA4QGIS (accessed 2021).
Grizzetti B, Lanzanova D, Liquete C, Reynaud A, Cardoso AC. Assessing water ecosystem services for water resource management. Environmental Science & Policy 2016;61:194–203.
Guida RJ, Swanson TL, Remo JWF, Kiss T. Strategic floodplain reconnection for the Lower Tisza River, Hungary: Opportunities for flood-height reduction and floodplain-wetland reconnection. Journal of Hydrology 2015;521:274–85.
Hanauer MM, Reid J. Valuing urban open space using the travel-cost method and the implications of measurement error. Journal of environmental management 2017;198(Pt 2):50–65.
Hein L, van Koppen CSA, van Ierland EC, Leidekker J. Temporal scales, ecosystem dynamics, stakeholders and the valuation of ecosystems services. Ecosystem Services 2016;21:109–19.
Huizinga J, Moel Hd, Szewczyk W. Global flood depth-damage functions: Methodology and the database with guidelines: Joint Research Centre (JRC); 2017.
ICPDR. Flood Risk Management Plan for the Danube River Basin District. Vienna, Austria: ICPDR; 2015.
ICPDR. Danube River Basin Water Quality Database, 2020 (accessed 2019). http://www.icpdr.org/wq-db/.
IEA. Fuel Consumption of Cars and Vans – Analysis, 2020. https://library.wmo.int/doc_num.php?explnum_id=7332 (accessed 2020).
IPCC, editor. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Hayama, Japan: Institute for Global Environmental Strategies; 2006.
IPCC, editor. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Switzerland: IPCC; 2014.
Jeuland MA, Pattanayak SK. Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest and climate impacts. PloS one 2012;7(2):e30338.
Krhin M. Questions on the Nature-Based Recreation around the Krka River. E-mail, 08/17/2020.
LimeSurvey GmbH. LimeSurvey: An Open Source survey tool. Hamburg, Germany: Limesurvey GmbH.
Logar I, Brouwer R, Paillex A. Do the societal benefits of river restoration outweigh their costs? A cost-benefit analysis. Journal of environmental management 2019;232:1075–85.
Monfreda C, Ramankutty N, Foley JA. Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. Global Biogeochem. Cycles 2008;22(1):n/a-n/a.

Monge JJ, Daigneault AJ, Dowling LJ, Harrison DR, Awatere S, Ausseil A-G. Implications of future climatic uncertainty on payments for forest ecosystem services: The case of the East Coast of New Zealand. Ecosystem Services 2018;33:199–212.

Motyčková K. Questions on the Nature-Based Recreation around the Morava River. E-mail, 08/17/2020.

Nisavic J. Nature Park Begecka Jama. E-mail, 08/18/2020.

Olsen A, Zhou Q, Linde J, Arnbjerg-Nielsen K. Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments. Water 2015;7(12):255–70.

Peh KS-H, Balmford A, Bradbury RB, Brown C, Butchart SHM, Hughes FMR et al. TESSA: A toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance. Ecosystem Services 2013;5:51–7.

Peh KS-H, Balmford AP, Bradbury RB, Brown C, Butchart SHM, Hughes FMR et al. Toolkit for Ecosystem Service Site-based Assessment (TESSA). Cambridge, UK; 2017.

Perosa F, Fanger S, Zingraff-Hamed A, Disse M. A Meta-Analysis of the Value of Ecosystem Services of Floodplains for the Danube River Basin. Science of the Total Environment 2021a:146062.

Perosa F, Gelhaus M, Zwirglmaier V, Arias-Rodriguez LF, Zingraff-Hamed A, Cyffka B et al. Integrated Valuation of Nature-Based Solutions Using TESSA: Three Floodplain Restoration Studies in the Danube Catchment. Sustainability 2021b;13(3):1482.

Petz K, Minca EL, Werners SE, Leemans R. Managing the current and future supply of ecosystem services in the Hungarian and Romanian Tisza River Basin. Reg Environ Change 2012;12(4):689–700.

QGIS.org. QGIS Geographic Information System: Open Source Geospatial Foundation Project; 2020.

Sartori D. Guide to cost-benefit analysis of investment projects: Economic appraisal tool for cohesion policy 2014 - 2020. 2014th ed. Luxembourg: Publ. Office of the Europ. Union; 2015.

Schägner JP, Brander L, Maes J, Hartje V. Mapping ecosystem services' values: Current practice and future prospects. Ecosystem Services 2013;4:33–46.

Süddeutsche Zeitung. Massive Ausgangsbeschränkungen für ganz Bayern ab Samstag, 2020 Mar 20 (accessed September 02, 2020). https://www.sueddeutsche.de/gesundheit/gesundheit-muenchen-massive-ausgangsbeschraenkungen-fuer-ganz-bayern-ab-samstag-dpa.urn-newsml-dpa-com-20090101-200320-99-404727.

Terrado M, Momblanch A, Bardina M, Boithias L, Munné A, Sabater S et al. Integrating ecosystem services in river basin management plans. J Appl Ecol 2016;53(3):865–75.

World Bank. Carbon Pricing Dashboard: Up-to-date overview of carbon pricing initiatives, 2020a. https://carbonpricingdashboard.worldbank.org/map_data (accessed September 08, 2020).

World Bank. State and Trends of Carbon Pricing 2020: (May). Washington, DC; 2020b.

Annex A1. Damage functions

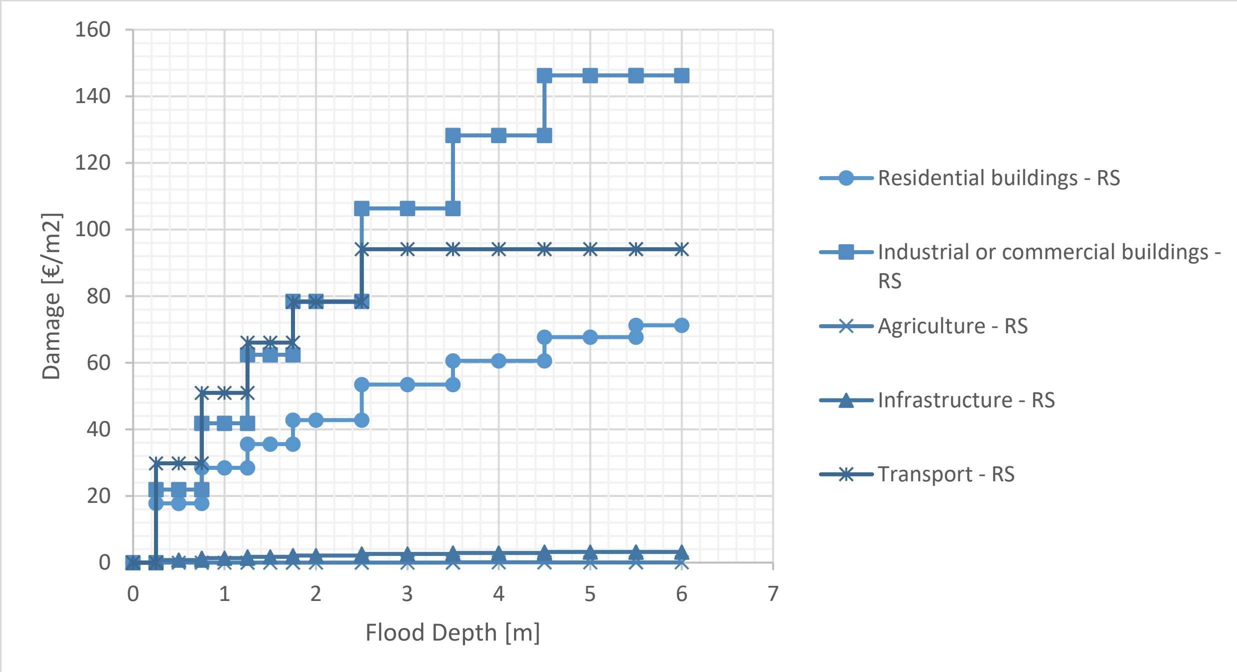


Figure A1.1. Damage functions for Begecka Jama (Huizinga et al., 2017)

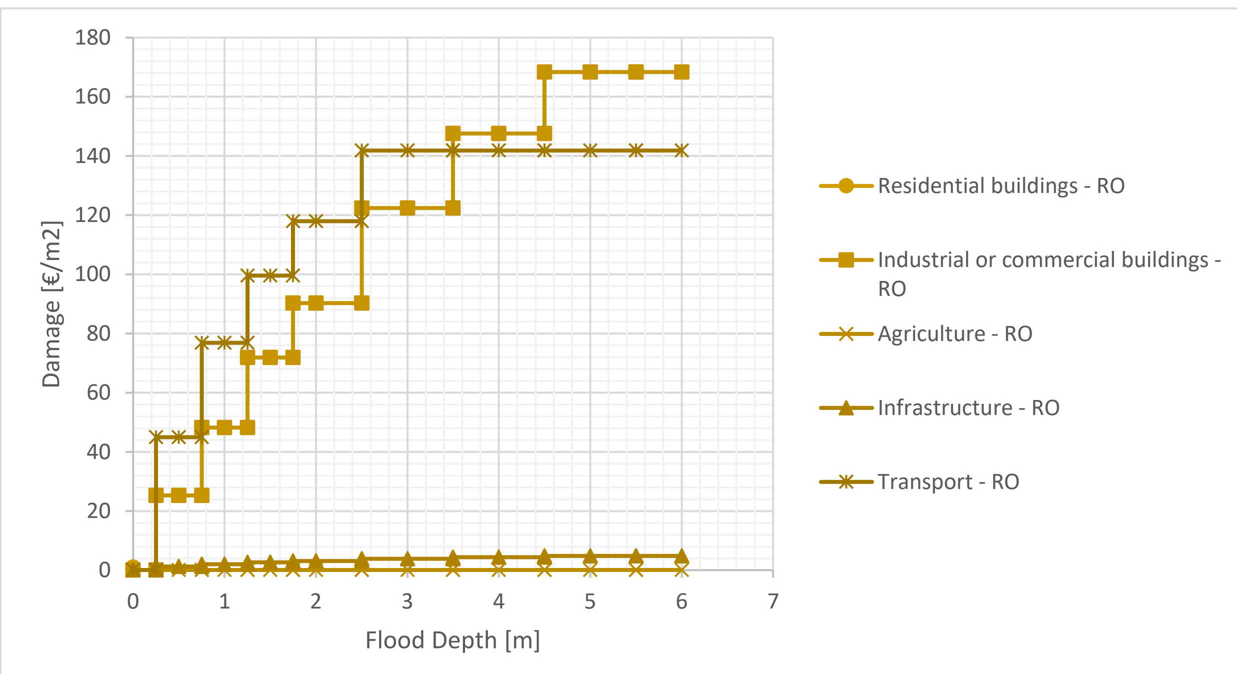


Figure A1.2. Damage functions for Bistret (Huizinga et al., 2017)

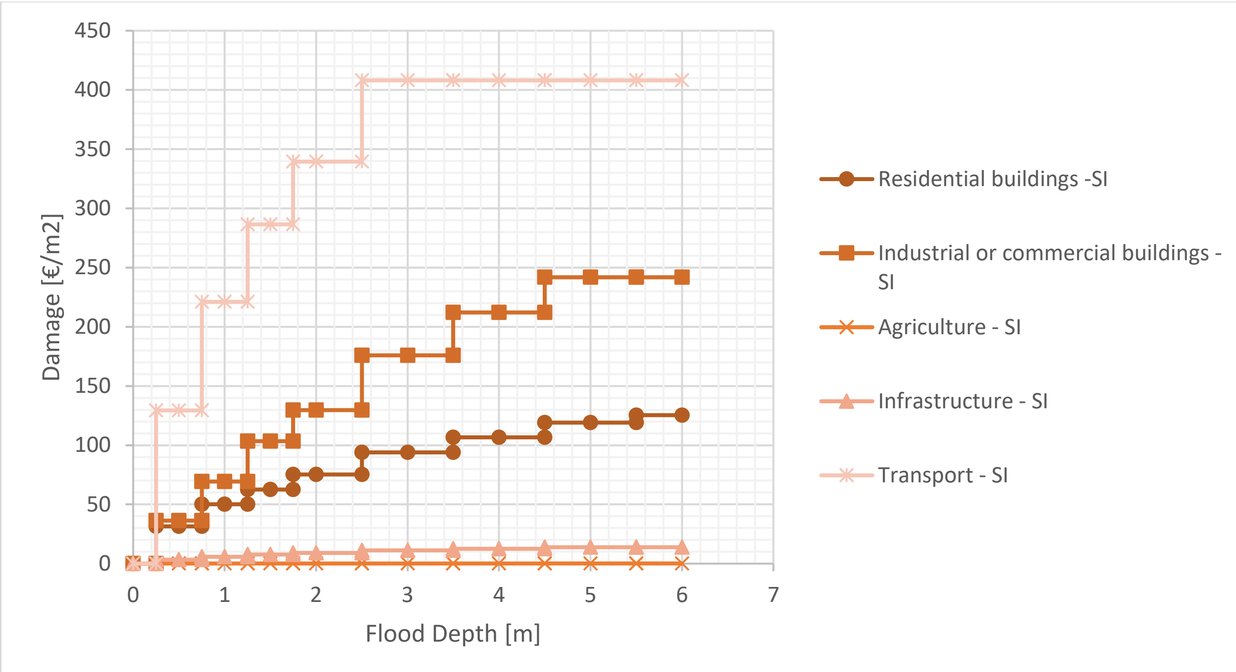


Figure A1.3. Damage functions for Krka (Huizinga et al., 2017)

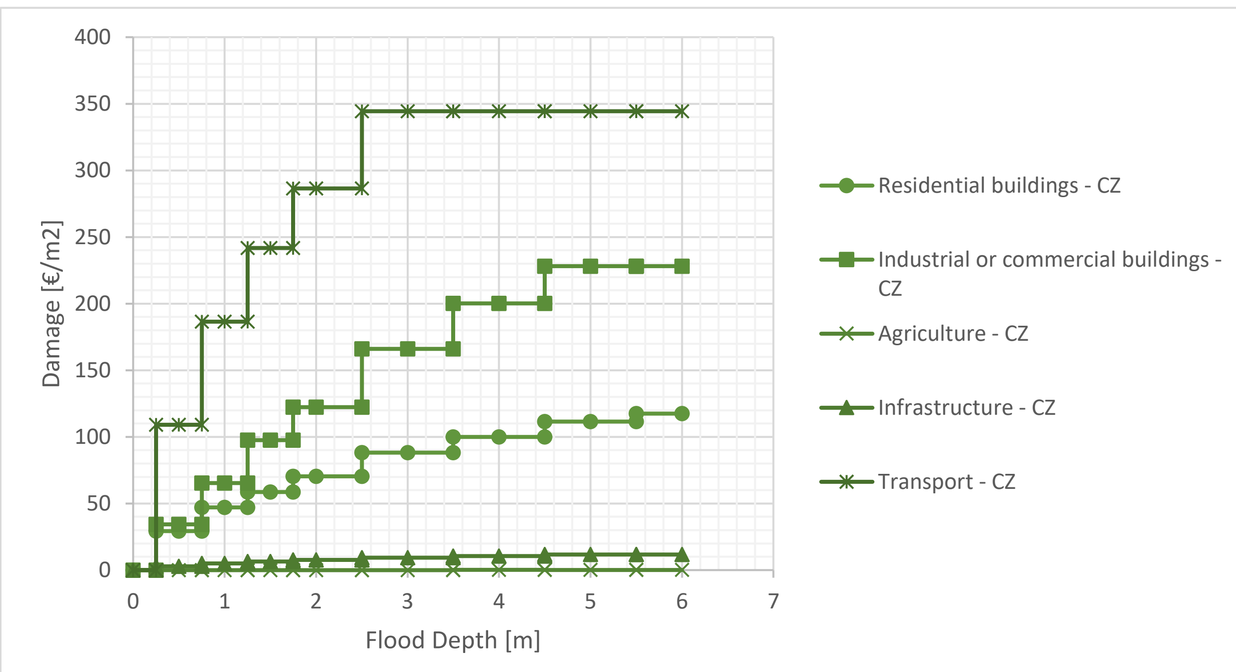


Figure A1.4. Damage functions for Morava (Huizinga et al., 2017)

Annex A2. Livestock producer prices

Table A2.1. Example of producer prices of primary livestock products in Serbia for the year 2017 expressed in USD/ton (FAO, 2019)

Item	Producer Prices [USD^{2017}/ton]
Eggs, hen, in shell	1586.90
Honey, natural	2796.90
Meat live weight, cattle	2015.40
Meat live weight, chicken	1037.10
Meat live weight, pig	1535.60
Meat live weight, sheep	2325.00
Meat, cattle	3802.70
Meat, chicken	1382.80
Meat, pig	1968.70
Meat, sheep	4008.60
Milk, whole fresh cow	282.60
Milk, whole fresh goat	500.10
Milk, whole fresh sheep	715.30
Wool, greasy	1054.10

Annex A3. Questionnaires for nature-based solutions

Interviews conducted online for the individual travel cost method in Begecka Jama.

As part of a research project, we are looking at how people enjoy the Danube river ecosystem. In particular, we are analyzing the site Begečka Jama, close to the Begeč village (RS) (https://www.google.com/maps/@45.2216434,19.5939344,14z) in its current state and looking at what people think about hypothetical ecosystem restoration scenarios. We would be very grateful if you could answer a few questions. We will not ask for any personal data, and any responses will be stored securely and you won't be able to be identified from this study. If you want to know more about the project, you can visit the website http://www.interreg-danube.eu/approved-projects/danube-floodplain.

Section A: Part 1-Current State

A1. **From the following options what are the two <u>most</u> important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A2. **From the following options what are the two least important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A3. How frequently do you visit this site?

- First visit ☐
- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A4. For first time visitors only: How frequently do you predict to visit this site in the future?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A5. How often do you visit the river/floodplain area in a typical month (including this site)?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Less than monthly ☐

A6. How many kilometers do you usually travel to the site?

A7. **How much money do you spend during a typical trip to this site? Please state also the currency**

Parking Fee

Restaurant/Café

HOtel/Accomodation

Other

Section B: Part 2

During the research project, hypothetical restoration strategies are investigated at the site and how they would, in theory, affect its ecosystem services. One strategy would widen and deepen the existing river channels. By doing this, better habitats for fishes would be created and a more natural appearance of the river would be created.

B1. **In this case and if your own circumstances were the same, would you still visit this site?**

Yes ☐

No ☐

B2. **If yes, how often do you think you would visit?**

Daily ☐

2-3 times a week ☐

Weekly ☐

Fortnightly ☐

Monthly ☐

Four times a year ☐

Twice a year ☐

Once a year ☐

Less than once a year ☐

Section C: Part 3

The alternative strategy would think the theory even further than the first one (Part 21). Not only existing channels would be restored but also new channels would be created, so that even more habitats would exist. The appearance of the river would be even more natural and diverse.

1 The first strategy would widen and deepen the existing river channels. By doing this, better habitats for fishes would be created and a more natural appearance of the river would be created

C1. In this case and if your own circumstances were the same, would you still visit this site?

- Yes ☐
- No ☐

C2. If yes, how often do you think you would visit?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

Section D: Part 4

And finally two short questions for the statistics

D1. How old are you? ☐

D2. What is your gender?

- Diverse ☐
- Female ☐
- Male ☐

Interviews conducted online for the individual travel cost method in Bistret.

As part of a research project, we are looking at how people enjoy the Danube river ecosystem. In particular, we are analyzing the site close to the city Bistret (RO) (https://www.google.com/maps/@43.8479695,23.4049111,12.25z) in its current state and looking at what people think about hypothetical ecosystem restoration scenarios. We would be very grateful if you could answer a few questions. We will not ask for any personal data, and any responses will be stored securely and you won't be able to be identified from this study. If you want to know more about the project, you can visit the website http://www.interreg-danube.eu/approved-projects/danube-floodplain.

Section A: Part 1 - Current State

A1. **From the following options what are the two most important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A2. **From the following options what are the two least important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A3. **How frequently do you visit this site?**

- First visit ☐
- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A4. **For first time visitors only: How frequently do you predict to visit this site in the future?**

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A5. **How often do you visit the river/floodplain area in a typical month (including this site)?**

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Less than monthly ☐

A6. **How many kilometers do you usually travel to the site?**

A7. **How much money do you spend during a typical trip to this site? Please state also the currency**

Parking Fee

Restaurant/Cafe

Hotel/Accomodation

Other

Section B: Part 2

During the research project, different hypothetical restoration strategies are investigated at the site and how they would, in theory, affect its ecosystem services. For the first strategy, the plan is to implement different measures:

to build a recreational and fish farming lake in the Rast area, to relocate the dikes in the confluent area Desnatui river and Bistret lake, and to create a large water channel to supply Lake Bistret and to facilitate the natural flow of Desnatui river back in the Danube.

B1. **In this case and if your own circumstances were the same, would you still visit this site?**

Yes ☐

No ☐

B2. **If yes, how often do you think you would visit?**

Daily ☐

2-3 times a week ☐

Weekly ☐

Fortnightly ☐

Monthly ☐

Four times a year ☐

Twice a year ☐

Once a year ☐

Less than once a year ☐

Section C: Part 3

The alternative hypothetical strategy would include, in addition to the measures of the first strategy from Part 21, the relocation of the dike from the Danube closer to the villages along the alluvial terraces.

1 For the first strategy, the plan is to implement different measures: to build a recreational and fish farming lake in the Rast area, to relocate the dikes in the confluent area Desnatui river and Bistret lake, and to create a large water channel to supply Lake Bistret and to facilitate the natural flow of Desnatui river back in the Danube.

C1. In this case and if your own circumstances were the same, would you still visit this site?

- Yes ☐
- No ☐

C2. If yes, how often do you think you would visit?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

Section D: Partea 4

And finally two short questions for the statistics

D1. How old are you? ☐☐

D2. What is your gender?

- Female ☐
- Male ☐

Interviews conducted online for the application of the individual travel cost method in Krka.

As part of a research project, we are looking at how people enjoy the Krka river ecosystem. In particular, we are analyzing the site close to the city Kostanjevica na Krki (SI) (https://www.google.com/maps/@45.8796333,15.3530745,12.31z) in its current state and looking at what people think about hypothetical ecosystem restoration scenarios. We would be very grateful if you could answer a few questions. We will not ask for any personal data, and any responses will be stored securely and you won't be able to be identified from this study. If you want to know more about the project, you can visit the website http://www.interreg-danube.eu/approved-projects/danube-floodplain.

Section A: Part 1-Current State

A1. **From the following options what are the two most important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A2. **From the following options what are the two least important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A3. How frequently do you visit this site?

- First visit ☐
- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A4. For first time visitors only: How frequently do you predict to visit this site in the future?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A5. How often do you visit the river/floodplain area in a typical month (including this site)?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Less than monthly ☐

A6. How many kilometers do you usually travel to the site?

A7. How much money do you spend during a typical trip to this site? Please state also the currency

Parking Fee ☐

Restaurant/Café ☐

HOtel/Accomodation ☐

Other ☐

Section B: Part 2

During the research project, different hypothetical restoration strategies are investigated at the site and how they would, in theory, affect its ecosystem services. One strategy would build three corridors so that the floodplain forest would be flooded in case of high water levels. This leads to a valuable wetland forest habitat.

B1. In this case and if your own circumstances were the same, would you still visit this site?

Yes ☐

No ☐

B2. If yes, how often do you think you would visit?

Daily ☐

2-3 times a week ☐

Weekly ☐

Fortnightly ☐

Monthly ☐

Four times a year ☐

Twice a year ☐

Once a year ☐

Less than once a year ☐

Section C: Part 3

The alternative hypothetical strategy would include not three (as in the first strategy, Part 21) but four corridors, leading to a more pronounced effect in the floodplain forest and to a more diverse habitat structure.

1 The first strategy would build three corridors, so that the floodplain forest would be flooded in case of high water levels. This leads to a valuable wetland forest habitat.

C1. In this case and if your own circumstances were the same, would you still visit this site?

- Yes ☐
- No ☐

C2. If yes, how often do you think you would visit?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

Section D: Part 4

And finally two short questions for the statistics

D1. How old are you? ☐

D2. What is your gender?

- Female ☐
- Male ☐

Interviews conducted online for the application of the individual travel cost method in Morava.

As part of a research project, we are looking at how people enjoy the Morava river ecosystem. In particular, we are analyzing the site close to Hodonín (CZ), Brodské (SK) and Hohenau an der March (AU) at the Morava river (https://www.google.com/maps/@48.7284529,17.0187231,11z) in its current state and looking at what people think about hypothetical ecosystem restoration scenarios. We would be very grateful if you could answer a few questions. If you want to know more about the project, you can visit the website http://www.interreg-danube.eu/approved-projects/danube-floodplain.

Section A: Part 1-Current State

A1. **From the following options what are the two most important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A2. **From the following options what are the two least important reasons for you visiting this site? Tick two**

- Exercise ☐
- See good scenery ☐
- Get away from it all/ tranquility ☐
- Walk the dog ☐
- Socialize ☐
- Experience nature/ wildlife ☐
- Education ☐

A3. **How frequently do you visit this site?**

- First visit ☐
- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A4. **For first time visitors only: How frequently do you predict to visit this site in the future?**

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

A5. **How often do you visit the river/floodplain area in a typical month (including this site)?**

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Less than monthly ☐

A6. **How many kilometers do you usually travel to the site?** ☐☐☐☐

A7. How much money do you spend during a typical trip to this site? Please state also the currency

Parking Fee

Restaurant/Café

Hotel/Accomodation

Other

Section B: Part 2

During the research project, it is investgated how hypothetical restoration strategies would influence ecosystem services at the site. In one strategy existing technical structures along the river course would be removed. This would give more space to the river to enter the adjacent areas in case of flooding and would create a more natural ecosystems.

B1. In this case and if your own circumstances were the same, would you still visit this site?

- Yes ☐
- No ☐

B2. If yes, how often do you think you would visit?

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

Section C: Part 3

An alternative hypothetical strategy would include, additionally to the measures described in the first strategy (Part 21), the river would be allowed to flow in a natural course. This means that the river would regain its meandering (bending) form, which improves the conditions for the habitat structure and the whole river ecosystem.

1 The first strategy would remove existing technical structures along the river course. This would give more space to the river to enter the adjacent areas in case of flooding and would create a more natural ecosystem

C1. **In this case and if your own circumstances were the same, would you still visit this site?**

- Yes ☐
- No ☐

C2. **If yes, how often do you think you would visit?**

- Daily ☐
- 2-3 times a week ☐
- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Four times a year ☐
- Twice a year ☐
- Once a year ☐
- Less than once a year ☐

Section D: Part 4

And finally two short questions for the statistics

D1. **How old are you?** ☐

D2. **What is your gender?**

- Diverse ☐
- Female ☐
- Male ☐

Annex A4. Extended cost-benefit analysis in the Middle Tisza (HU) pilot area

The following document ("ESS-CBA Decision Support Model and Methodology") shows the methodology followed for the extended cost-benefit analysis in the 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.

DANUBE FOODPLAIN PROJECT, WP 4.3:

ESS-CBA DECISION SUPPORT MODEL AND METHODOLOGY

REKK

2019 September

DANUBE FOODPLAIN PROJECT, WP 4.3:

ESS-CBA DECISION SUPPORT MODEL AND METHODOLOGY

REKK

2020

Table of Content

1 OVERVIEW

The Danube Floodplain (DF) Project faces the challenge of creating a common methodology for conducting a CBA analysis extended with Ecosystem Service valuation in an international, basin wide context. This document describes the proposed model of an extended decision support scheme that takes into consideration the most important issues to accomplish a flood risk reduction planning with a wide range of natural and social conditions to fulfil.

The diversity of the DF project sites both from a natural perspective (different river characteristics along the Danube and its tributaries) and social background (the countries of the basin operate different institutional structures and are in different income level) resulted in different planning procedures for flood risk mitigation development that the tool unanimously intends to support.

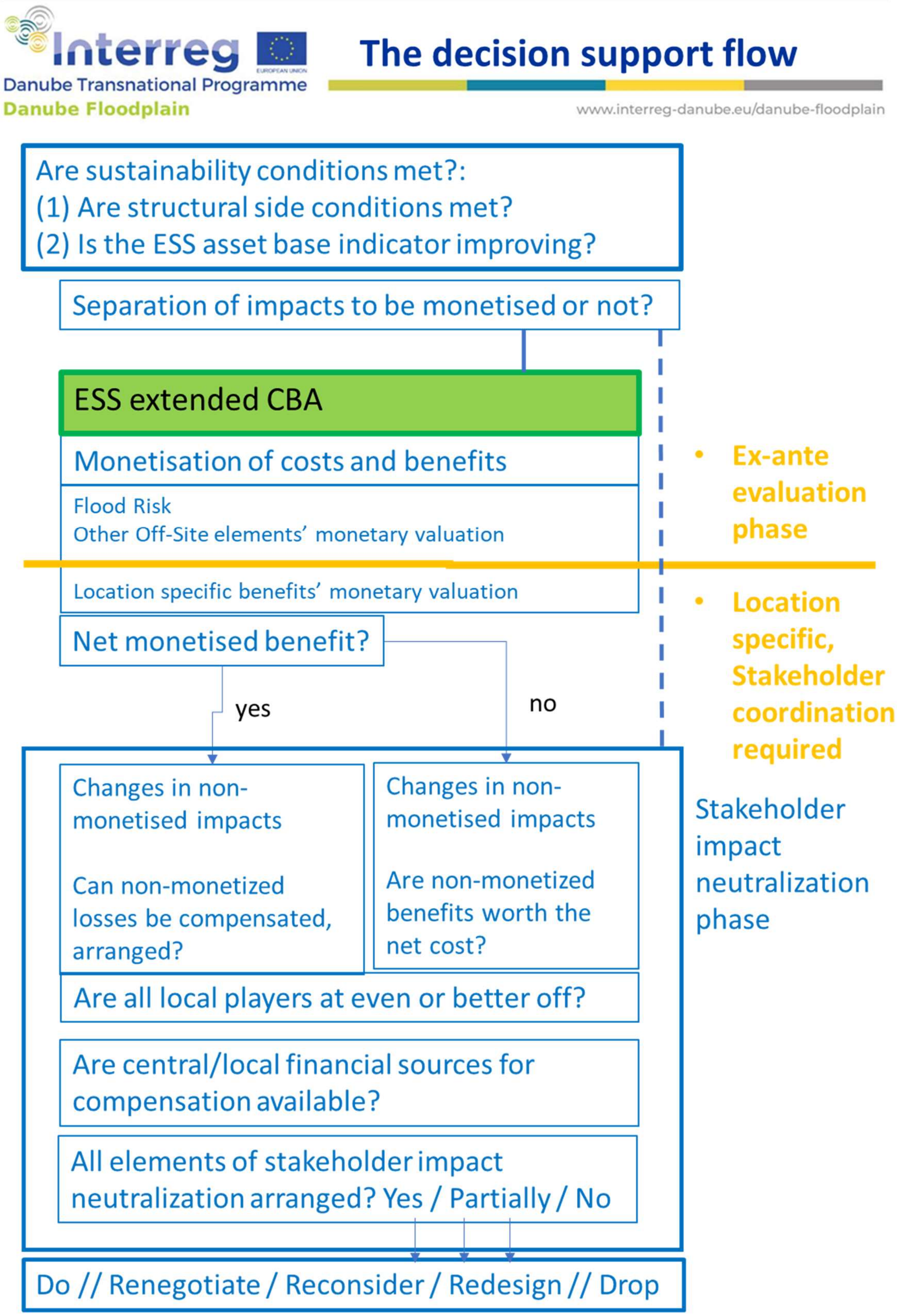
In order to fulfil this aim of social and site-specific diversity, the proposed methodology contains not just an extended CBA, but proposes a decision support flow model that includes the extended CBA and other necessary elements to satisfy the economic social and natural expectation of a good public investment decision.

The flood risk management planner is a public actor. Pursuing a flood development intervention from a public perspective it has to satisfy 1 + 3 different type of conditions:

- Positive net changes of flood risk exposure (=reduced risk)
- Positive net changes on the extended CBA (=improved overall outcome)
- No stakeholder groups (or persons) are worse off – the uneven distribution of costs and benefits is managed (negative impacts on livelihoods are neutralized)
- The natural bases of well-being are not reduced (at minimum) (=sustainability condition)

The below figure shows the proposed model of decision support, also incorporating the extended CBA analysis. The methodology is described in detail later in the report.

Figure 1. The structure of the decision support



This model of the decision support has been developed in close cooperation with the project partners: TUM, KÖTIVIZIG, WWF Hungary. The site-specific analysis of the Tisza (Fokorú puszta) dike relocation case has also served as a test of the methodology and provided important lessons for its fine-tuning.

2 CHALLENGES OF SOUND ECONOMIC DECISION SUPPORT FOR FLOOD RISK MITIGATION IN A MASSIVELY NATURE RELATED ENVIRONMENT

2.1 THE CHALLENGE

Flood risk-calculation-based mitigation intervention is a relatively new approach in the long human history of flood defence. The perception of risk is essential for the possibility of applying economic calculations in a proper, closed frame manner, where the costs of defence operations and investments can be compared against the value of the gained benefits in safety. The integration of risk calculation created the ground for applying sound cost-benefit analysis (CBA) to measure whether the pay-off of investments in flood defence is positive or negative. As a further step, economics-based policy decision support has been made available to be able to compare a wide range of different flood investment types by development alternatives and locations. Moreover, the technical development in hydrology simulation provided the basis for assessing the impact of diverse, nature-based catchment wide interventions on the emergence and passing of flood waves, making the flood risk mitigation service of these interventions economically calculable.

Meanwhile the improved understanding of the complex interconnections between social and natural processes and the elaborate feedback of social interventions to nature (MEA, 2006) has generated a demand for public financial sources to be applied in a manner that provides net benefits across a wide spectrum of sectors and locations, while avoiding outcomes where benefits in one sector are realised only at the expense of another one, but with an overall net loss from a social point of view. Interventions into natural flows, what flood protection is per se, is in the centre of such concerns. The integrated realization of the EU's Water Framework and Flood directives is based on the expectation that a net negative outcome can be avoided in the interest of both the public coffers and nature.

CBA has a clear role here, but it won't be able to solve the decision support challenge in-itself.

A CBA, regardless of how wide or encompassing it is, is an inherently human representation of changes in our natural environment, that has to be kept in mind when considering all the possibilities and limitations a CBA embodies.

The main reasons for applying an extended CBA in case when ecosystem service provision is involved:

- Structured comparison of intervention alternatives from a public policy implementation perspective, the EU law already provides a reasonably wide field for multi-sector evaluation.
- The CBA analysis identifies the stakeholder groups that are potentially impacted
- Mapping ahead in economic terms for the specific conflict / counter interest resolution of the intervenition

One of the key issues that a CBA cannot solve is that there are elements / impacts that cannot be included in an economic calculation (these ones must be distinguished from the elements, impacts, benefits that can be monetised and integrated into economic decision making, even if the information is difficult, expensive to obtain). In order to take these non-CBA compatible elements into consideration there must be other stages of the planning process to ensure the efficient use of public resources. What has to be stressed here is that this separation is not just a technical issue. Beyond the economic structuring of intervention alternatives there may remain differences among the alternatives that must be judged on values, that a CBA - even an ESS enhanced one - is not intended to cope with. This is embodied in the difference that a decision support and decision making tool aims at (in detail in chapter 2.2).

The other issue that challenges ecosystem service valuation based decision support across countries is the difference of institutional development in the countries / communities inside the same geographic unit, in our case the Danube river basin. The same natural characteristics result in different ecosystem values because of the different ability of the local institutions to enhance dynamic multi-party agreements on natural resource (landscape) management. The proposed methodology deals with this issue integrated into the condition of sustainability, because ecosystem service value derives from the interaction of an area's social and natural assets. Besides the components of the CBA there must be other elements that evaluate the integrity of natural flows among the changed conditions that the intended interventions would create (in detail in chapter 2.3) The methodology described in the document intends to give a complex tool in both aspects.

2.2 DECISION SUPPORT VS DECISION MAKING TOOL – THE ISSUE OF DECISION AUTHORITY

We strongly support the notion that an extended CBA methodology cannot play a role other than decision support which is in contrast to its use as a decision making methodology. The difference lies outside the terrain of methodological issues in economics. Positive net balance of an intervention is the condition of economic viability on a reasonable timespan. Using public financial resources invokes the notion that the clearly better net result is worth choosing, but there may be equally beneficial alternatives when the net financial position is not the only aspect to consider. Making decision assumes authority to take sides in issues where options differ in value judgements and preferences that cannot be specified beforehand by commonly accepted rules. If such elements are incorporated into the decision-making methodology (into the calculation formulas or ranking rules) then the planners / developers latently take decisions that they are not authorized to take. The result of such practice is the lack of legitimacy of the analysis results and the decision itself among the stakeholders.

The issues of credibility and efficient information collection sign the roles for the top-down and the buttom-up approaches in the development process. It is the top-down planning elements that evaluate the broad terms of the development and set the specific conditions for the arrangements with the stakeholders of the impact area.

In the case of decision-support the goal is to show what are the comparable elements of the scenarios and what are the distinguishing features of these scenarios, helping to specify the terms of the decision.

For this aim, besides the extended CBA economic result, each intervention scenario has a list of the non-monetised ecosystems services with the new, post-intervention characteristics of service.

Based on the economic difference of the scenarios there is a first round (intervention level) estimation of how the economic benefits/losses and the shifts in characteristics of the non-monetised services relate to each other. (In detail in chapter 6).

2.3 THE PAIRED CONSTRAINTS OF INSTITUTIONAL CAPACITY AND NATURAL CAPACITY ON WELL-BEING

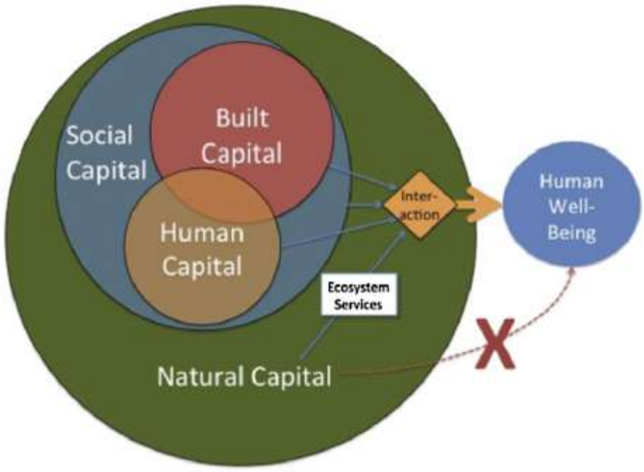
Ecosystem service provision is not a sole function that can be derived directly from an area's natural characteristics. The value of benefits that a location's ecosystem can provide is not independent from the ability of that area's social institutions to foster agreements among the stakeholders to resolve conflicts of interest among activities that have a restrictive impact on each other's benefits. For example: conflict of interests on provision levels of an area between farmers or foresters vs game managers; farmers vs beekeepers; nature protectionists vs game managers, rights of way walkers vs farmers, foresters vs nature protectionists, water managers vs farmers vs nature protectionists, foresters vs water managers, water managers vs anglers, anglers vs nature protectionists... the list is expandable ad infinitum.

In locations where the regulation of multi purpose land management reconciliation, or better say interest resolution is on an advanced level, the provided/harnessed benefits are more diverse and sum up higher in value (and the positive effects presumably extend to a greater proportion of the community).

The site by site differences in institutional capacity mean that the value of benefits from ecosystem services at a given place is just an actual composition of services, derived from a range of options specified by both the features of the ecosystem and of the local society. One can call it a bundle, as there are regularities that affect the compilations. Benefit transfer (one of the commonly applied methods for environmental valuation) calculations usually miss the importance of the institutional element as a constraint on benefit realization. This is due to the pre-assumption that a given type of benefit can be realized under more or less similar ecosystem circumstances, but one can argue that it is not just the ecosystem endowments, but also the quality of the social institutions that constrain the portfolio of benefits. (Figure 1 illustrates this duality.) Generally it is not the idea of a potential benefit that is missing, but the enabling institutional circumstances to realize it.

The below figure of Costanza (2014) clearly demonstrates the structure of the question. Natural capital or the ecosystem services don't contribute directly to human well-being, but through the interaction of the different elements of social capital. Institutions are important elements of human capital in fostering value creation (either economic or other type of value).

Figure 1. The natural-social interaction behind human well-being



Source: Costanza et al (2014)

These social – natural interactions that are in the background of ecosystem service provision constrain the generalization and unconditional use of valuation results in planning activities on sites with natural characteristics looking similar to the original one. There is a widespread ongoing scientific discussion about the applicability and the limits of transferring ecosystem valuation results between sites. In the influential research program, The Economics of Ecosystems and Biodiversity, de Groot et al (2010) expressed strongly the specificness of the analysis:

> "any ecosystem services valuation should begin with the detailed understanding of biophysical generation of services to provide solid ecological underpinning to the economic valuation" (de Groot et al, 2010)

From the many overviews on ecosystem service value transferability the conclusion can be developed that the main problems of value transfer emerge from the unintentional inclusion of the underlying assumptions and choices that were site specifically adjusted for the original use of the valuation methodology (Tammi et al, 2017).

The institutional capacity issues feature differences among regions and countries that define how natural resources are transformed to services that are useful for the society. A CBA valuation of ecosystem services reflects the interaction of these two types of capital, but one can see that any of the two could pose a constraint on benefit provision of an area.

This conditionality of ecosystem service values on the features of social capital in the multi-regional context of the Danube Floodplain project underlines the approach that decision support has to have an element that reflects changes in the natural conditions of the site independently from the local social capacities.

From the view of a long-term planning process (like flood defence) this problem is important because a decision has to be made: which level of benefits should the decision support tool consider? The actual one or the potential one? Does it consider the benefits that the natural endowments could supply, as a potential maximum or what the social conditions enable? For the methodology of this project we prefer that monetised valuations consider the actual benefits and the ones that the stakeholders consider as practically feasible since institutional development usually requires a long time to mature.

At the same time a long term planning process that uses public resources must take into consideration that it has to broaden / improve the future standing of its target area, which does not necessarily coincide with the stakeholders current activities. For the purpose of meeting this planning requirement as well, this methodology uses multi-aspect interpretation of the Supporting Ecosystem Service Group of the Millennium Ecosystem Assessment categorization (MEA, 2006).

The Supporting Ecosystem Service group stands behind all the ecosystem services that societies directly benefit from. The most expedient solution is to consider this group as a natural asset base of the direct ecosystem service provision. We refer to this as the **asset base of ecosystem services**, this is in line with the natural capital approach (there are some slight differences in the definitions, but for our case these can be used interchangeably.)

The size of the asset base of ecosystem services has a positive correlation with the ecosystem service benefits an area can provide, in this sense its change indicates the change of the potential for providing benefits without the institutional aspects of the interaction.

The case for the connection of the asset approach to the water related indicators is developed in chapter 3 on sustainability.

2.4 HOW TO SOLVE THE MAIN ELEMENTS OF THE CHALLENGE?

The Danube Floodplain project aims to develop a decision support methodology that supports flood related land use management planning in a region that spans across different fluvial ecosystems and countries with very different legal and social structure. All these elements have an impact on how an area's natural resources / endowments are transformed to bundles of ecosystem services for the societies of the river basin. Moreover, it differs from country to country how a given bundle of ecosystem services is ranked in comparison to competing bundles.

In order to meet the need of presenting transparent, comparable decision alternatives for decision support and the limited scope of even an extended CBA analysis a decision flow structure is proposed, where issues can be tackled by their own nature. At the same time, in spite of the multi-party and multi-disciplinary approaches, an integrity is provided from the perspective of "value for public money".

In order to detach from the institutional differences of the countries of the river basin, the interventions' effect on the size / volume of the ecosystem service asset base of the impacted areas should be included in the analysis as a separate element from the ESS-CBA, but in a way that fits into the ecosystem service approach.

The decision support model analyses the completion of the below conditions as prerequisites of a good development decision:

- The natural bases of well-being are not reduced (at minimum) (=sustainability condition)
- Positive net changes of flood risk exposure (=reduced risk)

- Positive net changes on the extended CBA (=improved overall outcome)
- No stakeholder groups (or persons) are worse off – the uneven distribution of costs and benefits is managed (=negative impacts on livelihoods are neutralized)

The results of the extended CBA analysis will support the judgement on the three latter conditions. For this aim the methodology separates the monetised and the non-monetised elements of the evaluation into two phases (it will be described in chapter 5.1). This method helps to demonstrate the structured differences of the intervention alternatives. Moreover, it creates the decision context to consider if there would be additional willingness to finance a given package at a specific price, where the net financial disparity of the intervention scenarios is understood as the value (based on the "production cost") of the additional non-monetised elements.

2.5 APPLICABILITY AND PROVISION OF THE NECESSARY INFORMATION – CREDIBILITY OF THE RESULTS

The applicability of the decision support information that a CBA provides heavily depends on the quality of the input data. The preparation of the input data for a site-specific decision raises costs through efforts and time (both are in limited supply for any project). Thus there is a need for the optimization of efforts, a decision sphere in-itself where the applicability and credibility of the information is in correlation with localization efforts and the methods, how information with local relevance is gathered. The planning of flood defence interventions usually has the top-down feature, but a CBA that compares different intervention scenarios requires economic information that cannot be generated only from centrally available information sources. Economic decision support needs bottom-up tools to enhance the co-ordinated collection of information as well.

The goal of this project is to facilitate the adaptation of the flood defence methods to the new social expectations and hydro patterns of flood occurrence. This adaptation of the defence practice inevitably requires further actions across different group of stakeholders (land use change, cultivation change, protection measures on real estates, relocation of activities…). These induced adaptations will generate costs for these stakeholder groups. For a proper public policy decision these social adaptation costs are to be taken into account and the livelihood effects of the intervention should be neutralized for the stakeholders.

Although these livelihood effects should be incorporated, gathering information about the real cost that adaptation imposes on these groups/individuals is not an easy task. Stakeholders naturally would like decision makers to accept the maximum possible adaptation cost (in order to avoid adaptation altogether or to get the best out of it). On the other hand, on behalf of the wider public, the central decision maker must ensure that as a whole these adaptation costs are at a reasonable level, there was no cheaper alternative to ensure the necessary stakeholder adaptation activities.

Some elements of this real cost information can be generated through desk top analysis (top-down method), but other elements may depend on local endowments that only the impacted few can evaluate in a creative, strategically driven way that will substantially improve the implementation design or reduce costs. In these cases, winning local engagement or having alternative, competing locations (e.g. several dyke sections for relocation) to create the basis for the use of economic instruments could be the bottom-up solution ahead.

3 SUSTAINABILITY

3.1 THE SUPPORTING ECOSYSTEM SERVICE GROUP'S CONNECTION TO SUSTAINABILITY

Sustainability has a range of social and natural interpretation. (By the MEA, 2006, Glossary: "A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs".) For the goals of this decision support structure that works with the concept of ecosystem services the site-specific characteristics of the supporting ecosystem service group is an obvious solution to use as a reference point.

This group contains elements that represent the fundamental environmental flows that support all other, direct contributions to well-being. The most important supporting services are water cycling, nutrient cycling, primary production, production of atmospheric oxygen, soil formation and retention, habitat provision and pollination (MEA Glossary).

The supporting ecosystem service concept provides the interpretation that sustainability of social well-being in a given area (ceteris paribus) depends on the preservation / continued maintenance of underlying environmental flows. For the decision support conditions two aspects are distinguished:

1, The investigation of area specific side conditions that ensure that the current level of natural activities / habitat maintenance conditions are kept and the area will not shift to a lower ecological quality than prior to the planned intervention

- The continuity or connection of natural areas that make animal and plant migration possible are not destroyed. Or, even better, new connections are developed.
- The size of open water surface area and the length of the shoreline doesn't decrease.
- Heterogenity of the area's land use pattern is increased or stays constant.
- The size of non-cultivated (natural) areas doesn't decrease and doesn't fragment.

2, The sum of these supporting services was interpreted as the ecosystem asset base, but their sole listing, the individual volumes do not give information about the functional interconnectedness of these services that defines / limits their joint ecological performance from the well-being production point of view. Our methodology proposes that terrestrial water cycling is a natural/physical phenomenon the intensity of which should serve as a combined indicator to describe the size of an area's ecosystem service asset base as one functional unit. The theoretical background of this proposal is elaborated in chapter 3.2 and a preliminary proposal for the calculation of the indicator that reveals the key element of this dynamics can be found in chapter 3.3.

To formulate it as a condition: the terrestrial water cycling intensity of the analysed area stays stable or it increases; the ecosystem asset base remains on the same level or increases. In these cases the intervention does not shrink, the basic interest of future generations is respected. The questions that remain for the extended CBA analysis: is the intervention viable from economic perspective and can the impacted stakeholder groups' interests be consolidated?

3.2 CONNECTING TERRESTRIAL WATER CIRCULATION INTENSITY TO SOCIAL WELL-BEING

In this chapter we argue that a water-turnover-based description of an area's ecosystem asset base is a satisfactory method to address the critical sustainability condition the ESS-CBA decision support flow must take into consideration.

The rich literature on ecosystem service valuations and the concept's connections to other fields of environmental and development economics make it possible to draw summative conclusions. Below we represent a line of studies that establish the connection between the water based physical characteristics of an area's ecosystem asset base and its well-being. The steps the series of articles take are as follows:

Water endowment – Net primary production – Ecosystem service value – GDP – Well-being

The separate elements along the line of linkages

1, Water endowment – Net primary production – Ecosystem service value

The ecosystem service approach was globally popularized by the Millennium Ecosystem Assessment (MEA, 2005), although it was the 1998 Costanza et al article that attracted wider attention to the ESS valuation issue. Figure 2 below of the Costanza et al (1998) article draws a parallel between the net primary production volume of a biome and the ecosystem service values that were attached to it.

Figure 2. The connection between the net primary production and assigned monetary value of a biome

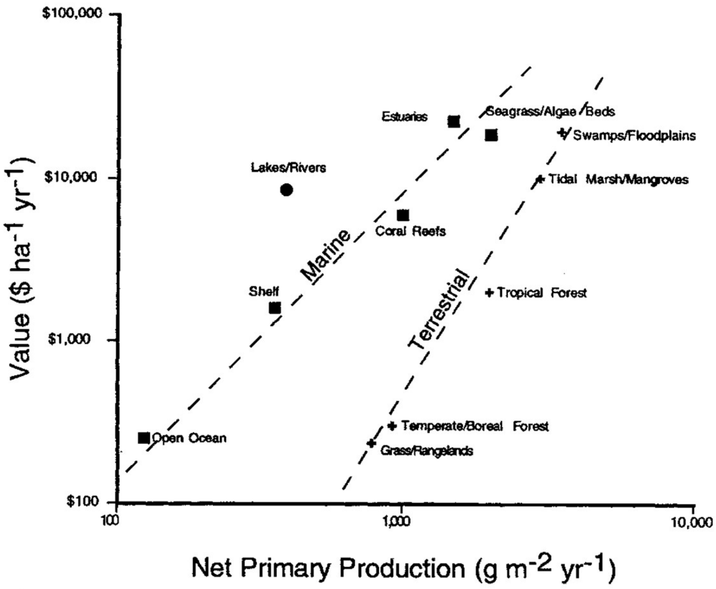


Fig. 1. Plots of NPP vs. value for terrestrial and marine systems.

Source Costanza 1998

The dotted lines suggest the correlation along the sea and the continental ecosystems separately. On the top of both spheres the wet-dry transition systems are located.

2, Net primary production - Ecosystem service value - GDP

The econometric analysis of Richmond et al (2007) compared the volume of ecosystem services to a country's GDP in the 1982-1999 time period. It used a complex indicator to describe the ecosystem service value, but net primary production had a large weight in it. The article found positive correlation between the ecosystem service indicator and the GDP.

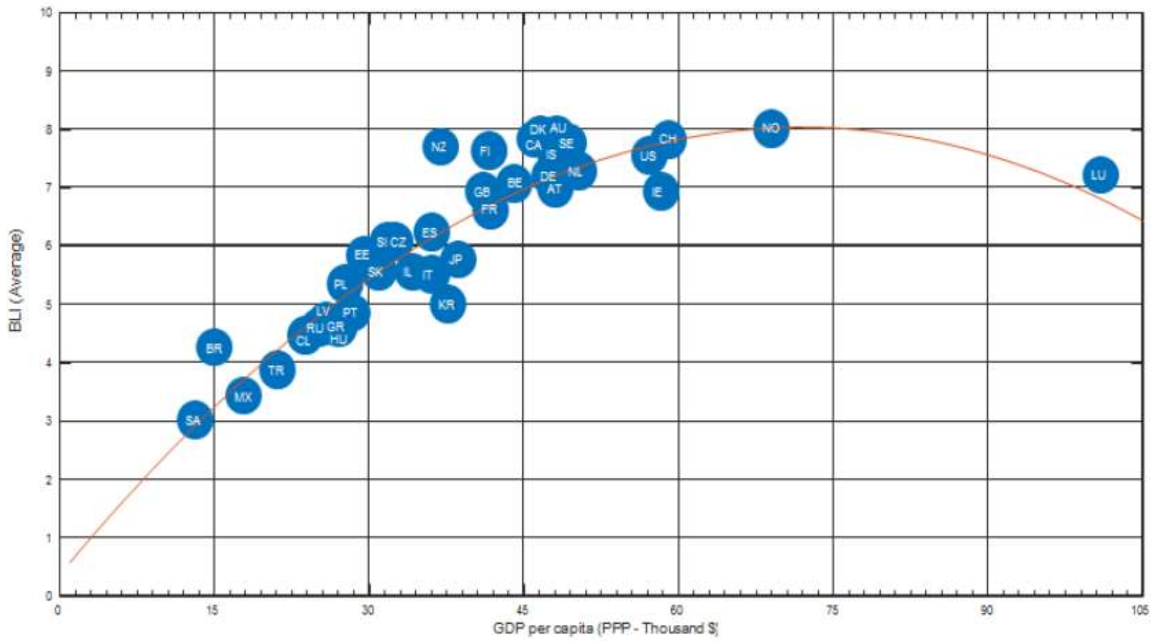
This positive correlation between primary production and GDP remained valid if the output value of the direct biomass harvesting sectors like agriculture and forestry were omitted from the analysis. This finding allows to draw the conclusion that in ecosystem's value production the water turnover of an area has other routes of contribution to economic performance than just the direct harvesting type of uses (indicated in the Provisioning Ecosystem Service Group).

The Richmond et al (2007) study's argument is also in line with the notion of our methodology proposal in other aspects as well. Economic growth was historically characterized by capital accumulation and land use change that reduced net primary production (replacing natural ecosystems with ecologically less productive landscapes). As far as the base of predictable hydrologic conditions was not over consumed, then a more revenue intensive utilisation of the ecosystem assets was still possible. But as recent incidents of climate instability show, there is a limit on the substitutability of capital to ecosystems services, or at least the ratio of substitution (assuming fixed output) is rapidly becoming steeper. Getting closer to the limits of substitutability or depleting the assets instead results in growing instability. This trend was reflected clearly in the upgraded and extended study of ecosystem service valuation (Costanza, 2014). The article gives a comparison of the 1997 and 2012 results of meta-analysis of ecosystem service valuation. One of the characteristic changes it revealed is the increase of the ecosystem service value due to the realisation of regulating, mitigating functions (storm protection, erosion control - sometimes facing the consequences of the previous elimination of the service base).

3, GDP – Better Life Index - Social well-being

There are many disputes whether GDP is a good measure of wellbeing, but as the below figure from Yilmaz (2017) shows there is a meaningful correlation between GDP and OECD's Better Life Indicator that has 11 elements. There are other drivers that have significant impact on well-being in addition to GDP, but a higher GDP definitely increases the probability of higher well-being.

Figure 3. Comparison of PPP based GDP per capita with BLI averages in OECD countries



Source Yilmaz 2017, based on 2016 data

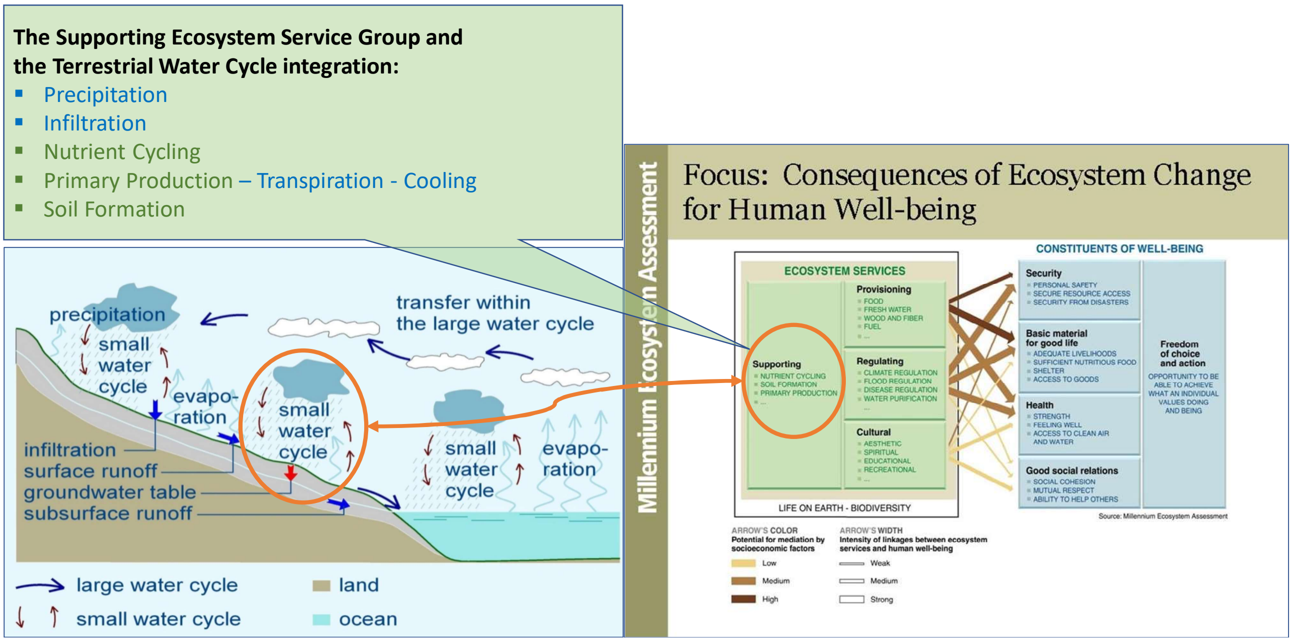
These correlations between net primary production – ecosystem service value and GDP from the one hand and from the other hand between the GDP and the Better Life Index can lead us to conclude that changes in net primary production have a positive correlation with the value of the whole set of ecosystem services and human well-being as well.

4, Terrestrial water cycle intensity – Supporting Ecosystem Service group (ecosystem asset base)

The crucial contextual step our proposal advocates is that the well-being described by the Millennium Ecosystem Assessment can be integrated with the concept of the terrestrial water cycle.

The composition of the Supporting Ecosystem Service Group (biomass production, nutrient cycling, soil formation, biodiversity) reflects land use features where biomass production is the function of the short term water availability, while the other elements (like soil accumulation) are the long term side conditions of the vegetation driven environmental flow management conditions (Ungvári & Kis, 2019). More importantly, the elements of the Supporting Ecosystem Service Group, if listed in a precipitation and water-traffic wise order, embody the phases of the terrestrial water cycle (see the above right extension of Figure 4, below.)

Figure 4. The connection between the ecosystem service level and the terrestrial water cycle



Sources of Figures: on the right: MEA 2005, left: (Kravčík, Pokorny, Kohutiar, Kováč, & Tóth, 2008)

The circulation intensity is the indicator that describes the combined functioning of the elements of Supporting Ecosystem Service Group.

This representation emphasizes that the terrestrial water cycle is best understood as a sequence or series of cycles based on the current state of land-use management and the subsequent functioning of existing vegetation. The intensity of the water cycle is an overall indicator on the functional relationship of a wide range of natural flows that describe the successfulness of an area's vegetation that results to drive the essential materials in circulation for enriching the local ecosystem vs letting essential nutrients and water for example to run off or leak away. For this physical / natural feature the ecosystem service context provides the context of interpretation for measuring the basis of well-being.

The set of Supporting Ecosystem Services highlighted by the Millennium Ecosystem Assessment is the framework that substantiates the view that the terrestrial water cycle intensity is the finite natural capacity on which human well-being creation and development is based under water limited climate conditions. That is why this indicator is suitable for measuring the sustainability condition of the analysed interventions.

Most precisely it could be approximated by the rainfall multiplier (van Ent, 2010), a numerical system index that describes an area's contribution to terrestrial water circulation and connects the effects of small-scale land use change on the ground to global climate processes. (Ungvári, Kis 2019). For the practical applicability viewpoint an easier to calculate indicator could be proposed for the project calculations (in detail in chapter 7).

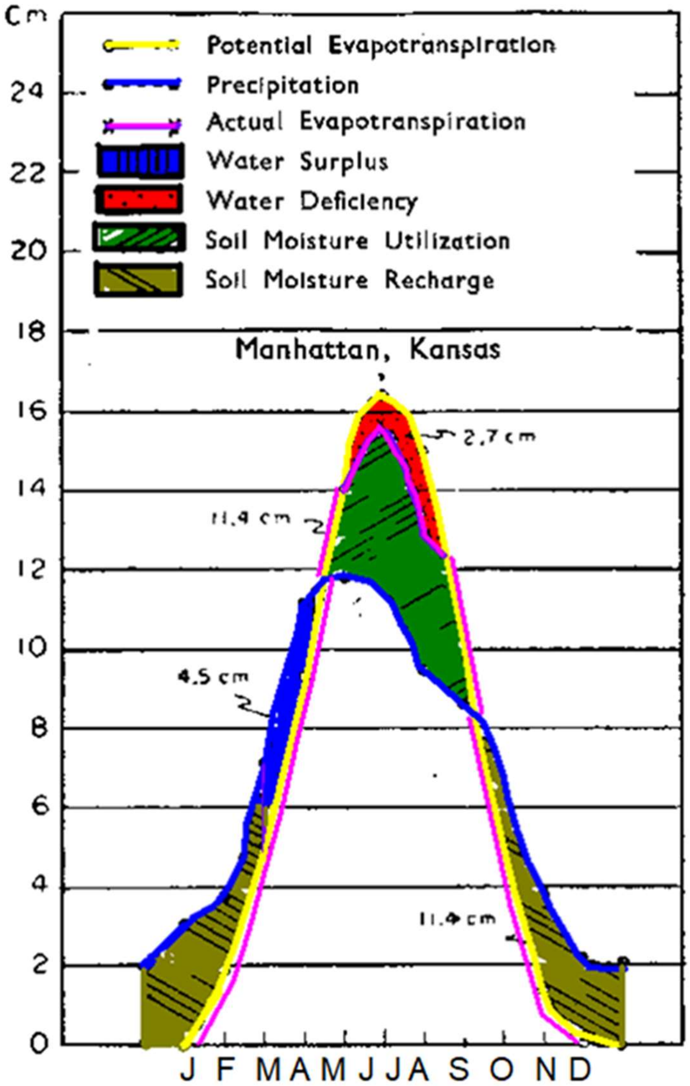
3.3 PROXIMATION OF THE ECOSYSTEM SERVICE ASSET BASE.

Calculating the rainfall multiplier is a possible, but highly complex task. It is important for connecting local land use patterns to global natural flow processes, but judging on local ecosystem changes a simpler approach is preferable if the key element of the indicator is preserved. In this chapter we argue that for local (watershed wide) application the key element to focus on is the trans-seasonal water allocation efficiency of the vegetation (the landscape). It means how successfully the annually available water volume in a given vegetation or landscape is finally being concentrated to the vegetation period for the primary production process of the area. The two key drivers behind the change of successfulness due to land use or land management change are the water volumes of infiltration and transpiration. In this sub chapter this indicator is developed in strong emphasis on creating a context that is line with the scarcity driven logic of economic understanding of allocation challenges.

In the article (Ungvári and Kis, 2019) we describe on an economics driven language that a natural resource allocation efficiency issue can be framed around Figure 4, if the ability of the vegetation (or land use in a broader aspect) to redirect water between run off vs biomass production and cooling is viewed on a trans-seasonal basis within an average year. The size (or level) of the ecosystem service asset base at a given location is strongly connected to the actual level of inter-seasonal water allocation capacity. The below quotation describes this dynamics:

> "Applying the Resource Efficiency Frontier Concept to Ecosystems
>
> In nature, the basis of all terrestrial life is plant life that stems from primary (biomass) production. This encounter happens on the soil where and when water meets solar energy in a plant's kitchen to produce biomass and transpiration. The vegetation period is the time window during the year when there is enough (or more than enough) solar energy to induce primary production, assuming adequate amount of water is available (Thornthwaite&Hare, 1955). This approach was further formalized and improved as the Thronthwaite-Mather water balance calculation method (Thronthwaite&Mather, 1957). Thornthwaite's principal contribution to the topic of this article is the combined representation of water (moisture) and energy in the same basic relationship. This is represented in Figure 5 (from Thornthwaite&Hare, 1955). This approach helps to bring together and frame water, energy and land as interlinked parts of the same allocation dilemma, within which the role and impact of limited resources and varying resource efficiency can be highlighted.
>
> Figure 5 illustrates this allocation issue for a specific geographic location based on monthly average values for available energy, water and the production of evapotranspiration. Solar energy radiation is represented through the amount of water (in centimetres height) that it can evaporate and transpire from the same land area on which monthly precipitation was measured. The water surplus, the blue area in the figure, is the runoff. This blue area represents the amount of water that the existing ecosystem is unable to retain or use. The unused, superfluous solar energy volume is defined as water deficiency, represented by the red area, which quantifies the mismatch, i.e. the failure of the constituent resources to align.

Figure 5. Trans-seasonal water allocation and the mitigation of warming



Source of Figure: Thornthwaite, Hare (Unasylva, 1955, 9. vol./ 2) Horizontal axis is the months. * - The white area below both the "Precipitation" and the "Actual Evapotranspiration" curves is explained as the transpiration from the readily available precipitation for a given period of the year.

As Figure 5 illustrates, the annual evapotranspiration (evaporation or biomass production of the vegetation) is lower than what the annual volume of solar energy and water could potentially produce under circumstances that better align. Specific features of the vegetation and the soil influence the efficiency of matching these two resources (water and energy) for primary production through trans-seasonal water reallocation. In other words, the actual status and structure of the vegetation and soil define the actual Resource Efficiency Frontier of biomass production at a specific location. If the features of the vegetation and soil that drive the trans-seasonal water allocation ability are improving, more biomass production will take place from the same annual set of resources – in essence, REF is moving outward, the potential is increasing. This is a crucial dynamics: the allocation challenge of the annual, on average finite amount of water, solar energy and the significance of the intra year water reallocation efficiency to maximize primary production and transpiration." (Ungvári and Kis, 2019)

This way an area's vegetation based natural resource allocation efficiency (REF) drives the volume of primary production among the given set of resources. An indicator can describe this dynamics comparing the volume of the surplus water resource (sum of the brown recharge and blue run off) to the volume of the trans-seasonally allocated (green, soil moisture) resource that the ecosystem successfully matched with the excess radiation (not used by the readily available water quantities from precipitation)

Resource allocation Eficiency (REF) = the volume of transpiration above the surface water budget of the excess solar radiation period divided by the volume of water budget over the solar radiation limited, excess surface water period.

$$\boldsymbol{REF} = \frac{\boldsymbol{V\ extra\ ET\ request\ (soil\ stored\ ET)\ in\ time\ when\ PET > JinT\ ET}}{\boldsymbol{V\ surplus\ water\ resource\ (runoff\ +\ soil\ recharge)\ above\ the\ JinT\ ET\ curve}}$$

The change in the trans-seasonal water allocation efficiency of the intervention area. REF(t1)/REF(t0), where REF compares the volume of transpiration above the surface water budget of the excess solar radiation period to the volume of water budget over the solar radiation limited, excess surface water period. The ratio will increase if primary production increases (due to the intervention). It also prefers constant vegetation cover to arable use, because crops may have high primary productivity, but they have a shorter season.

Figure 5 represents only precipitation as the source of water. In order to maintain the integrity of our approach for floodplain circumstances there must be some additional consideration that depends on the chosen scale of the area. If the unit of the investigation is a catchment where precipitation is the only supply of water, the REF(t1) / REF(t0) ratio is calculable without further considerations. In case smaller area units, for example floodplains, are investigated, where the different scenarios can result in different additional surface water endowments, there must be a common denominator to specify. This common denominator has to be the water supply of the scenario with the highest volume (where the source of origin for the runoff and the recharge is the sum of precipitation and the surface inflow for the area).

While the water endowment is a year specific variable, the other decisive long term driver of trans-seasonal water allocation is the status of the soil. Soil accumulation is a very long and complex process, what is important from our evaluation point of view is whether this process is broken or not. The carbon content of the top soil could be a good indicator, but it is very difficult to measure and calculate. Information on erosion as the inverse process of soil accumulation does not fit either, because simulations treat the plain areas as free of erosion, while crop production and bare soil surfaces contribute to soil loss. We propose a straightforward question: 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. But information can be gathered easily about it.

3.4 CONDITIONS FOR THE SUSTAINABILITY CHECK

The supporting ecosystem service group represents the stable and predictable material and energy flows of nature. This is the ecosystem asset base that the evaluated intervention should keep intact or improve.

A set of indicators would describe these conditions:

- 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.
- 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 above described functional ecosystem performance change of the analysed area should take form in a way that the following conditions ensure that the current level of natural activities / habitat maintenance conditions are kept and the area won't shift to a lower ecological quality than it was before the planned intervention:

- The continuity or connection of natural areas that make animal and plant migration possible are not destroyed. Or, even better, new connections are developed.
- The size of open water surface area and the length of the shoreline doesn't decrease.
- Heterogenity of the area's land use pattern is increased or stays constant.
- The size of non-cultivated (natural) areas doesn't decrease and the area doesn't fragment.

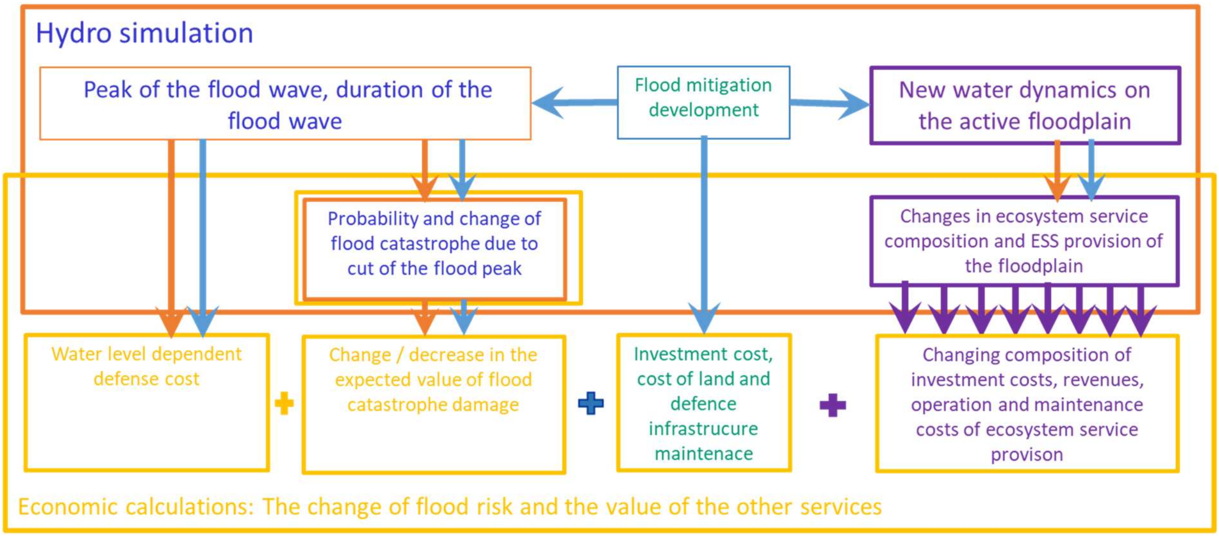
4 REDUCED FLOOD RISK

The change in flood risk is one of the components of the CBA that can be reasonable well estimated if suitable data is available. Flood risk is the product of the probability that water leaves the floodplain – as a result of dyke failure, or simply due to extreme high water levels – and the damage due to flooding protected areas, including settlements, industrial facilities and agricultural land and farms. Flood mitigation measures intend to reduce this risk. Such measures may include, for example, strengthened dykes, emergency polders, changed river morphology to ensure smoother flow of water. They may also target increased resilience, when the potential damage is reduced, for example by raising the foundation level of buildings or implementing emergency evacuation plans.

Figure 6 provides an example for the steps to calculate a change of flood risk. This example is further elaborated in the Hungarian pilot study. Large floods generate two main types of costs. Flood defense costs and catastrophe damage. The larger the peak flood water level and the longer the duration of the flood is, the higher the total expected cost will be. The red arrows of the figure describe the connections. In case of an intervention to mitigate floods (upper green rectangle, and along the subsequent blue arrows), the flood wave will change, its peak level can drop and as a result, flood defense costs will also decline and the probability of a flood catastrophe will be lower. As a results, the total expected cost will also decline.

The purple text on the right is not directly related to flood costs, but to other components of the CBA. (These elements are discussed in the next chapter.)

Figure 6. Assessing the change in flood risk



5 OVERALL NET POSITIVE CHANGE

5.1 THE SCOPE OF THE EXTENDED CBA AND THE CONDITION OF ADDITIVITY

It is a fundamental demand that public investments be applied in a manner that provides net benefits not only one, but across a wide spectrum of sectors and locations, while avoiding outcomes where benefits in the invested sector are realised only at the expense of disadvantageous changes in another one, but with an overall net loss from an overall social point of view. Interventions into natural flows, that flood protection is per se, is in the centre of such concerns.

In case of using public financial resources, it is necessary to extend the CBA analysis to sectors as wide as the impact pathways make it reasonable. Meanwhile there are limits to what elements a CBA analysis can and cannot include. This sub-chapter on the additivity issue describes the main theoretical limits we consider important to draw about expansibility of a CBA analysis.

There is an inherent antagonism in how elements that do not fit together by their nature are tried to be squeezed into CBAs in the good faith hope of better decision support. When such elements are converted to monetary values to arrive to a common denominator, the false illusion of additivity emerges.

> Methodology Proposal: According to ICPDR (2015) the costs and benefits addressed in an economic CBA may include indirect and non-priced external effects, such as environmental effects. If such externalities are included in the analysis in monetary terms, we refer, according to Brouwer (2005), to as an "extended CBA ".

While we share the goal that nature related flood defence interventions should be optimized above an as wide as possible impact sphere, our problem is that ignoring basic economic principles will in the end undermine both the validity and the credibility of the summed financial values. The CBA is a method of economic valuation where values are added, but there are serious underlying conditions of such additivity concerning what value means in economics. Economic value derives from the common interpretation of a resource situation, namely scarcity. If there is no scarcity, then there is no economic value, since there is enough supply of the given resource for free. Economic value is based either

- on scarcity by experience (by nature: e.g. there is a finite supply of a produce) or
- scarcity acknowledged and enforced by law (e.g. an amount of effluent a sewage plant is allowed to discharge into a river annually or the finite amount of carbon to be released to the atmosphere under a regulated carbon dioxide market).
- Based on the above two aspects, there is a pragmatic third level, quite relevant in water and environmental issues. Is the scarcity context enforceable? Is the access to the scarce resource controllable in practice? Will the cost of effective control be covered? If this is not the situation, then the experience based valuation becomes flawed. (A situation under which the resource or the environmental asset can quickly be consumed).

The above considerations mean that economic value can't develop in the absence of scarcity, and there is no basis for additivity because a value derived outside the realm of the markets or revealed preferences will not receive the same common / social approval.

Bringing an environmental problem (where scarcity is not self-evident) under the legal realm implies the extension of the sphere of the common social approval and that will create the legal ground (legitimacy) to acknowledge and enforce a new scarcity situation by law. An example is the process of how the creation of the carbon markets were issued through a series of acts in national and international legislation.

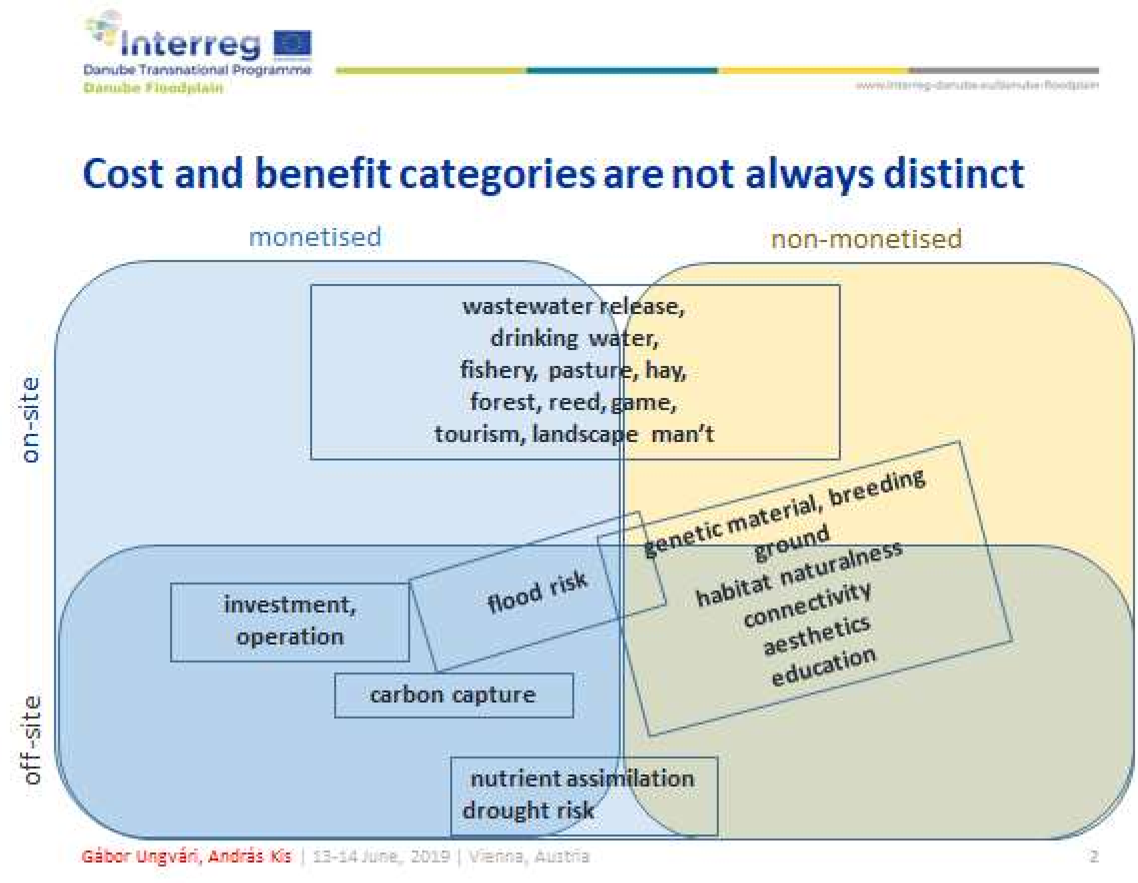
These legal acts resulted in the legitimacy that is the precondition to apply economic instruments for allocation of the scarce resource that will reveal the economic value subsequently. This process (or advancement) of the extension of social approvals provides an obligate frame of what can be valued on an economic basis and what cannot. Different countries are at different phases of such development and this places limits on how an evaluation of flood development scenarios can be conducted. There are alternative methods to choose where the comparison on quantitative basis doesn't necessarily mean adding up elements.

> This is in line with the Methodology Proposal: One of the main challenges of the proposed work will be to translate the ESS into quantitative values, so that they can be compared

with standard costs and benefits of the floodplain restoration measure, and therefore taken into account in the decisional process.

Sometimes physically, ecologically or socially understood impacts of an intervention are transformed by a novel algorithm to a value proposition and are added up with elements based on economic value. That should not be done, these transformations (designed by the planners) inadvertently substitute a social or political discussion, advocacy and decision with an arbitrary ranking of effects. These are the social conflicts of interest that are not compromised on and reflected in legal arrangements yet. As societies face new challenges and recognize new scarcities, the emergence of such conflict of interests are natural reactions. This is the role of politics to create the new legal conditions (rules) that make adaptation to the newly recognized scarcities (realities) possible. (The measure of political quality is the successfulness of initiating such social adaptation in terms of cost, time span and new opportunities compared to other countries.)

The inner workings of a decision support model do not possess the authority to make value judgement decisions instead of the stakeholders involved. The solution from this trap-like situation is that the evaluation procedure must be transparent, and the stakeholder reconciliation process of the planned intervention has to deal with issues that involve social ranking in the absence of economic values. The situation that an effect has no economic value doesn't mean that it can be omitted from the decision making process, moreover the decision support process have to specify it and include its place. This is a serious constraint on robust (mostly top-down initiated decision support) methodologies. A balance must be developed between the two planning approaches (top-down and bottom-up).



To manage the problem that there are impacts outside the terrain of monetisation, our methodology separates the monetised and the non-monetised elements of the evaluation into two phases. The methodology also includes a phase that demonstrates the structured differences of the intervention alternatives. It creates the decision context to consider if there would be additional willingness to finance a given package at a specific price, where the net financial disparity of the intervention scenarios is understood as the value of the additional non-monetised elements.

5.2 EXTENDED CBA: MONETISATION AND CALCULATION OF NET BENEFITS

Once it has been determined that the overarching ESS indicator is staying constant or improving, structural side conditions are met and the monetised and non-monetized impacts are separated, the monetisation of the costs and benefits of the intervention takes place. This process is aided by the TESSA toolkit, and specifically by the project document "TESSA's application to Danube Floodplain" (Perosa, 2019).

The goal of this exercise is to arrive at the financial present value of each cost and benefit item (investments, maintenance costs, changes in land use, changes in various ESS) for which monetisation is possible. In case of investments and other expenditures or revenues that take place in the present, discounting is not needed. For all future items, including annual costs or benefits, the future values should be discounted to the present through an appropriate real discount rate. The real discount rate is the difference of the nominal discount rate and the rate of inflation. In case of expenditures the real discount rate should correspond to the cost of financing. For example, if the government pays the investment, then the interest rate of government bonds or treasury bills adequately represents the cost of financing for the government. In case of ESS the proper discount rate is the social discount rate, which is generally a relatively low value falling in the 0%-3% range, highlighting that future ESS benefits are almost as important as current ones, only a slight value reduction takes place through discounting.

There are items the monetisation of which is not possible or not suggested, due to lack of data or uncertainty surrounding even its natural size. The package of unmonetised benefits should at the end of the CBA be evaluated against the net costs (or sometimes net benefits) of the monetised items, and it is the task of authorised decision makers to determine if the unmonetised benefits are indeed worth the monetised net costs.

To aid the cost benefit analysis, a spreadsheet tool was developed to take care of the necessary calculations and also to ensure that none of the cost or benefit items are neglected. The tool will make it possible to evaluate the net shift in the position of specific stakeholder groups. The tool will be tested on the Tisza pilot project before dissemination to the other pilots within the Danube Floodplain project.

6 STAKEHOLDER IMPACT NEUTRALIZATION

In this methodology conducting the CBA analysis has a triple role.

- Structured comparison of intervention alternatives from a public policy implementation perspective.

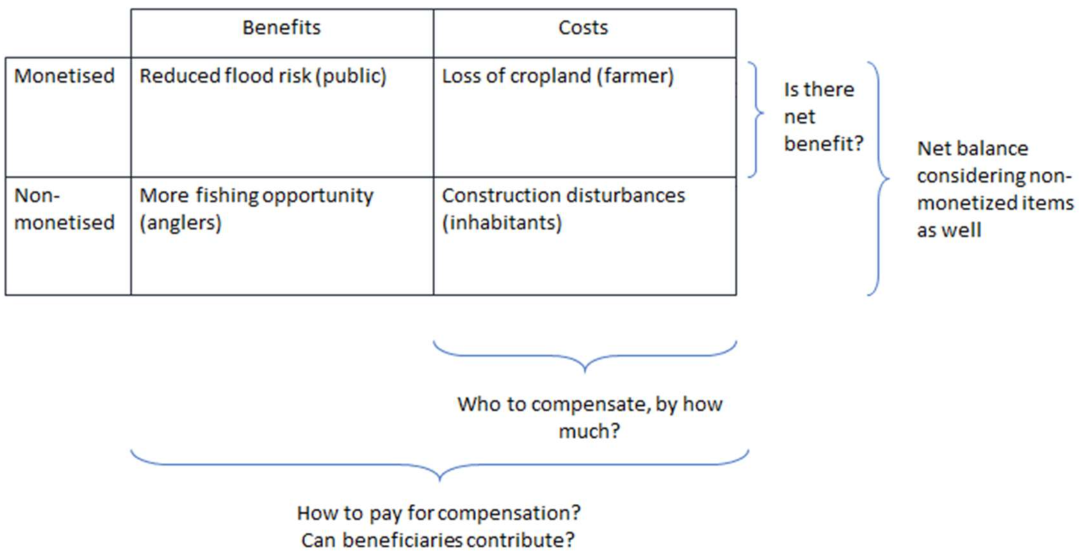
- The CBA analysis identifies the stakeholder groups that are potentially impacted
- Mapping ahead for the specific conflict / counter interest resolution of the intervention

Based on the results of the extended CBA analysis and the changes in the non-monetised benefits across the different intervention scenarios the starting conditions of the negotiations between the impacted stakeholders can be set. The goal is to break up the revealed counter interests into manageable smaller parts where reaching agreements is a viable goal.

In order to specify the issues it is reasonable to distinguish the state as a representative of the wider/general public interests and the public finances from the local actors whose position is different from each other and of the general public.

The results of the CBA show whether the planned intervention is worth further consideration or not. Unless the net present value of the intervention is greatly negative, there are specific aspects to consider in relation to the non-monetised benefits.

Figure 7. The impact structure



There can be a distinction between how compensation should be managed in case of the monetized and the non-monetised impact. In case of the monetized impacts, if the calculation is credible for the parties, the question is how should the beneficiaries split the compensation costs among themselves. Non-monetised impacts can be compensated both by financial methods or along other terms.

Even if the intervention makes sense as it generates overall net benefits, there may be actors whose position deteriorates. These people or entities are to be compensated by local or central funds to ensure that everyone is better off (or at the minimum, not worse off) following the implementation of the intervention. The CBA includes the costs associated with the deteriorating positions, while the positive net balance of the CBA means that the financial basis of compensation is generated on the beneficiaries' side. The stake of the negotiation is to determine which stakeholder group covers given shares of the bill. State actors can have a role here to facilitate agreements (in order to reduce transaction cost), while not necessarily paying up all the compensation cost, but for example bridging the time gap between present adaptation cost for one group and future benefits for others by advance payments in the present using the flexibility provided by its budget.

The next question is whether the positive net balance of the CBA could cover the compensation for the deterioration of the non-monetised benefits either in a form of direct negotiation of financial compensation for the impacted stakeholders or the cost of any agreement that sensibly mitigates the deterioration or replaces the previous status by other means. In all such cases the local features, ad hoc arrangements have very important role.

Non-monetised benefits can improve not just deteriorate, in that case the beneficiaries could be among the cost bearers of compensations. This is again a terrain where local features, connections can have significant role to help arrange stalled agreements.

Even in case of a negative net financial balance of the extended CBA the non-monetised benefits can bring in further consideration. Of course if the CBA is negative and the status of the non-monetised benefits deteriorate then there is no further consideration but the substantial redesign of the intervention. Meanwhile a negative net balance of the extended CBA with the improvement in the status of the non-monetised benefits raised the question whether this improvement is worth the difference. Whether it compensates for the negative balance and how the planners could obtain reliable information about it. Or are there stakeholders or new third parties who financially step in to secure the improvement of the non-monetised benefits?

These latter examples about the importance of the peculiar local conditions in settling/solving all the open issues of an ecosystem-heavy water – land management development process draws the attention to the fact that the planning process must be open and inclusive from the beginning in order to generate the necessary trust and affection that would be needed to solve the non-regular questions. Without solving them for common satisfaction even a whole, elaborated, nice plan can fail.

7 THE OVERVIEW OF THE EXTENDED CBA INTEGRATEDDECISION FLOW

A flood risk management planner is a public actor. Pursuing a flood development intervention from a public perspective it has to satisfy 1 + 3 different type of conditions:

- Positive net changes on flood risk exposure
- Positive net changes on the extended CBA
- No stakeholder groups (or persons) are worse off – the uneven distribution of costs and benefits are managed
- Sustainability - The natural and social bases of well-being are not exploited. Ecosystem service base, natural capital is not depleted.

In our decision tree sustainability is considered as a precondition that any intervention has to satisfy. The two boxes in question that reflect to this aspect are the:

"Are structural site conditions met?":

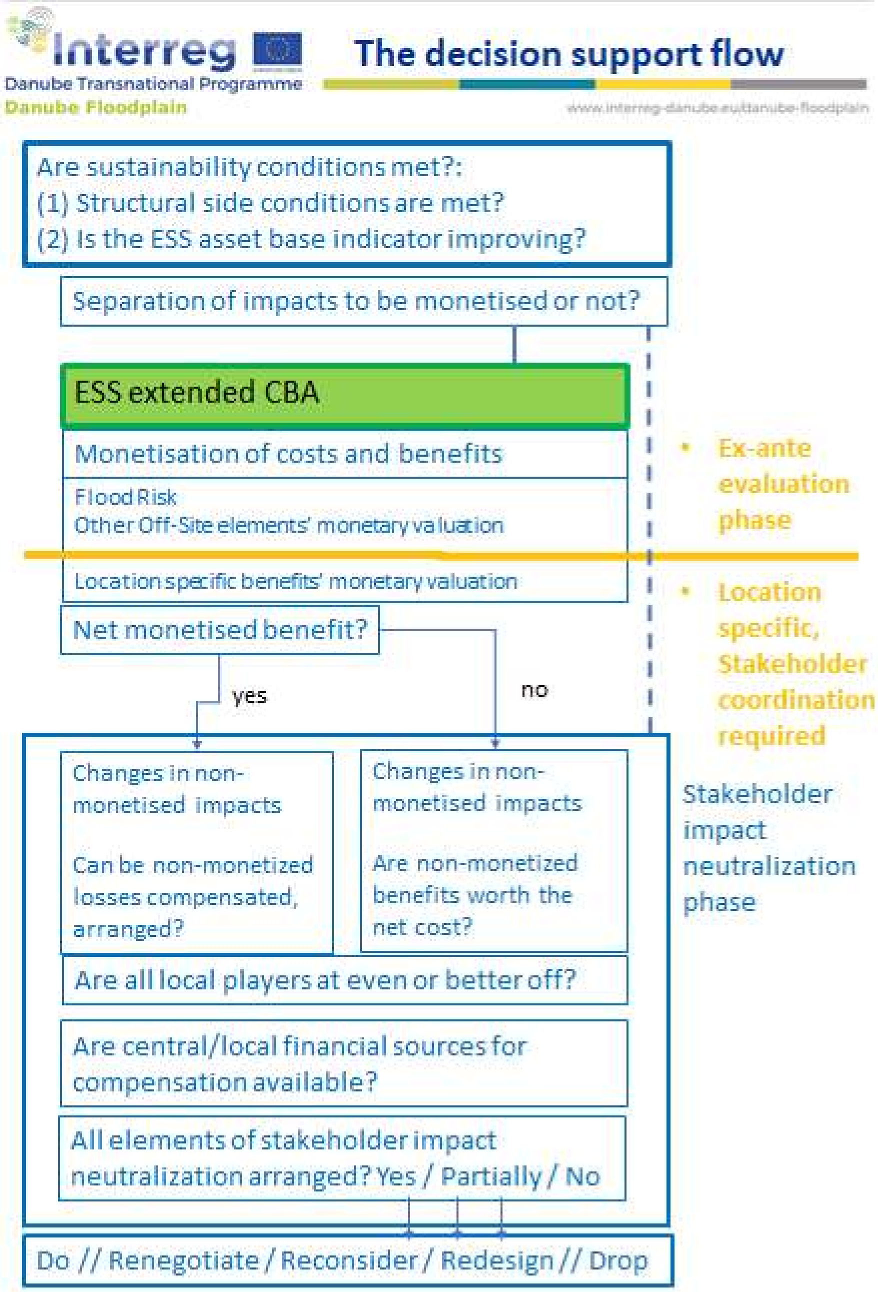
- The continuity or connection of natural areas that make animal and plant migration possible are not destroyed. Or, even better, new connections are developed.
- The size of open water surface area and the length of the shoreline doesn't decrease.
- Heterogenity of the area's land use pattern is increased or stays constant.
- The size of non-cultivated (natural) areas doesn't decrease and the area doesn't fragment.

And "Is the ESS asset indicator improving?"

- 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.
- 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.

Once these questions have been cleared, the planning-decision support process starts.

Figure 8. The structure of decision support



8 LITERATURE

Ungvári, G., Kis, A., (2019) A macroeconomics inspired interpretation of the terrestrial water cycle September 2019 Wiley Interdisciplinary Reviews: Water DOI: 10.1002/wat2.1380 https://www.researchgate.net/publication/335619466_A_macroeconomics-inspired_interpretation_of_the_terrestrial_water_cycle

Kravčík, M., Pokorny, J., Kohutiar, J., Kováč, M., & Tóth, E. (2008). Water for the recovery of the climate: A new water paradigm. Kovice, Slovakia: TypoPress.

R. de Groot, B. Fisher, M. Christie, J. Aronson, L. Braat, R. Haines-Young, J. Gowdy, E. Maltby, A. Neuville, S. Polasky, R. Portela, I. Ring (2010) Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation P. Kumar (Ed.), TEEB Foundations, The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations, Earthscan, London (2010)

TEEB (2010), The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington

Sheil, D., & Murdiyarso, D. (2009). How Forests Attract Rain: An Examination of a New Hypothesis. BioScience, 59(4), 341–347. https://doi.org/10.1525/bio.2009.59.4.12

Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., … Sullivan, C. A. (2017). Trees, forests and water: Cool insights for a hot world. Global Environmental Change, 43, 51–61. https://doi.org/10.1016/j.gloenvcha.2017.01.002

Pokorný, J., Brom, J., Cermák, J., & Hesslerová, P. (2010). Solar energy dissipation and temperature control by water and plants. International Journal of Water, 5(4), 311–336. https://doi.org/10.1504/IJW.2010.038726

Tammi, I., Mustajärvi, K., Rasinmäki, J., (2017) Integrating spatial valuation of ecosystem services into regional planningand development. Ecosystem Services Volume 26, Part B, August 2017, Pages 329-344, http://dx.doi.org/10.1016/j.ecoser.2016.11.008

Amy Richmond,Robert K. Kaufmann,Ranga B. Myneni Valuing ecosystem services: A shadow price for net primary production Ecological Economics Volume 64, Issue 2, 15 December 2007, Pages 454-462

Positive correlation of ES value with Net Primary Production "Net primary production is positively correlated with the flow of many provisioning and regulating services."

Yilmaz, Olcay. (2017). International welfare comparison using GDP and better life index parameters. Pressacademia. 4. 1-14. 10.17261/Pressacademia.2017.361. https://www.researchgate.net/publication/315938099_International_welfare_comparison_using_GDP_and_better_life_index_parameters

MAES (2016) Mapping and Assessment of Ecosystems and their Services 3rd Report – Final, March 2016; Mapping and assessing the condition of Europe's ecosystems: Progress and challenges European Environmental Agency; ISBN 978-92-79-55019-5 doi:10.2779/35158

Costanza Changes in the global value of ecosystem services. Global Environmental Change Volume 26, May 2014, Pages 152-158

Perosa, Francesca (2019) TESSA's application to the Danube Floodplain. Technical University of Munich. Danube Floodplain project document