sustainability

Supplementary Material: Integrated Valuation of Nature-Based Solutions Using TESSA: Three Floodplain Restoration Studies in the Danube Catchment

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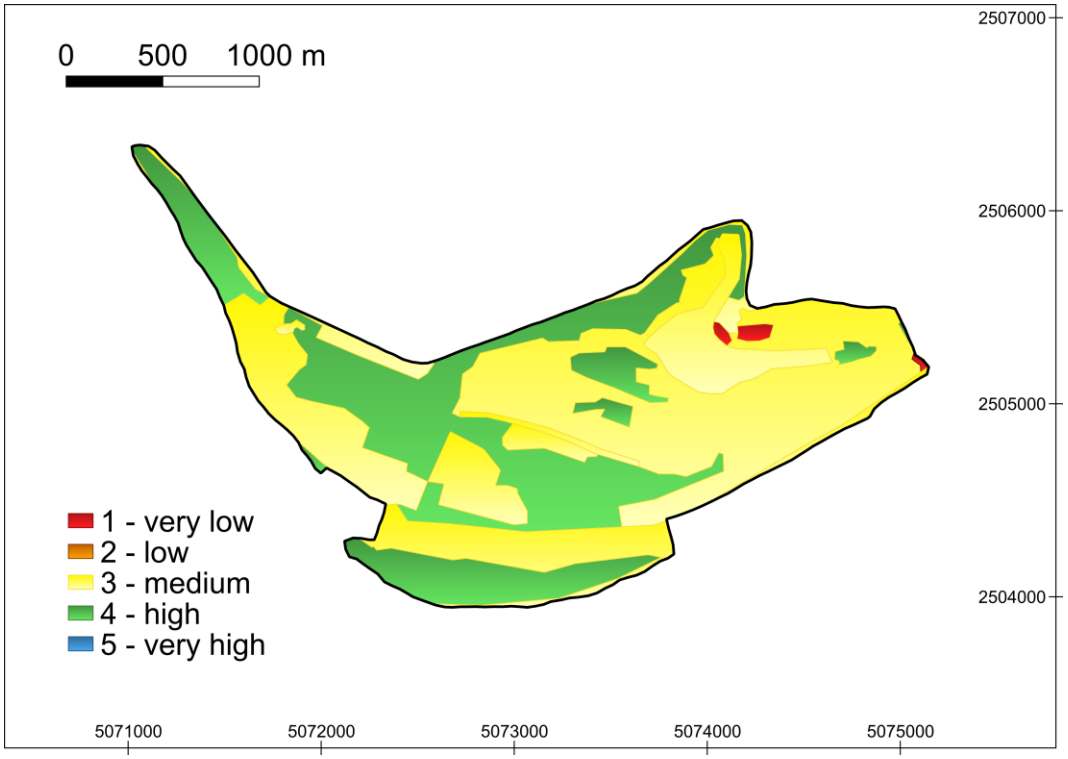
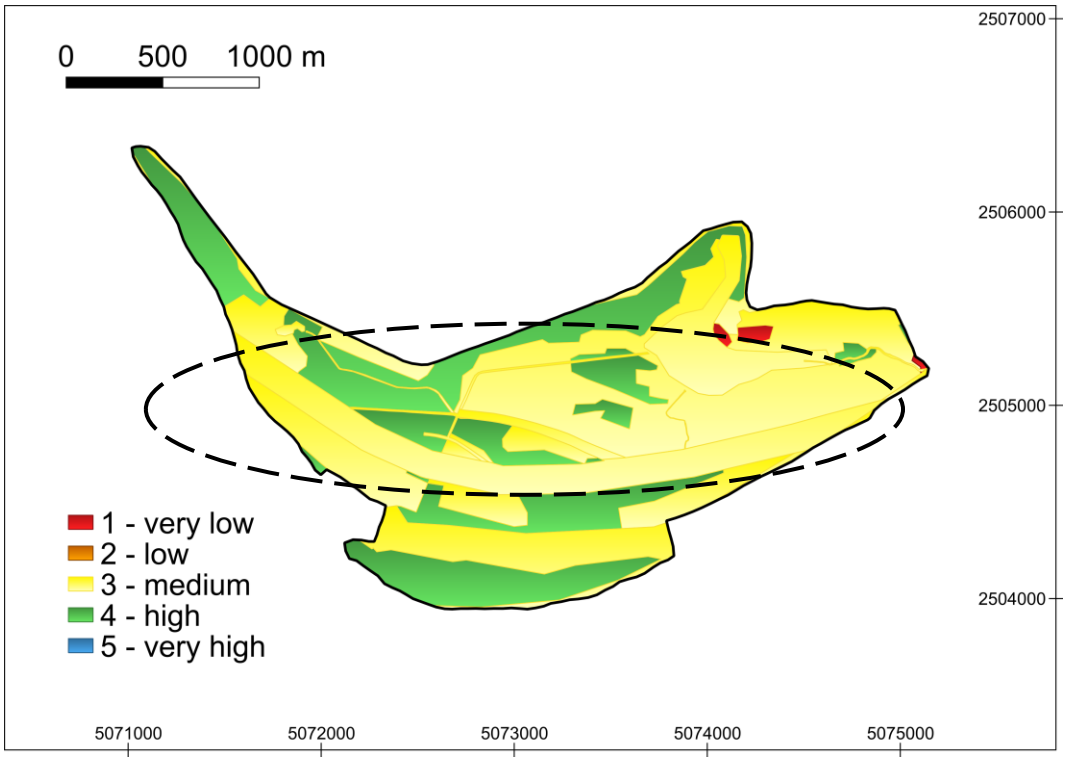
S1. Ecosystem services mapping

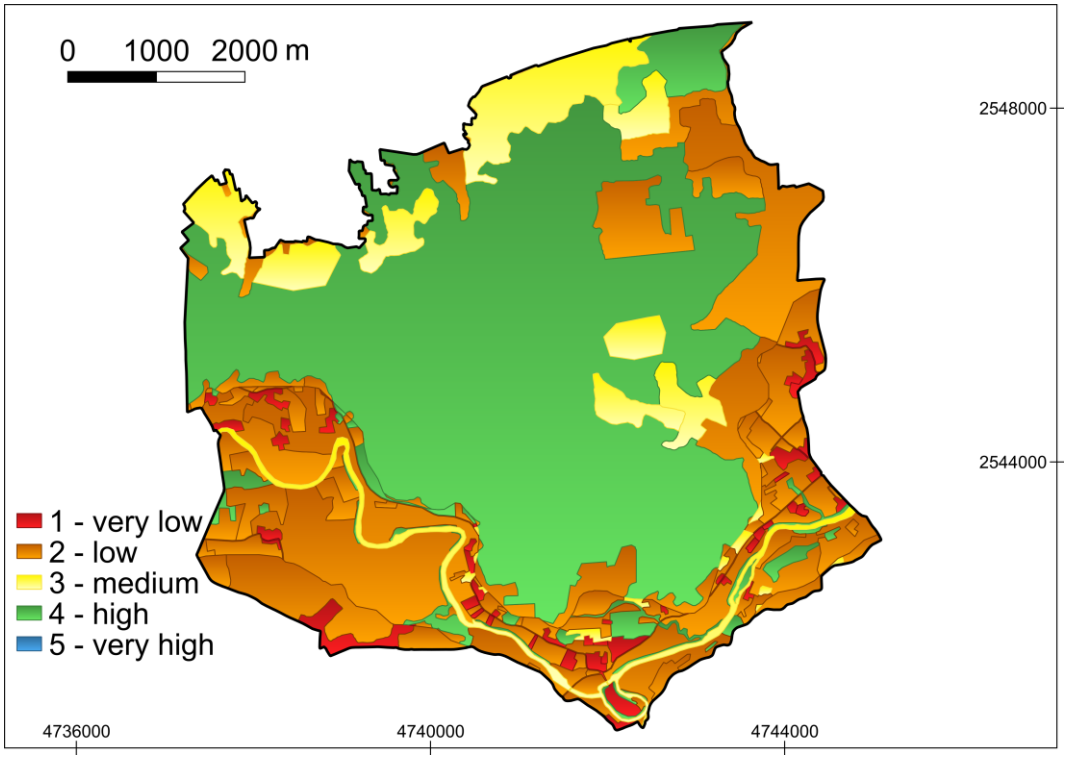


(**a**)

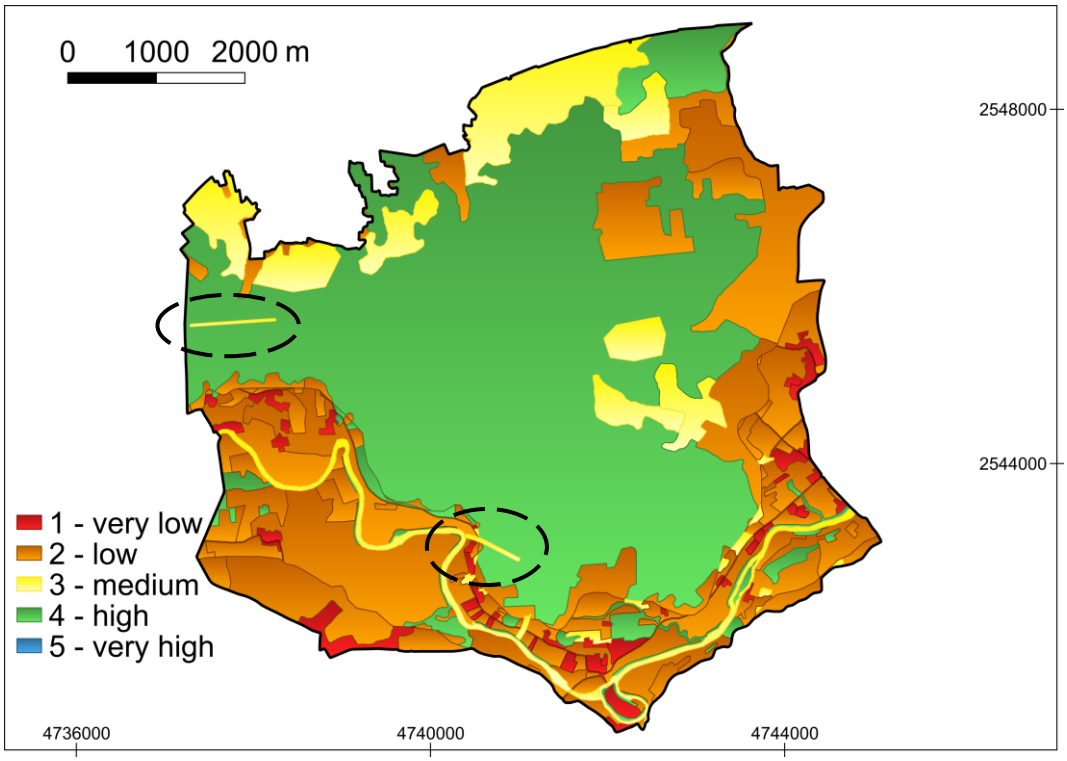


(**b**)

Figure S1. Ecosystem services (ES) supply intensity in Begecka Jama for the current state (a) and the restoration scenario (b). The ES considered in these maps representations are provisioning ES (agricultural products, wood, animal products and honey, game meat, fish, and water) and regulating ES (air purification and local climate regulation, low water regulation, flood retention, noise regulation, and nutrients retention). The dotted circle in (b) indicates the areas where changes can be observed in comparison to (a).

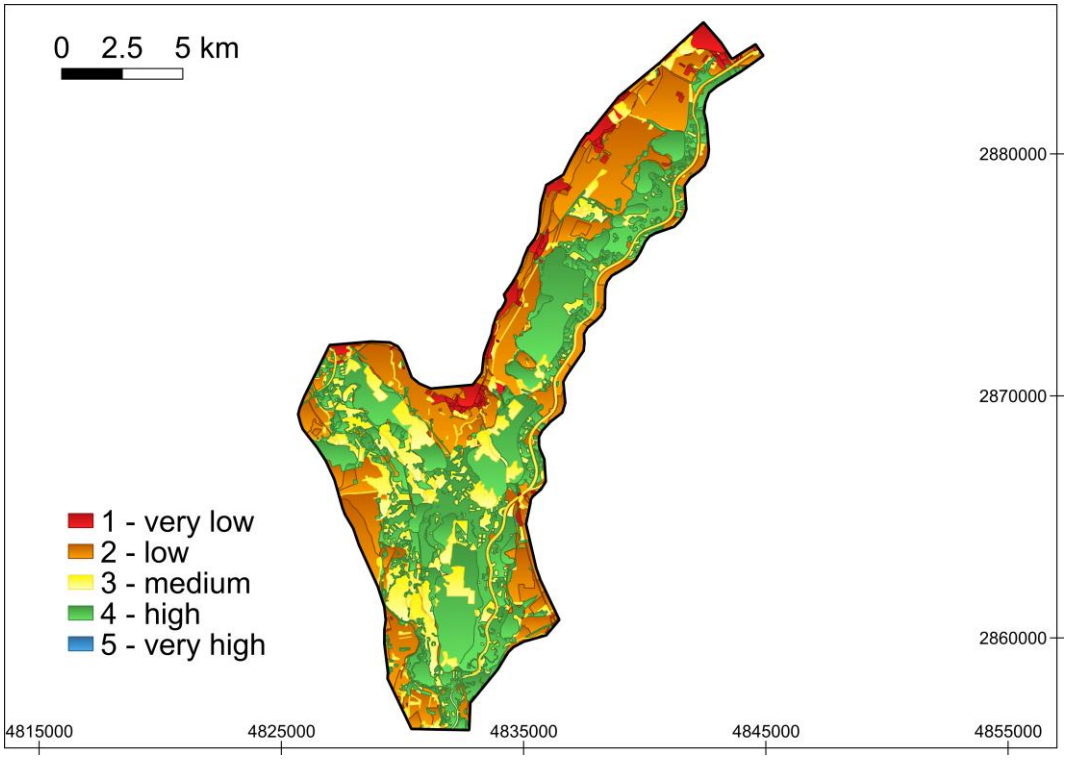


(**a**)

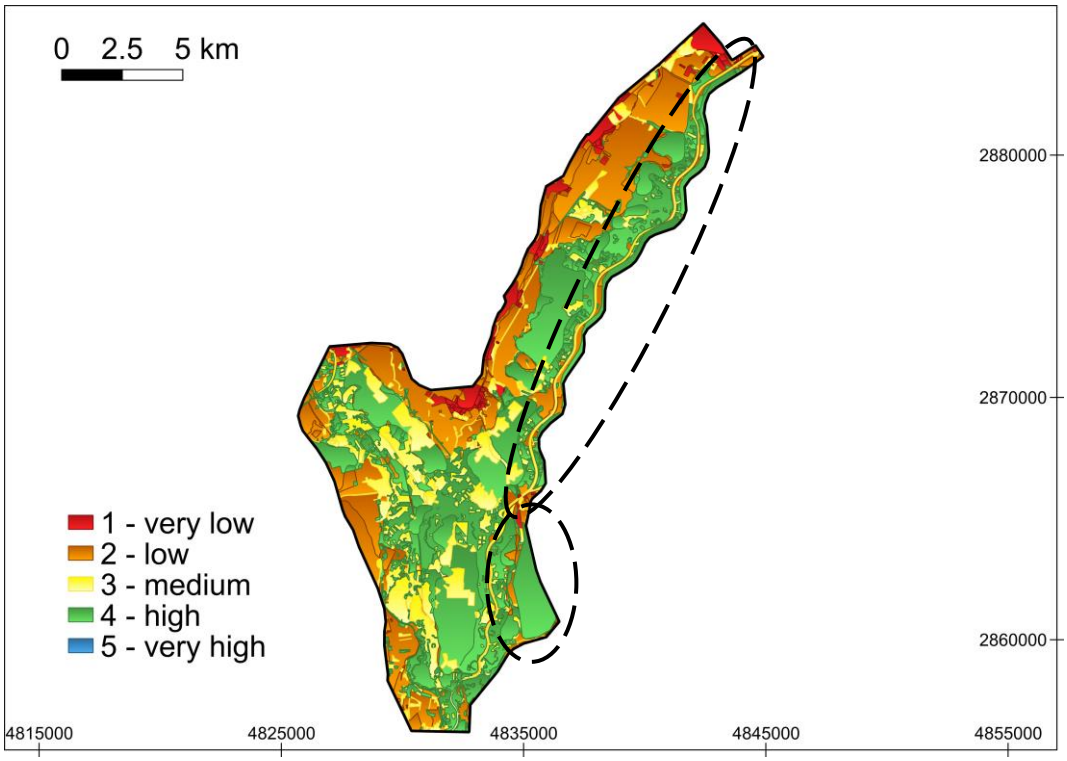


(**b**)

Figure S2. Ecosystem services (ES) supply intensity in Krka for the current state (a) and the restoration scenario (b). The ES considered in these maps representations are provisioning ES (agricultural products, wood, animal products and honey, game meat, fish, and water) and regulating ES (air purification and local climate regulation, low water regulation, flood retention, noise regulation, and nutrients retention). The dotted circles in (b) indicate the areas where changes can be observed in comparison to (a).



(**a**)



(**b**)

Figure S3. Ecosystem services (ES) supply intensity in Morava for the current state (a) and the restoration scenario (b). The ES considered in these maps representations are provisioning ES (agricultural products, wood, animal products and honey, game meat, fish, and water) and regulating ES (air purification and local climate regulation, low water regulation, flood retention, noise regulation, and nutrients retention). The dotted circles in (b) indicate the areas where changes can be observed in comparison to (a).

S2. Additions to the methodology

S2.1. Global climate regulation

Table S1 reports, as suggested in TESSA, the sources of the carbon storage factors used following the Tier 1 methodology of the Intergovernmental Panel on Climate Change (IPPC) reports [1, 2] from Anderson-Teixeira and DeLucia (2011) [3].

Table S1. Data sources used for the estimation of carbon stocks

Biomass source	Habitat	Data sources
AGB[1]	Tree-dominated	IPCC 2006 Guidelines - table 4.7 [1]
AGB[1]	Grass-dominated, Wetland-dominated	Values of GHGs flux for various habitats [4]
BGB[2]	Tree-dominated	IPCC 2006 Guidelines - table 4.4 [1]
BGB[2]	Grass-dominated	IPCC 2006 Guidelines - table 6.1 [1]
BGB[2]	Wetland-dominated	Values of GHGs flux for various habitats [4]
LB[3]	Tree-dominated	IPCC 2006 Guidelines - table 2.2 [1]
LB[3]	Grass-dominated, Wetland-dominated	Values of GHGs flux for various habitats [4]
DWB[4]	Tree-dominated, Grass-dominated, Wetland-dominated	Values of GHGs flux for various habitats [4]
SOC[5]	Tree-dominated, Grass-dominated, Wetland-dominated	IPCC 2006 Guidelines - tables 2.3, 6.2 [1] IPCC 2014 Guidelines – table 5.2 [2]
SOC[5]	Crop-dominated	IPCC 2006 Guidelines - tables 5.5 [1] IPCC 2014 Guidelines – table 5.3 [2]

The "Forestry Production and Trade" section of the FAOSTAT database [5] provides data on the national level on annual roundwood removals, annual fuelwood removals, and annual charcoal removals in [m^3/year]. Values used for the reference year 2017 (default year) can be seen in Table S2.

Table S2. National level data on annual roundwood removals, annual fuelwood removals, and annual charcoal removals. [5]

Country	Year	Fuelwood removal [m3/yr]	Roundwood removal [m3/yr]	Charcoal removal [tonnes/yr]	Charcoal removal [m3/yr]
Czech Republic	2017	2376000	19387000	7983	47898
Serbia	2017	6436000	7789000	28000	168000
Slovakia	2017	591109	9361492	4000	24000
Slovenia	2017	1038843	4509048	500	3000

[1] Above-ground biomass
[2] Below-ground biomass
[3] Litter biomass
[4] Dead wood biomass
[5] Soil Organic Carbon

S2.2. Water-related services: Flood Protection

For the flood-caused damages estimation, we applied to all hydrologic scenarios the Joint Research Centre (JRC) damage functions [6] shown in Figure S4 to estimate the flood-caused damage in the study areas. As Table S3 shows, the flood damage functions are applied to five land use types.

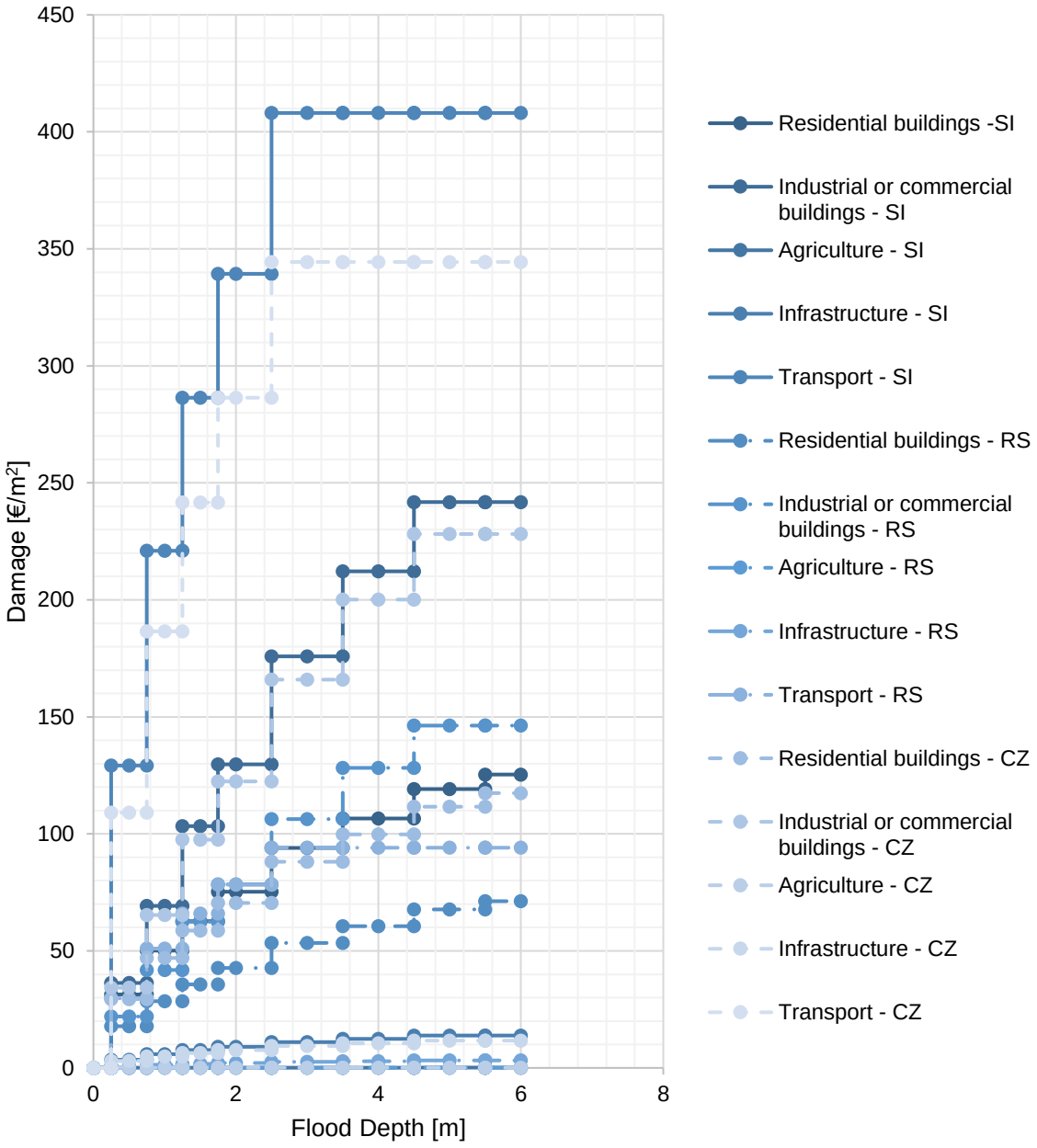


Figure S4. Flood-caused damage curves of the land uses according to Huizinga et al. (2017) [6] for the countries of the study areas: Czech Republic (CZ), Serbia (RS), and Slovenia (SI).

Table S3. Land use types included in the Joint Research Centre's damage functions [6]

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

The trapezoidal method for flood risk (expected annual damage, EAD) estimation [7] was applied according to equation (1) in the manuscript, for which different return periods T were used according to the study area. These were summarized in Table S4.

Table S4. 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	**Krka**	**Morava**
T_1 - High probability	3.5 yr ± 1.5 yr	3.5 yr ± 1.5 yr	5 yr ± 1.5 yr
T_2 - Medium probability	15 yr ± 5 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

S2.3. Water related services: Nutrients retention

The expected annual retention volume (EARV) was calculated the with the trapezoid method, as shown in equation (2) in the manuscript, for which different return periods T were used according to the study area. These were summarized in Table S5.

Table S5. Return periods T used for the retention volume estimation with corresponding lower and upper uncertainty boundaries, with a number of return periods of $n = 3$.

	Begecka Jama	**Krka**	**Morava**
T_1 - High probability	3.5 yr ± 1.5 yr	3.5 yr ± 1.5 yr	5 yr ± 1.5 yr
T_2 - Medium probability	15 yr ± 5 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

The retention volumes RV for each study area can be found in Table S6.

Table S6. 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 three study areas.

	Begecka Jama			**Krka**			**Morava**		
	RV_1	RV_2	RV_3	RV_1	RV_2	RV_3	RV_1	RV_2	RV_3
CS [m^3]	4.19×10^7	5.54×10^7	6.07×10^7	1.43×10^7	1.87×10^7	2.67×10^7	7.40×10^7	7.87×10^7	8.61×10^7
RS [m^3]	4.50×10^7	5.82×10^7	6.36×10^7	1.42×10^7	1.88×10^7	2.65×10^7	7.26×10^7	8.04×10^7	9.13×10^7

S2.4. Cultivated goods

The knowledge on the crops, livestock, and fish species present in the study areas was provided by interviews to local authorities [8, 9, 10] and is shown in Table S7.

Table S7. Crops, livestock, and fish species indicated by the local authorities as used as input data for the cultivated goods ES estimation [8, 9, 10]. These species are valid for both CS and RS scenarios.

Product	Begecka Jama	Krka	Morava
Crops	-	Barley, maize, triticale, apple, sour cherry, grape, pea, plum, potato, rapeseed, soybean, wheat	Barley, cereal, green corn, oats, oilseed, grape
Livestock animals (#)	Sheep (25), Beehives	Cattle, Chickens, Horses, Pigs, Beehives	Cattle, Horses, Beehives
Livestock products	Sheep milk, Honey	Cattle meat, Cow milk, Pig meat, Chicken meat, Hen eggs, Horse meat, Honey	Cattle meat, Cow milk, Horse meat, Honey
Aquaculture	-	Salmons, trouts, smelts, Pike-perch - Stizostedion lucioperca, Cyprinids nei - Cyprinidae	[6]Sea trout - Salmo trutta, Peled - Coregonus peled, Northern pike - Esox lucius, Grass carp (=White amur) - Ctenopharyngodon idellus, Tench - Tinca tinca, Common carp - Cyprinus carpio, Silver carp - Hypophthalmichthys molitrix, Wels(=Som) Catfish - Silurus glanis, European eel - Anguilla anguilla, European perch - Perca fluviatilis, Pike-perch - Stizostedion lucioperca

[6] Other fish types were provided about the Morava study area, for which however no data was available from Czech Republic and they were therefore neglected in the calculation: Asp - Aspius aspius, Barbel - Barbus barbus, Bleak - Alburnus alburnus, Burbot - Lota lota, Common nase - Chondrostoma nasus, Crucian carp - Carassius carassius, Freshwater bream - Abramis brama, Gobio gobio, Goldfish - Carassius auratus, Grayling - Thymallus thymallus, Huchen - Hucho hucho, Orfe (=Ide) - Leuciscus idus, Roach - Rutilus rutilus, Rudd - Scardinius erythrophthalmus, Sterlet sturgeon - Acipenser ruthenus, Vimba bream - Vimba vimba.

S2.5. Nature-based recreation

S2.5.1. Template of the interviews conducted online for the application of 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

S2.5.2. Template of the 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

S2.5.3. Template of the 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

S2.5.4. Fitted Poisson models

We used the responses to the questionnaires for nature-based recreation to fit the following function:

$$\text{number of visits per year} = \alpha + \beta \times TC + \gamma \times age\ , \quad \text{(S1)}$$

where α is the intercept, and β and γ are the coefficients estimates. The results of the fitted Poisson model can be seen for each study area in Table S8.

Table S8. Outputs of the fitted Poisson model to predict the number of visits to the study areas. The table shows the coefficient estimates and standard errors (SE) for models of the three study areas' datasets and the corresponding significance levels for p-values: <0.001 (***), <0.01 (**), <0.05 (*) and <0.1 (.).

	Begecka			**Krka**			**Morava**		
	Estimate	SE		Estimate	SE		Estimate	SE	
α (Intercept)	3.8565	0.0516	***	4.0839	0.0577	***	4.1960	0.0450	***
β (Travel cost)	-0.0081	0.0006	***	-0.0078	0.0007	***	-0.0181	0.0008	***
γ (Age respondent)	-0.0076	0.0014	***	0.0051	0.0019	**	0.0080	0.0010	***

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