Danube Transnational Programme
IDES

IDES

*Improving water quality in the Danube river and its tributaries by integrative floodplain management based on **Ecosystem Services***

DTP3-389-2.1 – IDES

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O.T1.1.1: Ecosystem Service based integrative floodplain management tool (IDES tool)

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Content

List of abbreviations:

AOI	Area of interest
CAP	Common Agricultural Policy
DRB	Danube River Basin
DRBMP	Danube River Basin Management Plan
DTP	Danube Transnational Project
ES	Ecosystem Services
EU WFD	EU Water Framework Directive
FRP	Fertilising Products Regulation
LU/LC	Land cover / Land use
N	Nitrogen
P	Phosphorus

Objectives of the IDES project as a preface

"The main objective of IDES is to improve water quality management along the Danube and its tributaries ***by applying an Ecosystem Service based integrative floodplain management (IDES tool)****. IDES thus contributes to an enhanced implementation of water quality management in the Danube region by identifying optimum sites to retain nutrients with nature-based solutions, mitigating conflicts among stakeholders and demonstrating synergies among different societal interests in floodplains Through these innovations, IDES supports the elaboration and implementation of sustainable, efficient and integrative management options for the whole river course of the Danube.*

There is a need to reduce nutrient loads (nitrogen and phosphorus) transported by the Danube to the Black Sea by integrative river basin management in order to achieve water quality goals set by the EU Water Framework Directive. According to the DRBMP (2015), diffuse pathways clearly dominate the overall emissions from the Danube catchment, but differ significantly between regions. Efficient measures to reduce nutrient input into rivers are the establishment of riparian buffer strips and the enhancement of retention potential in active floodplains. Thereby, relatively small subareas at the river banks and in floodplains are expected to contribute significantly above average to reduce nutrient pollution. However, progress in the implementation of such nature-based solutions has regrettably been rather slow so far. One of the main reasons for the slow progress in implementation is the multitude of human interests focusing on the river channels and floodplain areas, incl. navigation, hydropower, agriculture, nature conservation, tourism, flood and pollutant retention.

IDES strengthens water quality management by demonstrating synergies of nutrient retention with a wide range of other ecosystem services provided by the Danube and its floodplains (e.g. flood protection, recreational values, drinking water). The IDES tool, constituting of a transnationally harmonized evaluation system of ecosystem services, will enable decision-makers to identify the most effective and integrative option to implement related nature-based solutions at transnational level. IDES thus facilitates the

implementation of concrete actions for improving water quality at national level and to create synergies between different ecosystem services.

Specific Objective 1 (out of 3 specific objectives):

"Enhancing synergies and impeding trade-offs in floodplain and water quality management by employing a homogenous Ecosystem Service based approach

The use of Ecosystem Services (ES) concept in the Danube region is currently heterogeneous*, as concluded by the Ecosystem Service overview study funded by PAC06 of the EUSDR in 2018. Most ES studies were conducted at national or regional level, thereby mostly only a few services were considered, and often the scale was too small to obtain information for decision-making at river basin level.* ***Hence, IDES contributes to a transnational development and harmonization of the methods to assess all ES related to water quality.*** *The effect will be a better-informed policy and an improved and accelerated implementation of water quality measures with significant benefits to society.* ***The IDES tool thus represents a joint ES evaluation scheme adapted to varying regional data availability that benefits from already existing evaluation schemes in the different countries. The main effect of this joint and transnational ES assessment tool represents an improved assistance for decision makers to identify those management options which create the most synergies between different sectors."***

Introduction

The ecosystem services (ES) approach is a concept to describe human-nature relationships focusing on the utilization of specific natural components of the atmosphere, lithosphere, hydrosphere, and biosphere (Alcamo, 2003). Places where these “spheres” meet are, among others, floodplains. These areas alongside a stream or river are flooded when the discharge exceeds the water-carrying capacity of the channel (UNESCO, 2012). A regular inundation is therefore an integral character of floodplains and is a prerequisite for healthy fluvial ecosystems. Healthy floodplains are not only important for wildlife habitats (Aarts et al., 2004), but also contribute to other ecosystem services like nutrient retention (Mitsch et al., 2005), carbon sequestration (Sutfin et al., 2016), groundwater recharge (Bullock and Acreman, 2003), and recreation (Gren et al., 1994). Concluding, floodplains are important areas for providing key ES ES to society that are expected to gain even more importance with climate change.

Several approaches for ES classification to support evidence-based policy making were developed in the past years, including those used in the Millennium Ecosystem Assessment (MEA, 2005) and “The Economics of Ecosystems and Biodiversity” (TEEB, 2010). More recent examples have built on these pioneering efforts through broad consultative processes, including the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin, 2012; Potschin and Haines-Young, 2016) which was used by several EU initiatives (e.g. MAES, ESMERALDA, OpenNESS), some of them were focusing on rivers and floodplains (e.g. MARS). Analysing these interactions between nature and society using ES as a proxy enables to characterise the socio-ecological components in riverine systems and the potential changes to this system induced by water management measures or land use changes. However, more elaborated tools are still needed to introduce these approaches effectively into practical floodplain management and restoration. In order to address cross-sectoral challenges in river-floodplain landscapes, the integrative „River Ecosystem Service Index (RESI)” has been developed and successfully applied in Germany (Podschun et al., 2018). Based on this promising experience, we identified the structures (e.g. topography, soil types, LC/LU) and processes (e.g. floods, sediment deposition and remobilization) of floodplain ecosystems and searched for suitable environmental data within the Danube River Basin (DRB) that characterise their condition. The large, transnational and heterogeneous DRB requires an adaption of the existing RESI approach and harmonization of data to calculate and map the respective ES.

ES assessment tools as the RESI have been developed in order to collect and visualize the various political goals and societal uses related to river corridors. It is a common recognition that e.g. the objectives of the Water Framework Directive may be much better reached, and certain uses as pollutant retention or recreation could be better fulfilled if conflicts and trade-offs among involved policies would be systematically analyzed and minimized. Hereby, the assessment of ES may help to create a common communication basis and to mediate between stakeholders. Such ES assessments contribute to the aggregation of information and transparency in planning processes, and thus also facilitate the active participation of stakeholders in decision-making processes. Such evaluation methods with a focus on water quality issues have a high potential to improve reaching several management objectives in the DRB, too.

On the one hand, the here presented IDES tool provides work flows to assess the potential of certain floodplains and river stretches in the DRB to contribute to an improvement of water quality. On the other hand, it provides a framework assess the current provision of relevant ecosystem services in the floodplains. To facilitate the application of the IDES tool for potential users, we provide Excel files, computer code and geodata, besides the manual here. In this document, we describe 1) the definition of the assessment scheme and spatial units 2) the spatial evaluation of floodplains and potential measures to improve water quality and 3) two alternative methods how to assess all relevant ES depending on the quality of the available data (resolution, information). While the first method is based on land use classes only, the second one is based on additional indicators and extends the RESI by newly developed approaches. The methods were applied for the whole DRB and, with more precise data, exemplarily for pilot areas.

Contents of the output

Beside the description of the methods and the results of the evaluation for the selected rivers, the output provides several files to be used for the application of the IDES tool listed in the Annex:

1. **Delineation and segmentation** methods of large floodplains in the DRB
    a) Separation into river, active floodplains and former floodplains (shape files)
    b) Delineation of the morphological floodplain and segmentation into river-floodplain segments of 1 and 10 km lengths (shape files)
2. **Flexible identification of relevant floodplains for water quality improvement / actions**
    a) Computer code, input and output files and maps for the DRB
3. **Methods for ES evaluation**:
    a) Capacity matrices on river level (Excel sheet)
    b) Original indicator-based evaluation approaches (RESI fact sheets)
    c) Modified approach to the DRB (fact sheets)
    d) Exemplary maps for the DRB and pilot areas

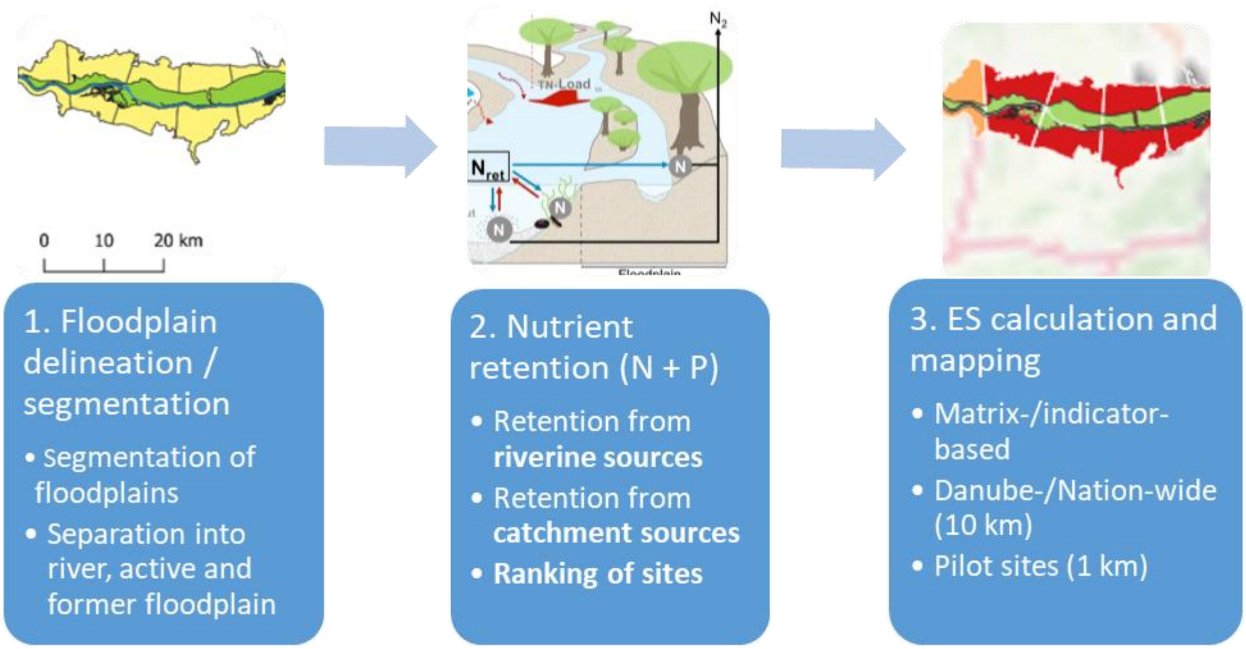


Figure 1: Overview of the main objectives

1. Delineation of river, active and former Danube floodplain segments

Along river Danube and its main tributaries Tisza, Mura, Sava, and Yantra a number of floodplains and pilot areas were selected in the countries represented in the IDES project team. In order to enable ES evaluations in different compartments of the river-floodplain system, the entire **morphological floodplain** was further laterally divided into **river**, **active floodplain**, and **former floodplain** (Figure 2). This classification is crucial as characteristics, uses, and services of these compartments differ significantly.

To delineate the **morphological floodplain** along the selected rivers, we examined existing and available GIS data on riparian zones, flooding frequencies and risks. These were often derived for larger scale, potentially containing spatial inaccuracies and causing challenges. The morphological floodplain was defined by the area of interest (AOI) of the Copernicus riparian zones land cover/land use (LC/LU) dataset (RZ Land Cover/ Land Use 2018 — Copernicus Land

Monitoring Service). This dataset was selected instead of alternatives (e.g. the JRC or ICPDR flood hazard areas) because of the following qualities:

- Full coverage of the DRB
- AOI approximates morphological floodplain and areas with typical riparian characteristics. In narrow river sections with steep valleys the AOI does not represent the floodplain, but an excessive buffer area around the rivers. To reduce erroneous labelling, we manually removed these parts and used the river compartment only.
- For the entire AOI, high resolution vector data with detailed CL / LU mapping is provided (more classes, higher resolution than in Corine Land Cover)

The compartment **river** refers to the main river and the interconnected waterbodies of the river system. It was defined as MAES level 4 classes “9.1.1.0 interconnected watercourses” of the COPERNICUS LC/LU dataset and in some cases “9.0.0.0 UA - Rivers and lakes”. **Active floodplains** are areas subject to frequent floods and are separated from the former floodplain by anthropogenic structures for flood protection (e.g. levees, dykes). Areas of active floodplains were adopted from the DTP Danube Floodplain (Activity 3.2, Danube Floodplain GIS (u-szeged.hu)). They represent the inundated areas of a flooding event with a 100-year return period (HQ 100), which are larger than 500 ha, wider than the width of the main channel and hydrologically connected. The Danube delta has a distinct hydrology and was therefore not delineated using these criteria and considered for further analysis. The **former floodplain** is the remaining part of the morphological floodplain.

To ensure a spatially explicit assessment of ES on comparable spatial units and to facilitate their visualization, we divided the entire morphological floodplain into 10-km segments along the river course using the Voronoi segmentation algorithm in ArcGIS Pro. This was achieved by creating point elements every 10 km of the river course (line element from ECRINS or Copernicus EU-Hydro database) and generating the Voronoi polygons for these points. The procedure resulted in 298 segments for the r. Danube, 90 for r. Sava, 75 for r. Tisza, 47 for r. Mura, and 23 for r.

Yantra. To increase the level of detailedness in the five pilot areas, a segment length of 1 km was applied (cf. Podschun et al., 2018; Figure 2). The resulting shapefiles can be found in the Annex.

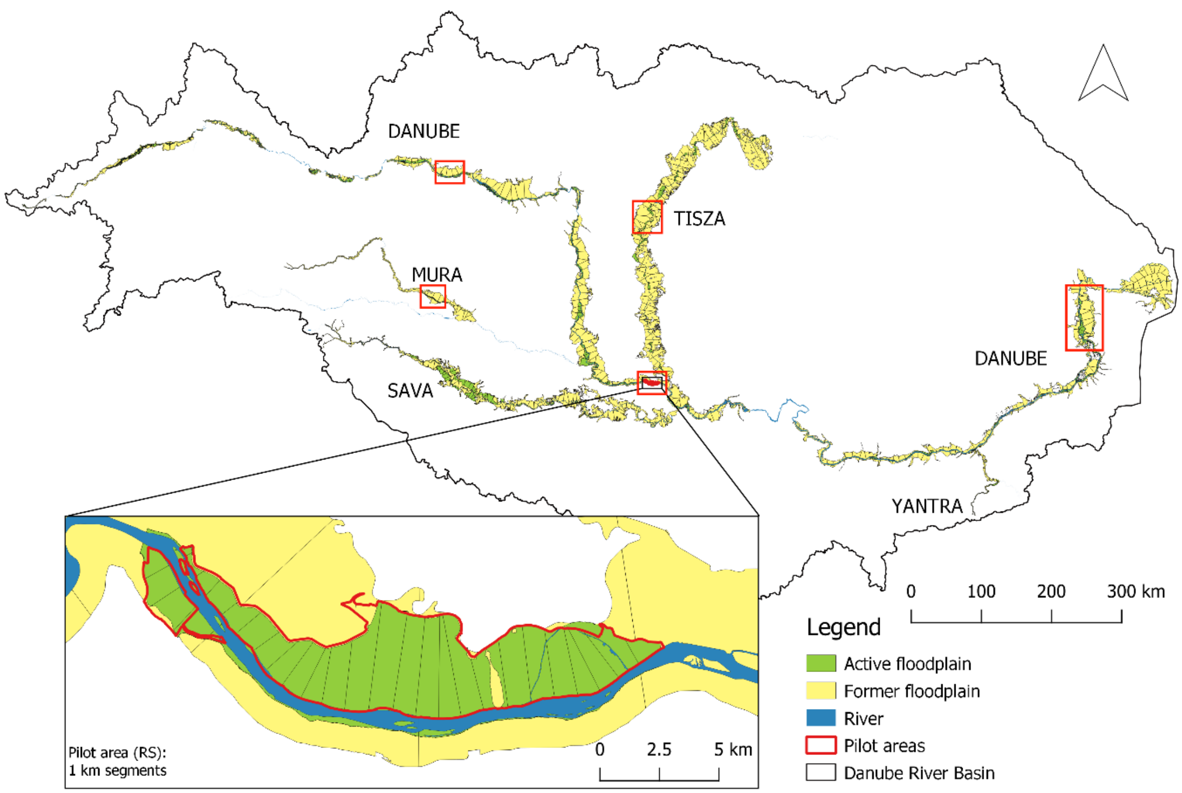


Figure 2: Morphological floodplain, differentiated into the compartments river (blue), active (green) and former (yellow) floodplains, and its 10-km segmentation of the selected rivers of the Danube River basin and the location of the five pilot areas with a 1 km-segmentation (here in Serbia), respectively.

2. Calculations of the nutrient retention in active floodplains

Active floodplains are able to retain nutrients transported by rivers (i.e. from upstream catchment sources) and may additionally act as natural riparian buffer strips intercepting nutrients from upslope catchments. For the analysis of those active floodplain areas that are especially effective in nutrient retention (Deliverable T1.1.1), we defined active floodplains of high nutrient retention potential located in areas of high nutrient pollution as "highly relevant areas". The assessment focused on nitrogen (N) and phosphorus (P) for which a combination of indicators was derived to prioritize the areas on basin-wide and national levels.

Following indicators were derived for N and P using established models: "(local) nutrient emission", "in-stream retention" and "nutrient concentration" (MONERIS, Venohr et al., 2011, Lemm et al., 2021), as well as "floodplain retention (potential)" and "flooding days" (derived using Heinen, 2006; Schulz-Zunkel et al., 2021; Schleuter, 2016). These indicators take into consideration the amount of nutrients entering the river system, locally (i.e. upslope, lateral to the river stretch) and in upstream catchments and how much is or can be retained in-stream and in the floodplains. The values of each indicator were ranked and classified for each active floodplain and 10km-segment into terciles (1-3, low-medium-high) and these class values were further aggregated to evaluate the relevance of the active floodplains for improvement of water quality (

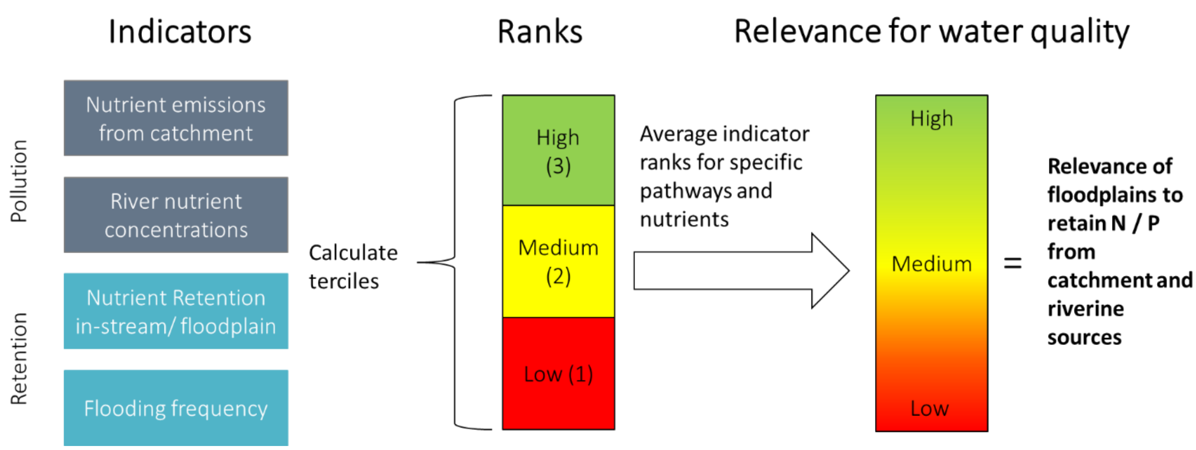


Figure 3). For riverine sources the indicators "floodplain retention (potential)", "flooding days", "in-stream retention", and "nutrient concentration" were used and for catchment sources the indicators "(local) nutrient emission" and "floodplain retention (potential)". Higher ranks indicate higher importance. The deliverable T1.1.1 and the Annex provide a more detailed methodological description and files to reproduce, visualize, and adapt the prioritization on basin and national scales. These analyses enabled to elaborate aggregated basin-wide rankings of active floodplains in terms of their efficiency to retain nitrogen and phosphorous inputs both from catchment

emissions and river sources, respectively (Figure 4). Certain floodplains differ in the specific efficiency to retain nitrogen or phosphorous, depending on the amount of nutrients arriving from local immissions from the catchment, or transported by the river from upstream parts of the catchment.

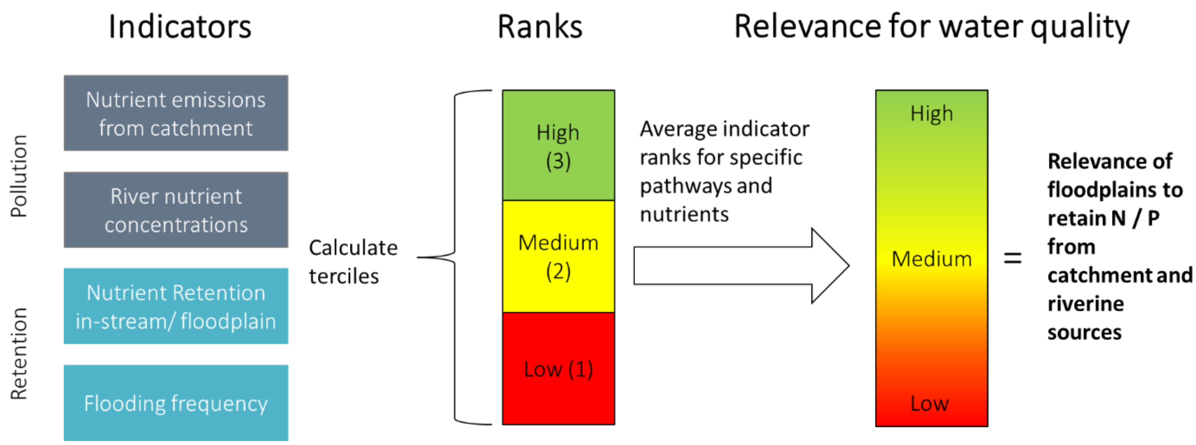
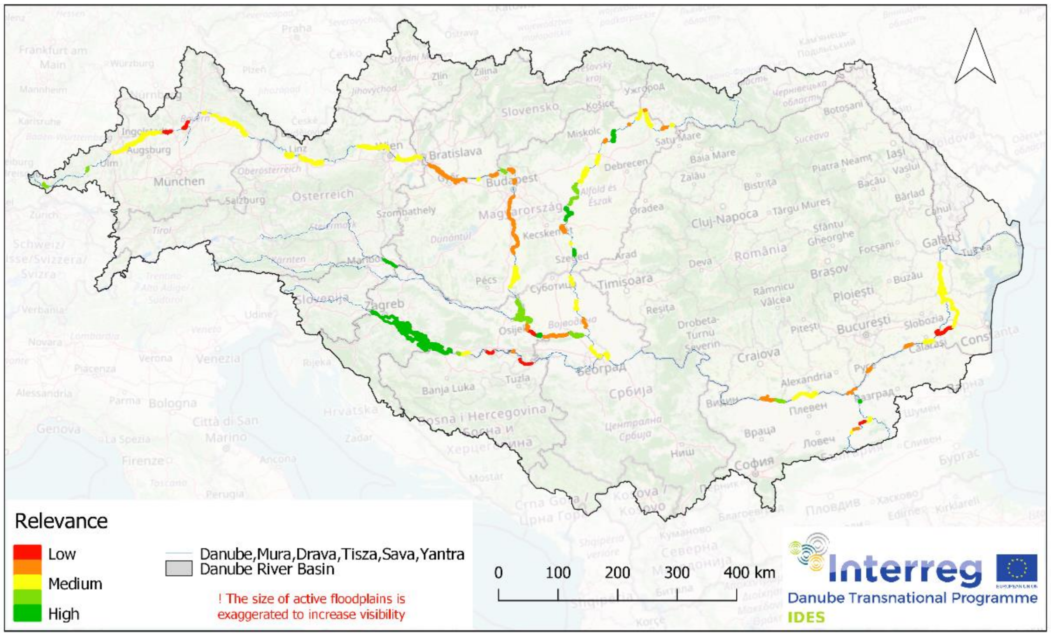
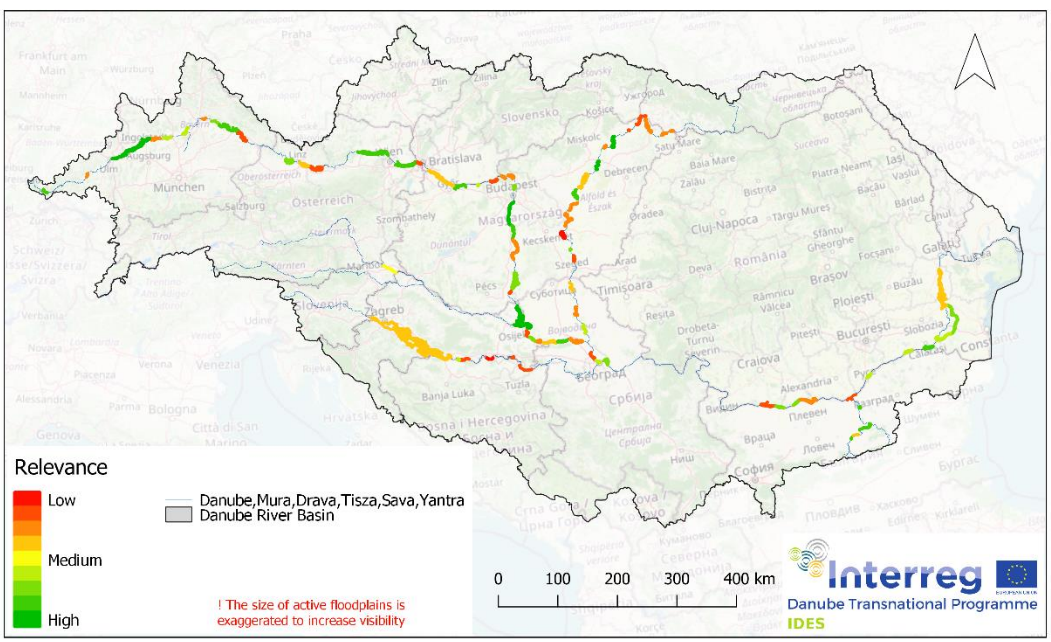


Figure 3: Scheme for evaluating the relevance of active floodplains for water quality improvement and actions

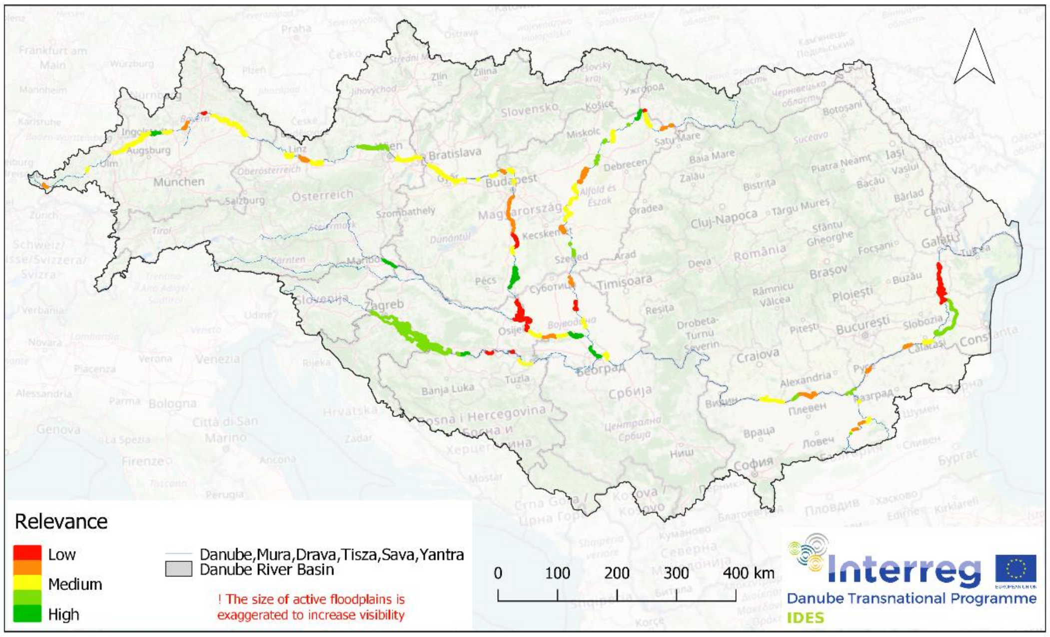
D.T1.1.1: Prioritization of active floodplains for N retention from catchment emissions on river basin scale



D.T1.1.1: Prioritization of active floodplains for N retention from river sources on river basin scale



D.T1.1.1: Prioritization of active floodplains for P retention from catchment emissions on river basin scale



D.T1.1.1: Prioritization of active floodplains for P retention from river sources on river basin scale

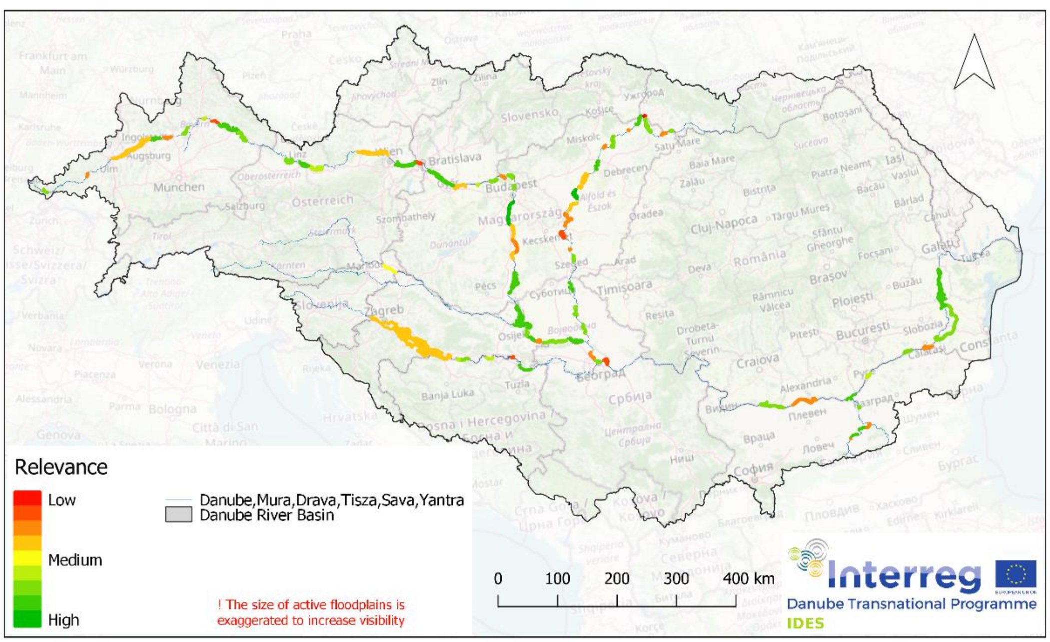


Figure 4: Basin-wide relevance of active floodplains for water quality, regarding N and P retention from river and catchment sources.

3. Selection and evaluation of ecosystem services

Which ES are relevant for the analysis or the considered floodplains? Generally, it is recommended to use the broadest possible range of ES for evaluation and mapping, to better detect (unforeseen) changes (Podschun et al., 2018). A minimum number of selected ES should be representative of all ES main groups, which are supplying, regulatory and cultural ES (CICES, Haines-Young and Potschin, 2012). The broad range enables trade-offs and synergies to be recognized not just among individual ES but also the main ES groups. In addition, there might be regional differences in how ES interact with nutrient retention and which ES will be most affected through (planned) measures. To cover these aspects, we selected 26 ES from all 3 main groups (Table 1).

Table 1: Selection and type of ES, their evaluation approach (indicator-based or capacity matrix), links to factsheets and resulting maps. The factsheets and maps can be found in the Annex following the ID.

Type	Ecosystem Service	Description	Evaluation approach	Factsheet / map ID
Provisioning	**Arable crop production**	Used arable crops (e.g. cereals, root crops, vegetables, fruit)	Indicator	111
	Plant biomass grassland	Plant biomass used for agricultural purposes (yield of meadows and pastures)	Indicator	112
	Commercial fishing	Catches of the commercial fishing activity in designated areas	Indicator	121
	Timber production	Yield of forests managed for timber production (used as material or for energy)	Indicator	122
	Commercial hunting	Yield of the commercial hunting activity in designated areas	Indicator	123
	Freshwater	Water withdrawal for drinking water purposes, irrigation or cooling purposes	Capacity Matrix	FW
	Wild foods	Food resources that can be foraged in the wild	Capacity Matrix	WF
	Abiotic energy sources	Energy generated by hydropower plants, wind etc.	Capacity Matrix	AES
	Mineral resources	e.g. sand / gravel quarries	Capacity Matrix	MR
Regulation & Maintenance	**N-Retention**	Permanent elimination of nitrogen (N) by denitrification (conversion to N2) or temporary retention by incorporation into stationary biomass (e.g. mussels, floodplain vegetation) or in river sediments (sedimentation)	Indicator	212
	P-Retention	Temporary or permanent retention of phosphorus (P) by incorporation into stationary biomass (e.g. bivalves, macrophytes, floodplain vegetation) or by uptake into sediments (deposition, sorption)	Indicator	213
	Greenhouse gas regulation and carbon sequestration	Emissions and sequestration of the greenhouse gases (GHG) carbon dioxide, methane and nitrous oxide (CO_2 equivalents)	Indicator	221
	Flood risk regulation	Reduction of the flood discharge and lowering of the flood peak: wave flattening (retention volume is used by overflow/flooding, river/floodplain morphology influences roughness)	Indicator	231
	Low water level regulation	Low water level regulation by hydrological self-regulation due to macrophyte growth and morphology (reduction of water level), if applicable also compensation by strong groundwater inflow (expert assessment)	Indicator	232
	Sediment regulation	Evaluation of the internal sediment balance of the river by naturalness of morphological structures and effects of transverse structures on sediment consistency / morphological effects	Indicator	241

Type	Ecosystem Service	Description	Evaluation approach	Factsheet / map ID
	Soil formation in floodplains	Evaluation of natural fen formation (peat accumulation) and anthropogenically caused fen degradation (lowering of water body and of groundwater level, changes in flood dynamics) and floodplain soil formation	Indicator	242
	Local climate regulation/ cooling	Cooling effect due to evaporation based on the latent heat of evaporation (assessed from April to September)	Capacity Matrix	LCR
	Habitat provision/simplified assessment (Danube-wide)	Habitat provision describes the functional and structural quality of typical floodplain habitats, communities and species which serve as basis for a wide range of human uses. The habitats with their typical diversity of animal and plant communities of the natural and cultural landscape are an expression of the characteristic site conditions of floodplain landscapes.	Indicator	300
	Habitat provisioning / detailed assessment (pilot area)	See "Habitat provision /simplified assessment"	Indicator	301
	Habitat provision / river	Evaluation of water quality as well as the functional and structural quality of biologically relevant water body structures in the river and the directly adjacent river bank.	Indicator	302
Cultural	**Opportunities for non-water-related activities**	Experiencing animals, plants and landscapes (e.g. nature observation, cycling, walking) for the purpose of recreation	Indicator	431
	Opportunities for water-related activities	Specific water-related activities for recreational purposes (recreational fishing, swimming, non-motorized boating, motorized boating)	Indicator	441
	Landscape aesthetic quality	The aesthetics of the landscape is characterized by its diversity, uniqueness and perceived naturalness (according to Hermes et al. 2018)	Capacity Matrix	LAQ
	Natural Heritage	Entity of natural sites and features of value from the point of view of science, conservation or natural beauty of objects	Capacity Matrix	NH
	Cultural Heritage	Entity of mental and cultural reflection of material natural assets by man and living cultural expressions which are not tangible	Capacity Matrix	CH
	Knowledge systems	Value of the landscape for research projects, educational activities etc. in the floodplain areas.	Capacity Matrix	KS

3.1. Evaluation scheme

Due to the heterogeneous data situation in the DRB, we selected two complementary methods to evaluate the ES in floodplains. In countries/regions with a better data availability an adapted version of the comprehensive **indicator-based approach** by Podschun et al. (2018) was applied. In data-scarce countries/regions, the **capacity matrices** (adopted from Burkhard et al., 2009 and Stoll et al., 2015) were applied to compensate for areas where the detailed indicator-based approach is not feasible. This simple method is widely applicable and originates from an expert evaluation on the capacity of landscape features to provide ES (see Burkhard et al., 2009 and Stoll et al., 2015). The assigned evaluation approaches of the selected ES are given in Table 1**Fehler! Verweisquelle konnte nicht gefunden werden.**, and additionally a list of data, including factsheets documenting evaluation methods are given in the Annex.

A 5-level scale is used to easily visualize and compare the ES per compartment/segment/land cover type. This categorisation reflects the range of provided ES from "very low" (1) to "very high" (5). The categories were defined for each ES individually by either the ratio to the maximal possible ES indicator value, reference values, or quintiles. In case an ES is cannot be provided (e.g. agriculture in forested or water-covered areas), the class "0" (no ES) was optionally introduced for the indicator-based approach. This 5-level framework is similar to other operational 5-level evaluation frameworks, e.g. the EU Water Framework Directive (EU WFD).

3.2. ES evaluation methods

To apply and visualize the **capacity matrices** approach**,** ranks of ES per land use types are first joined with Corine (Burkhard et al. 2009) or Copernicus riparian zones (Stoll et al. 2015) land use classes. Then, the ranked capacity for each ES can be mapped using a GIS program. Corine data have a greater spatial coverage but a lower resolution, consisting of 44 classes in the hierarchical 3-level CLC nomenclature, a minimum mapping unit (MMU) for status layers of 25 ha and a minimum mapping width (MMW) of 100 m. By comparison, the Copernicus riparian zones dataset is based on a pre-defined nomenclature using the MAES typology of ecosystems (Level 1 to Level 4) and CLC providing 56 distinct thematic classes with an MMU of 0.5 ha and a MMW of

10 m. For this assessment, we used MAES level 4 and the original ranks of Stoll et al. (2015) and visualized the ES ranks (Annex). Gaps of the dataset were filled with Corine data and ranks from Burkhard et al. (2009). For the application of specific issues, the ranks can be updated with expert opinions or local knowledge about LC/LU classes.

Code04	EI **Ecological Integrity**	EI 01 Exergy Capture (Radiation)	EI 02 Entropy production	EI 03 Storage capacity (SOM)	EI 04 Reduction of Nutrient loss	EI 05 Biotic waterflows	EI 06 Metabolic efficiency	EI 07 Abiotic heterogeneity	EI 08 Biodiversity	RS **Regulating services**	RS 01 Global climate regulation	RS 02 Local climate regulation	RS 03 Air Quality Regulation	RS 04 Water flow regulation	RS 05 Water purification	RS 06 Nutrient regulation	RS 07 Erosion Regulation	RS 08 Natural hazard protection	RS 09 Pollination	RS 10 Pest and disease control *	RS 11 Regulation of waste *
1111	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1112	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1113	1	1	1	1	1	1	1	1	2	0	0	0	0	0	0	0	0	0	1	0	0
1120	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1210	1	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
1220	1	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
1230	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	0	0	0
1240	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1310	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
1320	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
1400	3	4	3	2	3	2	1	3	3	1	1	2	1	2	1	1	2	0	1	1	1
2110	3	5	4	4	1	3	4	3	2	1	1	2	0	1	0	0	0	1	1	1	1
2120	3	5	4	4	1	3	4	3	2	1	1	2	0	1	0	0	0	1	1	1	1
2200	3	4	3	3	2	3	2	2	2	1	1	2	1	1	1	0	1	1	0	0	0
2210	2	3	3	2	0	3	2	3	2	1	1	1	1	1	1	0	1	1	1	1	0
2220	3	3	2	3	2	4	2	4	3	2	2	2	2	2	1	1	2	2	5	3	2
2310	3	4	3	3	2	3	2	2	2	1	1	2	1	1	1	0	1	1	0	0	0
2320	3	4	3	3	1	3	2	4	3	1	1	2	0	1	0	0	1	1	1	3	2
2330	3	3	2	3	2	3	2	3	3	2	2	3	1	2	1	0	3	1	1	3	2
2340	4	4	4	4	4	4	3	4	4	1	1	2	1	2	1	1	2	1	3	1	1
3000	4	5	4	5	5	5	4	3	4	4	4	5	5	2	5	5	5	3	4	5	5
3110	4	5	4	5	5	5	4	3	4	4	4	5	5	2	5	5	5	3	4	4	4
3120	4	5	4	5	5	5	4	3	4	4	4	5	5	2	5	5	5	3	4	4	4

Code04	PS **Provisioning services**	PS 01 Crops	PS 02 Energy (Biomass)	PS 03 Fodder	PS 04 Livestock	PS 05 Fibre	PS 06 Timber	PS 07 Wood Fuel	PS 08 Capture Fisheries	PS 09 Aquaculture	PS 10 Wild Foods	PS 11 Biochemicals / Medicine	PS 12 Freshwater	PS 13 Mineral resources ***	PS 14 Abiotic energy sources ***	CS **Cultural services**	CS 01 Recreation & Tourism	CS 02 Landscape aesthetics , amenity and inspiration	CS 03 Knowledge systems	CS 04 Religious and spiritual experiences	CS 05 Cultural heritage & cultural diversity	CS 06 Natural Heritage & natural diversity
1111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4	4	3	4	4	1
1112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4	4	3	4	4	1
1113	0	1	1	1	0	0	0	0	0	0	1	0	0	0	1	2	3	2	1	4	2	0
1120	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	0
1210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1	0	1	0
1240	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1310	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1320	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1400	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2	3	3	1	0	2	0
2110	1	5	3	2	0	2	0	0	0	0	1	1	0	0	0	1	1	1	2	0	2	0
2120	1	5	3	2	0	2	0	0	0	0	1	1	0	0	0	1	1	1	2	0	2	0
2200	2	5	5	5	5	0	1	1	0	0	1	5	0	0	0	1	1	1	1	0	1	1
2210	1	4	4	1	0	0	0	1	0	0	1	2	0	0	0	2	5	2	2	0	3	1
2220	1	5	1	0	0	0	3	3	0	0	1	0	0	0	0	2	5	2	2	0	3	1
2310	2	5	5	5	5	0	1	1	0	0	1	5	0	0	0	1	1	1	1	0	1	1
2320	1	4	1	3	0	3	0	0	0	0	0	1	0	0	0	2	2	2	2	0	3	1
2330	1	3	2	1	2	2	2	2	0	0	3	1	1	0	1	2	2	2	3	0	2	3
2340	2	3	3	2	3	2	3	3	0	0	3	3	1	0	0	2	3	2	2	0	3	3
3000	1	0	1	1	0	0	4	5	0	0	4	4	0	0	0	4	4	5	4	3	3	4
3110	2	0	1	1	0	0	5	5	0	0	5	4	0	0	0	4	5	5	4	3	3	5
3120	2	0	1	1	0	0	5	5	0	0	5	4	0	0	0	4	5	5	4	3	3	5

: Part of the capacity matrix from Stoll et al. (2015) which is applied to the MAES level 4 of the Copernicus riparian zones LC/LU. For the complete Excel sheet refer to the Annex

The original **indicator-based approach** from Podschun et al. (2018) requires more detailed data about soil parameters, topography, habitat types, etc. and should be applied wherever these data are available. As specific datasets were not available in all countries of the DRB, we partly modified the original calculation approach (see factsheets in the Annex). This included the substitution with more widely available data (e.g. EU datasets) or proxies. The objective of the modifications was to harmonize ES evaluation between the Danube countries and to provide clear factsheets similar to Podschun et al. (2018).

3.3. Outlook: Evaluation of the natural capital

The range of ES for which IDES assessment tools were elaborated well covers all three groups of ES. However, our set of tools may be easily complemented in areas where respective indicator data are available to cover other uses of the natural capital of rivers and floodplains, as e.g. hydropower and navigation. The extent of uses of the abiotic natural capital provided by rivers and floodplains can be evaluated using simple indicators. For hydropower, an appropriate indicator might be the number and the installed capacity of the hydropower plants in Danube region (*e.g.* http://www.icpdr.org/main/activities-projects/hydropower, https://github.com/energy-modelling-toolkit/hydro-power-database.git). For the respective assessment score, the available theoretical hydrological potential and existing legal limitations of hydropower use, as e.g. Natura 2000 areas or habitats of Natura 2000 species could be additionally considered. For navigation, examples of indicators might be the number of the Danube ports, the number of vessels (bulk cargo vessels, tugs or pusher vessels), the power of fleet (KW), the carrying capacity of fleet, or the volume of goods transported per year (https://www.danubecommission.org/dc/en/danube-navigation/ports-on-the-danube/; http://www.interreg-danube.eu/approved-projects/danube-skills; http://www.icpdr.org/main/activities-projects/joint-statement-navigation-environment; https://climate-adapt.eea.europa.eu/knowledge/adaptation-information/research-projects/econnet). The scoring of these navigational activities could also include potential limitations of navigability, as floods or droughts. In IDES, we restricted ourselves to the evaluation of ES but recommend to also consider a wider range of uses of river-floodplain systems.

4. Links to other activities

The IDES tool will be applied in floodplains of the DRB and the 5 pilot areas (Activity T2.3). In the pilot areas, water quality measures will be assessed with the help of this tool (T2.2). The interpretation of the results, recommendations and best practice examples will then be disseminated in the IDES manual (T2.4) and communicated in the following stakeholder workshops in the pilot areas (T2.1), and on transnational level (T3.1). For key actors in the water sector, the application of the IDES tool will be explained in national training courses (T1.2) and finally, a strategy developed for its implementation in the DRB (T3.2).

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Annex: List of data provided

1-Floodplain Geodata (shapefiles)

- All active floodplains from DTP Danube Floodplain: *AFP_IDES.zip*
- 10-km segments of active floodplains, rivers and former floodplains: *Segmentation_10km.zip*
- 1-km segments of pilot areas: *Pilot areas_segmentation_1km.zip*

2-Files to evaluate the relevance of active floodplains for water quality improvement and actions

- Detailed overview and method description: *Overview_DT1_1_1_final.pdf*
- Computer code (R script) to evaluate relevance of floodplains for water quality: *IDES_Prioritization_floodplains_for_water quality_151021.R*

which reads…

- Prepared MONERIS output: *export_fp_Sep_2021_E-HYPE_LT_adjusted_buffer_ monthly_merged_fixed.txt_monthly_merged_loads_no_remob_2021.txt*
- Assignment of analytical units (AU) to floodplains: *AU_intersect_FP_DRSV_edit.txt*
- Assignment of AUs to floodplain segments: *AU_intersect_Seg.txt*
- Modelled nutrient retention in floodplains: *Mean_retention_flooding_days.csv*
- Modelled nutrient retention in segments: *Mean_retention_flooding_days_seg.csv*
- Water surface area for floodplains: *River_area_aFP.csv*
- Water surface area for segments: *River_area_segments_aFP.csv*
- Water temperature in AUs: *AU_Wassertemperatur.csv*

… and calculates and exports the ranking

- Floodplains: *Output_Floodplain_WQ_relevance.csv*
- Segments: *Output_Segment10km_WQ_relevance.csv*

Output of R script and maps:

- *Output_DT1_1_1_.xlsx*
- *Maps_basin_scale.pdf*

3-Folder for indicator-based approach: *Indicator_approach*, including:

- 17 Fact sheets guiding through the evaluation of the selected ES using the original and modified indicator approaches
- Examples to visualize the indicator-based approach in maps

4-Folder for capacity matrix approach: *Capacity_matrix,* including:

- Excel sheet for ES evaluation: *1-Capacity_matrix_Burkhard09_Stoll2015.xlsx*
- Examples to visualize the capacity matrix approach in maps